INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

# Rain and ground water drainage systems for buildings

**Eduardo João Vindeirinho Rino**

Extended abstract of thesis submitted to obtain the Degree of Master in

## Civil Engineering

**Jury**

| | |
|---|---|
| President: | Professor Augusto Martins Gomes |
| Supervisors: | Professor Albano Luís Rebelo da Silva das Neves e Sousa |
| | Professora Maria Cristina de Oliveira Matos Silva |
| Vowel: | Professora Filipa Maria Santos Ferreira |

**October 2011**

# 1. Introduction

This document aims to gather and organise information on rain and ground water drainage systems in buildings. This information includes insight into design methods and constructive characteristics of the main elements of such drainage systems. Also included are the main regulation and standard requirements, as well as good practice recommendations, such as those concerning the comfort of building occupants.

The resulting document is aimed to support designers on choosing the most adequate drainage system for each situation.

# 2. Rainwater drainage network

Rainwater drainage systems in buildings are designed to collect rainwater and then direct it to the public network. Compliance with mandatory requirements stated in standards and regulations as well as fulfilment of quality and economic objectives must be the main aims of such drainage systems.

The design of rainwater drainage systems in buildings is generally divided into three stages. First, the existing data, such as topography or architecture plans, is gathered and analysed. Then, geometry of pipe sections and location of complementary accessories and installations are defined. Finally, calculations are made in order to define dimensions of all system components.

Three different types of rainwater drainage systems can be defined depending on the method used to direct the waters to the public network:

- Gravity drainage is used when the waters are located above the public drainage collector, thus allowing water transportation by gravity.
- Drainage with elevation is used when the waters are located below the public drainage collector, thus requiring elevation by mechanical means.
- Mixed drainage includes both of the aforementioned types of rainwater drainage systems.

## 2.1. System components

A rainwater drainage system consists of a network of collectors, accessories and final discharge devices, which direct the water to the public network.

These elements are described in table 2.1.

Table 2.1 – Components of rainwater drainage systems in buildings.

| Elements | Description |
|---|---|
| Gutters | Open ducts of slight slope, designed to collect and conduct rainwater to discharge branches or downpipes. |
| Outlets | Outlets designed to channel water from collection devices to downpipes, when existing, or to drains, sanitary wells, ditches or any other appropriate reception areas. |
| Downpipes | Plumbing designed to collect and transport water from discharge branches to building collectors or ditches. |
| Drains | Plumbing designed to collect the water from downpipes, or discharge branches if downpipes do not exist, and to channel it to the final building network branch connecting to the public collector. |
| Accessories | Auxiliary devices designed to ensure maintenance and operation conditions, sometimes used for retention of heavy or light materials. |
| Complementary Installations | Installations designed to improve the performance of the system (pumps and retention systems which prevent the discharge of forbidden residues to the public network are examples). |

## 2.2. Designing

Design of rainwater drainage systems requires the use of adequate and sufficiently accurate methods for a number of estimates.

The first quantity which has to be assessed is the rainwater flow rate. This quantity depends directly on the rainfall intensity, thus varying according to the building location.

Sizing system components depends on the quantity of runoff rainwater. Sizing includes definition of pipe diameters, discharger areas and orifices, and also pumps or separator chambers characteristics when these devices are required.

Design of rainwater drainage systems in buildings in Portugal should be carried out in accordance with the General Portuguese Regulation [1], although the European standard EN 12056-3 **Error! Reference source not found.** can also be used in some cases which are not considered in the GPR. These two documents present different design approaches and differ mainly on the determination of effective collection areas, thus differing on the considered flow rates. A correct design also should be supported by the experience of the designer and others which have worked and published on the subject. Other national standards are often a good source of information. In this thesis, the Brazilian standard NBR 10844 [3] was considered.

## 2.3. System comfort and quality

The quality of rainwater drainage systems in buildings and the comfort provided by the systems to building occupants should be considered carefully. This is often forgotten thus leading to complaints from occupants. Comfort and quality issues of rainwater drainage systems, such as smells or noise, should not depend on the social status of the occupants. The only acceptable exceptions are those related to aesthetic considerations.

In the following are list some of the main factors which affect comfort and quality:

- Noise generally generated by flow impact on piping turns.
- System accessibility for maintenance and inspection operations minimizes the disruption caused by eventual anomalies, thus preventing the obstruction of private or common spaces for long periods.
- Smelling normally is not a problem of rainwater, although it can occur in cases of connection with public collection of domestic sewage.

The quality of rainwater drainage systems in buildings can be improved by:

- Siphonic drainage systems are relatively new systems that provide a more effective drainage. When water flows down pipes, negative pressures occur at the top thus generating a suction effect which increases the flow rate. Like in siphons, the negative pressure is created by the absence of air inside the pipe.
- Rainwater recycling systems use rainwater for non-potable functions, like garden irrigation, washing machines and toilet flushes.

# 3. Drainage systems for groundwater

Groundwater is rainwater infiltrated into the ground. This water flows down through the ground until it finds a waterproof layers on top of which aquifers will be formed.

Buildings are often constructed with basements or underground floors, usually used for car parking. This option, justified by the rationalisation of the available space, requires that possible, if not almost certain, presence of groundwater is taken into account.

Perhaps because construction of underground structures was not so common 20 years ago, there are no regulations in Portugal ensuring the quality of groundwater drainage systems and, as a consequence, there are many buildings in which such systems are totally absent.

Groundwater drainage systems are designed to collect and conduct infiltrated waters to a pumping chamber. As these waters are often conducted to the rainwater drainage public network, the pumping chamber can actually be shared by rainwater and groundwater drainage systems in the building.

## 3.1. System components

The components of groundwater drainage systems in buildings depend on the specificities of each situation. The most common components are listed in Table 3.1.

Table 3.1 - Components of groundwater drainage systems in buildings.

| **Element** | **Description** |
|---|---|
| Gutters | Are usually used to remedy situations in buildings constructed without the necessary protections and are placed between internal an external walls, where collected groundwater is conducted to the pumping chamber. |
| Drains | Plumbing designed to collect underground water through open joints, orifices or permeable surfaces. |
| Inspection chambers | Are spread throughout the drainage system in order to ease maintenance operations. |
| Waterproofing layers | Screens, often in asphalt, although other material can be used, which are designed to protect pavements and walls against humidity. |
| Draining curtains | Membranes usually sold in rolls, which are riddled with granular nodules of high-density polyethylene (HDPE) and applied to buried walls to drain underground water. |
| Elevatory installation | Installation designed to elevate groundwater to the public network level. |

## 3.2. Designing

Similarly to rainwater drainage systems, assessment of the flow rate to drain is the first step of any calculation. These estimates are difficult due to the number of uncertainties involved.

According to Duerholt **Error! Reference source not found.**, the basis for calculating the flow rate should be precipitation. Assuming that 50% of rainwater infiltrates in the soil and that drainage time is about 1 hour per each 5 minutes of precipitation, the groundwater flow rate of about 1 l/s per each 1000 m$^2$ of infiltration basin. Generally, the drainage flow rate needs to be well estimated, considering, for example, that in urbanized terrain the basin's area will be much smaller than in less built-up terrains. Other authors, such as Torres **Error! Reference source not found.**, admit a range of values between 0.8 and 1.2 l/s per 1000 m$^2$ of contributing basin.

# 4. Materials

Selection of materials for rain and groundwater drainage systems in buildings is mainly driven by economy and durability. There are no concerns about the quality of the water and therefore the chemical behaviour of piping materials is not as important as it is in water distribution systems.

The same type of materials are used both for rainwater and groundwater systems, although normally metal pipes are not use in groundwater systems. The most common materials are:

- Metal: galvanized steel, cast iron, cast aluminum;
- Thermoplastic: Polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP);
- Vitrified clay;

- Concrete.

# 5. Case study

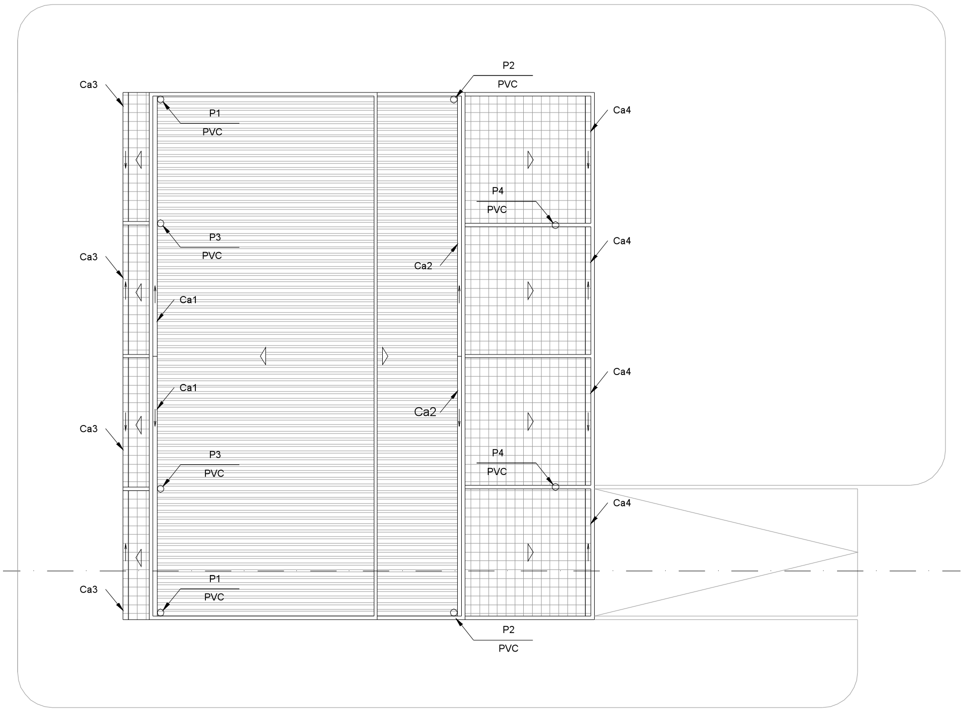
In order to illustrate the differences between different designing methods, a simple case study was considered for rain and ground water drainage. A residential building located in the Lisbon area was considered. This particular building features a double sloping roof and a terrace in the third floor.

## 5.1. Adopted solutions

On the roof, the rainwater will be collected by gutters, which will conduct it to downpipes equipped with strainers. The gutters will direct the water to the four roof corners, where the downpipes are located (Figures 5.1 and 5.2).

On terraces and balconies, the floor has a slight slope towards the edges, where gutters are installed and connected to branches, which conduct the water towards downpipes. The drain branches will be applied underneath the corresponding balcony or terrace thus being covered by a dropped ceiling.

In the basement (Figure 5.3), a waterproofing system will be applied to the pavement with a network of drains. The floor is served by six washing taps and the drainage of this water will be ensured by six drains in the pavement, which are connected to main drain conducting the water to a pumping chamber. This chamber receives both washing and infiltration waters. An elevation system then conducts the waters to an inspection chamber shared by the rainwater coming from the roof, terraces and balconies. Connection to the public network is made by gravity.



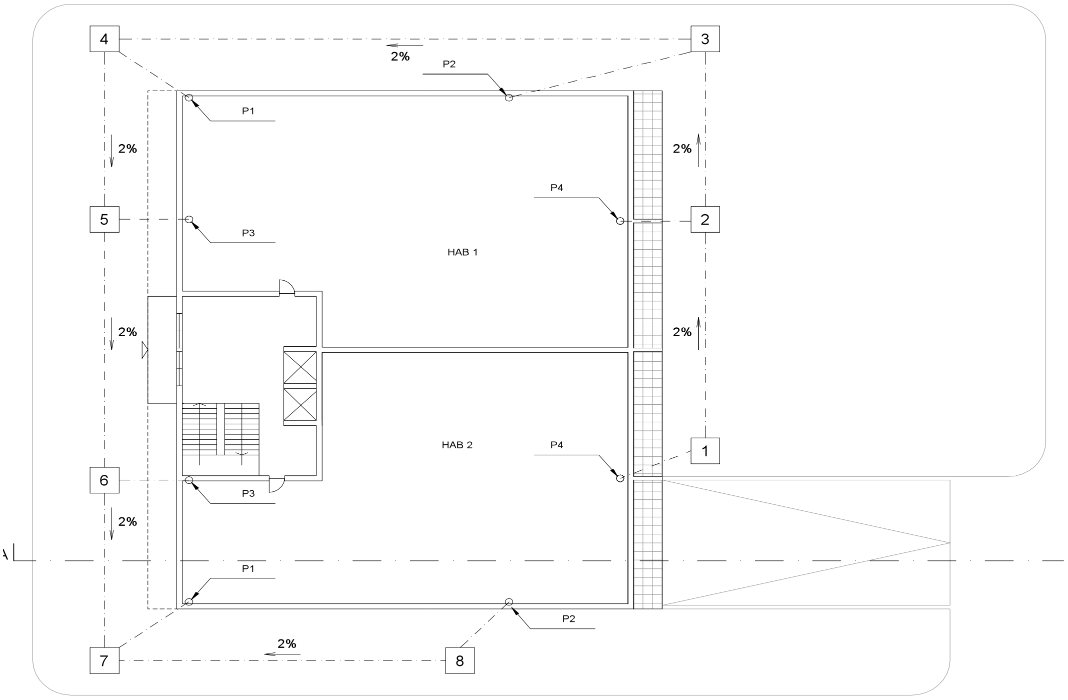


Figure 5.2 – Ground level plan (drains).

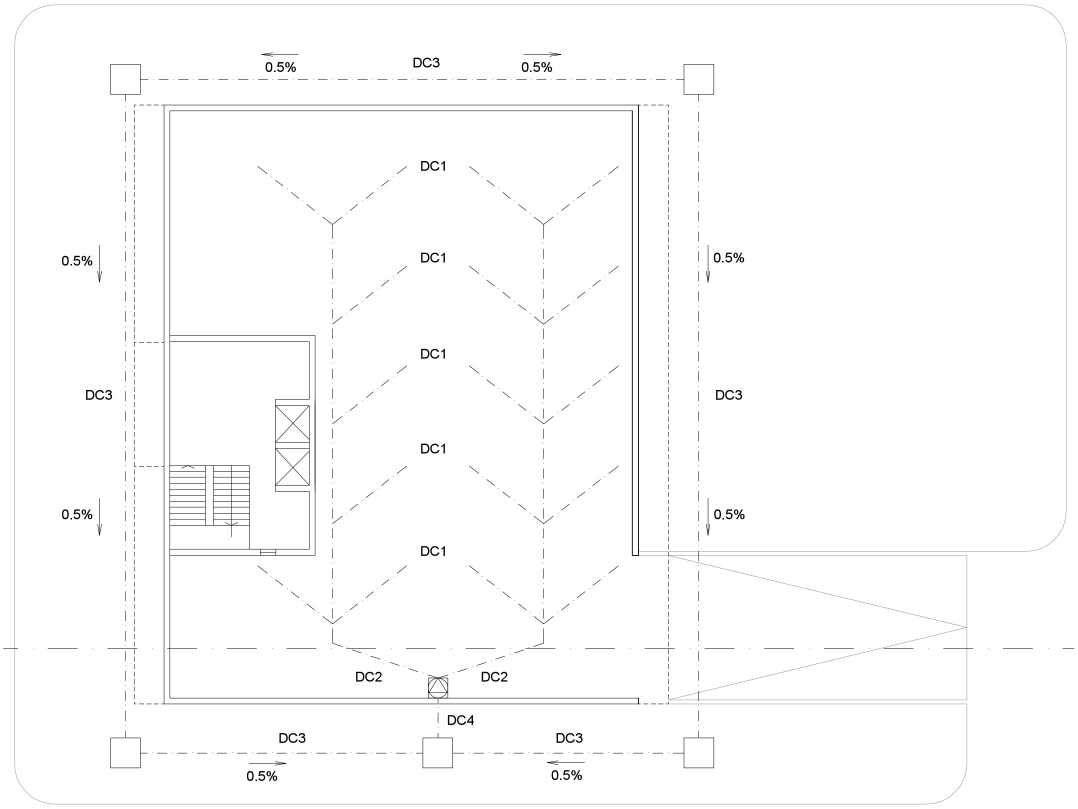


Figure 5.3 – Garage plan (collector drains).

## 5.2. Designing

The rainwater drainage system of the building was designed in accordance with three different methodologies: the Portuguese Regulation [1], the European standard EN12056-3 [2] and the Brazilian standard NBR 10844 [3]. The groundwater drainage system was designed according to published methods [1, 12], as regulation is inexistent.

Rigid PVC (K=120 $m^{1/3}.s^{-1}$) gutters were considered with a slope of 0.7%.

A water depth (H) of 7/10 of the radius of the connecting gutter was assumed for downpipes designing. This estimate yields higher diameters, but this is not an issue since downpipes are generally oversized. Downpipes were assumed to be in rigid PVC.

Rigid PVC (K=120 $m^{1/3}.s^{-1}$) drains were considered with a slope of 2.0%.

The infiltration flow rate was estimated considering an infiltration basin of 2000 $m^2$. Therefore, the areas of all underground pavements are multiplied by this rate to obtain the infiltration flow rate in the building. A network of drains and collectors designed to gather ground water will ensure the drainage system, thus conducting waters to the pumping chamber with a slope of 0.5%.

Six taps were considered in the basement with a design flow rate of 1.25 l/s which are drained by six pavement drains and conducted to the pumping chamber through six rigid PCV (K = 120 $m^{1/3}.s^{-1}$) branches. This means that each branch drains a flow rate equivalent to one tap.

The base flow rate of the elevator installation is obtained by adding the infiltration and washing flow rates together and applying a safety margin of 20%. To estimate pipe diameters, a maximum flow velocity of 2 m/s was assumed. Then, a higher nominal diameter was selected and the actual flow velocity was assessed. Since the obtained value is within comfort thresholds, the continuous head loss is calculated (Flamant's formula [8] can be used) and added to the elevation difference between the level of the pumping chamber and that of the chamber where the water is being lifted to, in order to estimate the pump total head. In order to account for localised head losses, the pipe length is increased by 20%.

A pump efficiency of 70% was assumed.

The volume of the pumping chamber (0.70 $m^3$) was designed for eight start-ups per hour.

In the following (Tables 5.1 to 5.7) all obtained results are shown.

## 5.3. Results

### 5.3.1. Rainwater system

#### 5.3.1.1. Gutters

Table 5.1 – Designing of gutters.

| Gutter | Portuguese Regulation | | | | EN 12056-3 | | | | NBR 10844 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ac ($m^2$) | Qc ($m^3/s$) | D (mm) | Dn (mm) | Ac ($m^2$) | Qc ($m^3$) | D (mm) | Dn (mm) | Ac ($m^2$) | Qc ($m^3$) | D (mm) | Dn (mm) |
| Ca1 | 186.5 | 0.0054 | 152.3 | 160 | 198.6 | 0.0058 | 187.1 | 200 | 198.6 | 0.0058 | 155.9 | 160 |
| Ca2 | 71.0 | 0.0021 | 106.0 | 110 | 74.3 | 0.0022 | 126.3 | 125 | 74.3 | 0.0022 | 107.8 | 110 |
| Ca3 | 10.9 | 0.0003 | 52.5 | 50 | 10.9 | 0.0003 | 58.5 | 63 | 18.6 | 0.0005 | 64.1 | 63 |
| Ca4 | 51.8 | 0.0015 | 94.2 | 90 | 51.8 | 0.0015 | 109.3 | 110 | 59.5 | 0.0017 | 99.2 | 110 |

#### 5.3.1.2. Downpipes

Table 5.2 – Designing of downpipes.

| Downpipe | Portuguese Regulation | | | EN 12056-3 | | | NBR 10844 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) |
| P1 | 0.0054 | 22.7 | 50 | 0.0058 | 36.4 | 50 | 0.0058 | 50 | 50 |
| P2 | 0.0021 | 13.6 | 50 | 0.0022 | 25.2 | 50 | 0.0022 | 50 | 50 |
| P3 | 0.0019 | 84.1 | 90 | 0.0019 | 24.0 | 50 | 0.0032 | 50 | 50 |
| P4 | 0.0043 | 69.2 | 75 | 0.0043 | 32.6 | 50 | 0.0056 | 50 | 50 |

#### 5.3.1.3. Drains

Table 5.3 – Designing of drains.

| Drain | Portuguese Regulation | | | EN 12056-3 | | | NBR 10844 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) |
| CI1-CI2 | 0.0043 | 69.3 | 110 | 0.0043 | 125.9 | 125 | 0.0056 | 84.2 | 110 |
| CI2-CI3 | 0.0086 | 89.9 | 110 | 0.0086 | 157.7 | 160 | 0.0113 | 109.2 | 110 |
| CI3-CI4 | 0.0107 | 97.5 | 110 | 0.0108 | 169.8 | 200 | 0.0134 | 116.6 | 125 |
| CI4-CI5 | 0.0161 | 113.8 | 110 | 0.0165 | 196.0 | 200 | 0.0192 | 133.4 | 140 |
| CI5-CI6 | 0.0180 | 118.7 | 125 | 0.0184 | 203.3 | 250 | 0.0225 | 141.4 | 140 |
| CI6-CI7 | 0.0199 | 123.3 | 125 | 0.0204 | 210.1 | 250 | 0.0257 | 148.8 | 140 |
| CI8-CI7 | 0.0117 | 101.0 | 110 | 0.0084 | 156.8 | 200 | 0.0084 | 97.9 | 125 |

Table 5.4 – Designing of balconies and terraces' drains.

| Drain | Portuguese Regulation | | | EN 12056-3 | | | NBR 10844 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) |
| Ra1 | 0.0006 | 33.9 | 50 | 0.0006 | 40.1 | 50 | 0.0011 | 45.3 | 50 |
| Ra2 | 0.0030 | 60.8 | 63 | 0.0030 | 74.8 | 75 | 0.0035 | 70.2 | 75 |

### 5.3.1.4. Final drain

Table 5.5 – Designing of final drain.

| Ramal de ligação | Regulamento Geral | | | EN 12056-3 | | | NBR 10844 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) | Qc ($m^3/s$) | D (mm) | Dn (mm) |
| RL | 0.0316 | 146.6 | 160 | 0.0288 | 269.6 | 315 | 0.0342 | 165.5 | 200 |

## 5.3.2. Groundwater system

### 5.3.2.1. Drain collectors

Table 5.6 – Designing of drain collectors.

| Drain collector | Qc ($m^3$) | D (mm) | Dn (mm) |
|---|---|---|---|
| DC1 | 0.00004 | 21.0 | 110 |
| DC2 | 0.00075 | 60.6 | 110 |
| DC3 | 0.00031 | 43.7 | 110 |
| DC4 | 0.0013 | 73.4 | 110 |

## 5.3.3. Elevatory installation

Table 5.7 – Designing of the pump.

| | |
|---|---|
| Qc ($m^3/s$) | 0.0063 |
| b (PVC) | 0.000134 |
| D (mm) | 63.2 |
| Dn (mm) | 63 |
| v (m/s) | 2.01 |
| J (m/m) | 0.0574 |
| L (m) | 2.5 |
| Leq (m) | 3 |
| z (m) | 3 |
| H (m.c.a.) | 3.81 |
| P (kW) | 0.334 |

# 6. Conclusions

In Portugal, adequate design and installation of rainwater drainage systems in buildings is controlled by mandatory regulations and standards. These regulations and standards do not consider groundwater drainage systems, although they are required in most new buildings. Other publications of research results and field experience then can be used.

Designing of rain and ground water drainage systems in buildings is based on current hydraulics theories. Thus, the main differences between designing methods are those related to estimation of the contributing precipitation area. Some important differences also were identified on the estimation of downpipes diameters.

The case study has shown that the European standard EN 12056-3 [ref] generally leads to higher pipe diameters.

# 7. Bibliography

[1] Regulamento Geral dos Sistemas Públicos e Prediais de Distribuição de Água e de Drenagem de Águas Residuais (Decreto-Regulamentar nº23/95). Lisboa, 1995.

[2] EN 12056-3 – Gravity drainage systems inside buildings - Part 3: Roof drainage, layout and calculation. Brussels: CEN, June 2000.

[3] NBR 10844 – Instalações prediais de águas pluviais. Rio de Janeiro: ABNT.

[4] DUERHOLT, E. – “Impermeabilização e drenagem na construção. Protecção contra as águas freáticas” (Tradução 467). Lisboa: Laboratório Nacional de Engenharia Civil, 1974.

[5] PEDROSO, V. M. R. – “Regras de dimensionamento das redes prediais de distribuição de e de drenagem de águas residuais domésticas e pluviais – ITE 31”. Lisboa: Laboratório Nacional de Engenharia Civil.

[6] PEDROSO, V. M. R. – “Manual dos sistemas prediais de distribuição e drenagem de águas”. 3ª Edição. Lisboa: Laboratório Nacional de Engenharia Civil, 2007.

[7] TORRES, J. A. A. – “Sistemas de drenagem em Edificações: Águas servidas e pluviais”. Lisboa: Livros Horizonte, 2005.