Building systems of cold water supply

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1. Introduction

Water, a substance essential to human life, has always been used for many different purposes. The constant demand forced men to create conditions so that it would be possible to transport it to the necessary locations, thereby creating water supply systems. Throughout the centuries of existence of the human race, there has been a constant evolution of these systems, which has allowed current constructions to include a wide choice of options. This increase of solutions is linked with the concepts of quality and security which, other than having propelled the plumbing industry, in pursuit of the raw material which provided the best quality conditions, economy, safety or concern with the main environment, has also allowed the creation of regulations, which are nowadays essential in building an effective system.

The water supply systems are used to provide both cold and hot water, as the water used while fighting fires. In this document, only cold water supply systems, which include the means to fighting fires and the networks to provide water for consumption, shall be addressed. The so called networks are built by pipes which, connected by accessories, allow supply to come from different devices. The execution of all these elements can be made using plastic materials or metallic ones, which will be applied depending on the project at hands.

As mentioned in the first paragraph, the notion of civic responsibility, through caring for the maintenance of quality in our main environment, has been continuously increasing. This development is equally felt in the water supply systems, whether it is by sustainable techniques, or by the regulations of fighting the unmeasured usage of this substance.

2. Cold water supply systems

As mentioned on the initial chapter, the cold water supply systems, divide themselves into drinking water supply systems for human consumption and water supply systems for fire fighting. Next, these two means of supplying water shall be addressed, analyzing in turn the options which both contemplate. The materials used to craft these networks will also be addressed.

2.1. Drinking water supply systems for consumption

The implementation of systems to supply drinking water is essentially divided into two stages. Initially its route is developed, taking into account the laws that apply within the project implementation site. This first stage is to find an optimization among the choices of projects from other specialties (sewage, gas, etc.) and essential options to execute a network of water supply. It is therefore of great importance that the existence of communication between all the designers work. The second phase of the implementation of water distribution networks is the preparation of calculations which, based equally on legislation, determine the dimensions of the piping components of the network.

This design is further restricted by the flow needed to supply each unit and adjusted taking into account the pressures that arise in each section.

In performing the two steps mentioned above key factors are taken into account such as economy, conditions of application and use, the needs of designing and also the chemical composition of each material. The water supply systems are built based on the optimization of these factors, taking into account the legislation in the area of deployment. In Portugal, the following of the criteria is based on "*Regulamento Geral dos Sistemas Públicos e Prediais de Distribuição de Água e de Drenagem de Águas Residuais*" (referred to as RGSPPDADAR throughout this document) [N2] and on the European normative, EN 806, which also regulates the other countries belonging to the European Committee for Standardization (ECS). It should also be noted that the RGSPPDADAR [N2] alludes to the possibility of using municipal regulations that dictate some specific rules for each county.

The completion of the delineation of water supply networks, besides respecting the laws and taxes and some predefined rules [3], is highly dependent on projects of other specialties. Therefore, the purpose of designing/planning is to find a solution that optimizes the options provided and to avoid conflict with other projects. While referring to designing it is of utmost importance to highlight the impact which the material chosen has on the final solution. This importance is clearly evident if one compares the trace metal piping (linear mesh) and the layout of a pipeline that uses tubes made of polymers (irregular outline).

For the dimensioning of the supply networks of drinking water, two distinct approaches are considered: the method advocated by RGSPPDADAR [N2] and the calculation procedure proposed by the 3rd part of the European Standard, EN 806-3 [N4]. The first is characterized by greater accuracy of the calculation, providing solutions more comfortable but also more expensive. The calculation method of the European standard has a lower degree of difficulty and achieves the most economical solution, but also with a lower level of comfort. Despite the differences, the two methods consist of three distinct phases (Image 2.1): evaluation of the data provided and definition of desired conditions, calculation of the flow of design, estimation of pipe diameters.

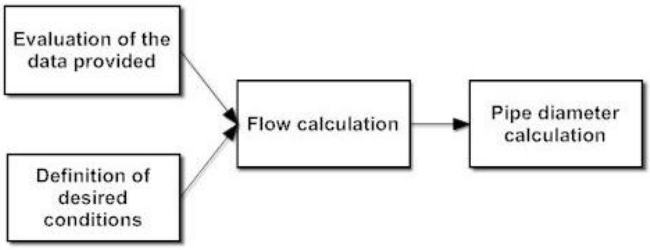

Image 2.1 - Dimensioning of the supply networks of drinking water

2.2. Systems of water supply for fire fighting

The systems of water supply for fire-fighting are essential in any building, therefore, they are defined in the legislation (in Portugal it is the "*Regime Jurídico de Segurança Contra Incêndios em Edifícios"*- called RJSCIE throughout this document - which sets the rules to adopt these types of system). [N1] In this document, it is made clear that some of these rules, have a higher accuracy compared to systems identified in Section 2.1, and it also defines the options for layout and design of these systems. Despite the accuracy required, the implementation of networks of fire-fighting is also based on building solutions that optimize the relationship between economy and quality of the system.

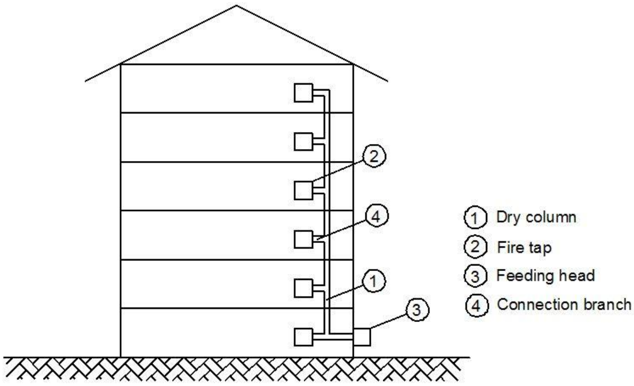

Image 2.2 - Dry column system (adapted from [3])

In the analysis of the mechanisms used against fire the different forms of intervention are taken into account, namely the use of manual methods and automated means. Such means may be of first (intervention by building occupants) or second intervention (intervention by specialized personnel, including fire-fighters). Among the manual means of second intervention highlight the dry column (Image 2.2), the wet column (Image 2.3) and the armed fire-fighting network which uses flexible hoses (Image 2.4). The hose reel networks of fire-fighting are considered manual means of first intervention (Image 2.3). The automatic means (sprinklers and water curtains), not requiring any human intervention to be activated, are also considered first means of intervention.

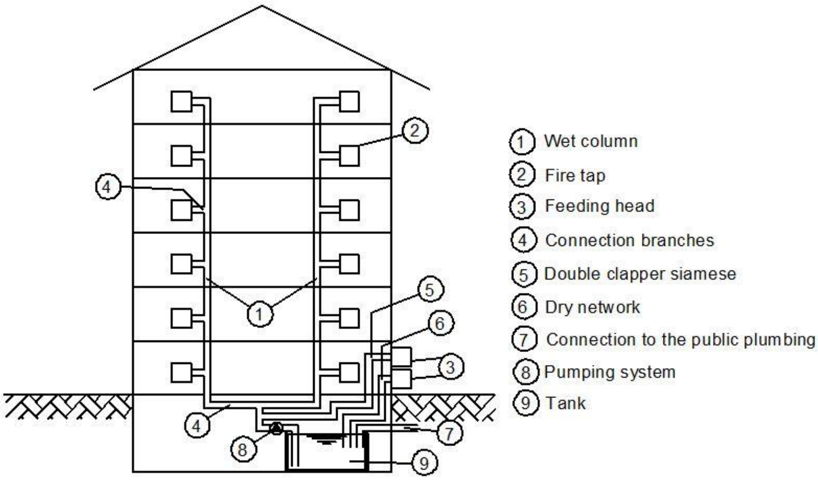

Image 2.3 - Wet column system (adapted from [3])

The manual methods of fire-fighting have an identical structure, formed by pipes that develop mainly in the vertical and allows supplying fire-hydrants installed in common passageways [N1], providing an effective fire fighting. The difference between various methods of manual intervention lies primarily in the way they are loaded (permanently or just for fire-fighting) and also the type of fire-hydrants used. As for the fire hydrants, they may be armed (direct use, due to the presence of hoses previously installed), or unarmed (use of fire hoses installed by the time of the fire fighting). The armed fire hydrants are divided into two types: reel hydrantes, which are made of semi-rigid hoses, easy to use for any user and other kind of hydrants, made of flexible hoses, which require more technique. Despite the existence of several common points, the differences between the manual methods translate into inequalities regarding some aspects of construction and to its scalability, which is made based on some laws which are also used on hydraulic supply systems for consumption.

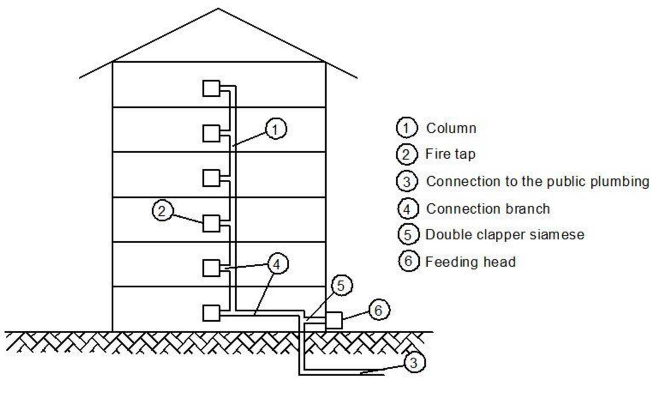

Image 2.4 – Armed fire-fighting network (adapted from [3])

Automated methods of extinction, although they may be designated as fire fighting systems, are best used as a means of delaying or preventing the fire, since they do not have a large capacity in terms of volumes of water billed in each discharge, and also due to the short time of action, therefore they do not suffice to fight a fire. Because of this fact, it should always be carried out through manual fire fighting. As a means of automatic extinguisher we should highlight the sprinkler (Image 2.5) and the water curtains (Image 2.6), which differ in the type of element that releases water into the area to flood.

Image 2.5 - Sprinkler and supplying system

Image 2.6 - Water curtains system to protect tanks [I2]

The automatic system, being operated automatically, has a more complex constitution than those of manual fire fighting. They consist of a command post that, when activated by alarms, causes the water from a power source (tank or direct connection to public network) which circulates throughout the pipe network system, to flood the zone which needs intervention. This complexity means that both its stroke and the design require a more complex approach, in relation to those required by manual methods.

2.3. Materials and other elements used in cold water supply systems

The materials used in the pipes of water supply networks can be grouped into two major groups: metal and plastics. The metallic ones are most commonly used in fire-fighting systems, while the application of plastic pipes is limited to networks of water supply for drinking and may or may not, depending on their characteristics, be used in hot water systems.

Table 2.1 - Advantages and disadvantages of the different type of pipes

Pipes	Advantages	Disadvantages
Metal	Good resistance to shock and high temperatures; durability; insignificant dilation; application with little demands of manpower; high pressure resistance.	Elevated localized head losses; difficulty in handling; low capacity for heat retention; possibility of corrosion (higher in certain metals); obligation to construct a linear grid.
Plastic (General)	High corrosion resistance; light weight; high capacity for heat retention.	Low resistance to high temperatures; ultraviolet vulnerability; high dilation; low resistance to high pressure; inability to use on fire-fighting networks.
Plastic (Flexible)	Low localized head loss; ease of repair; ease of handling.	Junction box use obligation and sometimes, other material to give continuity to the network; requires a perfect implementation.
Plastic (Rigid)	Ease of implementation.	Obligation to construct a linear network plumbing; relevance of localized head loss.

For the choice of material to be taken one should consider the applicability and characteristics of the material, in addition to the economic component. Table 2.1 shows the advantages and disadvantages that are inherent to these two materials.

In addition to the entire network of piping systems, the supply of drinking water is also composed of other elements including deposits, pumping systems and devices that are also responsible for monitoring and providing water supply. The tanks used in water supply systems are built to store cold water, allowing a distribution according to the conditions imposed up on the respective and aforementioned regulations. The deposits referred in both types of systems have two specific functions: to distribute water or regulate the pressure and the pump starts. Due to the similarities between the tanks of fire fighting systems and supply systems for drinking, it is possible to consider a solution that encompasses the same deposit requirements of both systems. Although this option is quite effective, is not very advisable, its use being limited to certain rules related to the quality of drinking water.

There are three pumping systems used to eliminate situations of lack of pressure in the network: overpressure from the public grid or by installing a tank elevation, elevation for a deposit installed on top of the building and use of a hydropneumatic system. In Portugal it is more common to apply the first system, since the pressure conditions are permanently guaranteed by the public water supply, unlike what happens in less developed countries, where it is necessary to use a tank mounted on top building that guarantees the pressure levels in the various devices. The hydropneumatic system is also widely used on national territory, since it allows a reduction of the ignition pumping group, allowing lower energy costs and increased durability of these devices. Relatively to the differences between the pumping system of networks of water supply for consumption and fire fighting, it is possible to say that it relies essentially on the ongoing maintenance of operability of the pumping groups. This way, in the fire fighting systems, is required by RJSCIE [N1] the installation of additional pumps which allow quick restore of pressure levels, guaranteeing them in case that the main pumping system, or the electrical system of the building fails. The water supply systems would not be complete with the application of pipes that provide a flow of liquid. It is necessary to control this flow according to user needs. In addition to this primary function, the devices used in such systems also allow the transition between all the plumbing and the consumer. We must also highlight the role that sustainable devices can have in a system of water supply for consumption, as they allow significant reductions in water consumption. Yet it is noteworthy that despite having great importance in a policy of sustainability, this information may not have the desired performance, since they alter the normal functioning of the systems. So, this is one aspect that should be taken into account in applying these devices.

3. Systems at work

The construction of any building is always the achievement of two main activities, the design and implementation, with the management of the construction depending on the way they are developed. The dissociation of these two processes is unworkable, since the execution quality always depends on the clarity of the project, which is related to existing conditions to perform the work. The implementation phase should include, beyond the stage of completion of construction, an initial period where you should pay special attention to the materials to be used. The conditions for receiving the material have great influence on their conservation status, which is directly related to the quality of water supply networks. The reception of the material can be separated into two distinct phases: transport and storage. It is therefore essential, in both transmission and storage, that the materials remain intact, free from any action that could damage them, either by the possibility of a direct damage or by the possibility of any pathology.

The implementation of networks, a crucial stage of the work, is mainly dependent on the techniques used, features of the project, the quality of manpower, material and equipment, the conditions encountered at work (security, climate, and others) and also the complexity of the work. The optimization of these conditions allows the improvement of the systems characteristics, which results in their final high quality, therefore the reduction of pathologies that they may be associated. Currently, as stated in [1], the pathologies inherent in building systems for water supply, fire fighting and drainage represent over 90% of the whole problems encountered in construction. Many of these pathologies are due to deficiencies in the implementation phase, which demonstrates the great importance that this phase has in the quality standards of installations inside buildings. Besides the problems mentioned in the preceding paragraph, the natural abrasion of the material and the changing conditions of supply from the public network are also defects that cause pathologies that are associated with these systems. These conditions vary depending on the material used. While in metal pipes corrosion (Figure 3.1) is the most commonly found problem, in plastic pipe ruptures are more usual.

Image 3.1 - Corrosion in a metal piping [I1]

In the implementation phase of a cold water supply network, piping conditions must be checked. For this it is necessary to test compliance, as has been established in RGSPPDADAR [N2]. This regulation states that two different tests must be performed to check the conditions of the whole network: the leak test and the hydraulic operation test. Both tests should be done with the pipe in sight, so it is possible to make an easy adjustment if necessary. The construction phase represents the initial phase of the life of a building and it is assumed, in most cases, as the stage of shorter duration. During the remaining period of life conservation of the system should be ensured, in order to reduce the risk of defects that may change its normal operation.

The conservation of water networks is not only to maintain a constant maintenance, but also, the rehabilitation of part or the whole supply system. It may also be necessary to change its constitution, resulting in the need to modify the water network. All these changes must be made taking into account the conditions for the water supply.

4. Sustainable systems

The issue of sustainability has been discussed more and more, which means that there has been an increase in sustainable policies in several areas. The water supply systems do not escape this trend. The implementation of sustainable policies for water consumption can be done using various methods. In a sustainability plan is important, besides the application of technical solutions, to aware the population. In Portugal there are some programs related to the policies outlined in the preceding paragraph, for example, Programa Nacional para o Uso Eficiente de Água, sponsored by the Ministério do Ambiente e do Ordenamento do Território [M1]. For more technical solutions, sustainability in water networks can be applied through different processes, depending on the type of project under study. This way, can be created both sustainable networks of water supply, waste water and pluvial water. There is also the possibility of developing a comprehensive project to link the various specialties.

Concerning the utilization of waste water and sewage systems, it is possible to create systems to reuse water through a treatment capable of conferring properties that allow its use in non-drinking destinations (discharges from toilets, shower, laundry, fire fighting systems, among others). The sustainability of water supply may also be applied upstream, through the use of devices (Section 2.3) that allow the rational use of the liquid or a decrease in pressure in the network, taking into account the limit values. The use of more efficient devices (laundry machines, dishwashing machines, among others) with lower consumption of water, is also a point to take into account in the issue of sustainability. The implementation of sustainable projects of water supply is always associated to a higher cost, which is lower in a normal project. This initial investment is, in most cases, an obstacle to execution of the water utilization plan. Another downside of these systems is related to the susceptibility that they show, relatively to the emergence of some failures. These gaps stem from the fact that these kinds of projects change the normal operation of supply systems, which have a way to run established long ago. The changing of conditions may result in a lack of results. These two negative aspects are important when implementing a system of sustainable water supply. In the other hand, the concept of liability and the decrease in spending of water is one big advantage of the application of such systems.

5. Work cases

The following buildings are mentioned in [2]. Three distinct types of buildings were analysed, in order to find their similarities and differences. To this end it was studied a mixed-use building, a warehouse and also a school. It should be noted that for the warehouse and the school, only the route was considered, since the sizing is done identically to the mixed design of the building.

5.1. Mixed-use building - Seixal

The following building is composed by four residences with 3 bedrooms each, and four with 2 bedrooms, throughout 3 floors. While the ground floor is composed by a store, the basement is used for parking [M2].

5.1.1. Drinking water supply network

The design of the water supply network for consumption was made considering the guidelines imposed by RGSPPDADAR [N2]. Still, it is important to notice that some options were made by the designer, which could be modified to improve both the quality of the network, as well its cost. PEX pipes are normally used to provide better comfort levels, and in this solution they were considered downstream of the counters. Comparing this alternative with a mixed solution (connection between the various junction boxes and the counter through walls made of masonry using PVC pipes) despite being more costly, it is more advantageous in terms of hydraulic operation, due to the advantages of PEX pipes throughout the network, not only within each division. Moreover, a mixed solution entails greater lengths of pipes which force the necessity of using accessories, leading to greater head losses. Regarding the length, a shorter route could possibly be adopted. Additionally, the location of junction boxes could be different, in order to improve the access to them in case of repair, since they are located in an area of cabinets. Finally, the kitchen plumbing of the apartments with 3 bedrooms is strictly connected to the sanitary sewage system. It would be advantageous to separate these two divisions independently so that in case of a situation where the division supply must be stopped, the other division maintains its normal functioning.

The sizing analysis shows that the economic aspect was more important than the comfort conditions, mainly because the minimal pressure levels were too low (in the order of 60 kPa), and in several situations velocity values were greater than 1.50 m/s.

5.1.2. Fire-fighting water supply network

The water supply network is composed by galvanized steel pipe which supplies two fire reels installed on the underground floor. Focusing on the network it is important to refer that all the conditions imposed by RTSCIE [N3] were taken into consideration, as well as the options to optimize the cost-efficiency, creating a network as short as possible.

Regarding the sizing, flow and velocity values within the limits were considered.

5.2. Warehouse – Seixal

The warehouse in question is composed by three tranches with direct access, isolated and independent to the outside. Each fraction possesses a wide area for parking (level -1), a wide area to store and two toilets (floor 0), and finally a gallery installed on a floor. Each fraction has also inherent a coverage area for the installation of solar panels [M4].

5.2.1. Drinking water supply network

Concerning the warehouse's water supply network, two different types of piping were considered: PVC for the outside plumbing and PP-R for the inside plumbing of the building [M4]. Regarding the network grid, it is important to refer that was taken into account the rules which allow the construction of a network in good conditions, respecting the economic efficiency.

5.2.2. Fire-fighting water supply network

The regulatory requirements obligate the construction of armed network fire-fighting to meet the warehouse exigencies of RTSCIE [N3]. So it was considered the installation of three reels in each fraction of the building (one in the basement and two on the ground floor), which are serviced by a galvanized steel pipe. The good conditions of the storage area in terms of reels, compared to the parking floor, shows the evident concerns about the risk of fire in this building area. Similarly to what happen in other buildings discussed during this work, the fire network obeys to the guidelines imposed by the RJSCIE [N1]. Thus, it is easy to verify that the reels are sufficient to cover all the exposed areas in case of a possible accident. Also, there was a deep concern to install these devices in the communication areas. Then, finally in order to supply the fighting network in the case of a public network failure, it was considered an extra fire-tap, installed in the front, which is area of easy access for the emergency vehicles.

It should also be noted that all the construction options make possible the execution of a network in good quality conditions.

5.3. Josefa de Óbidos Secondary School – Lisboa

This building is a school composed by five distinct blocks, which includes classrooms, laboratories and all other essential equipment needed in a school. The school's rehabilitation comprehends initially the rehabilitation of three blocks and then the construction of two new blocks within the same school zone.

5.3.1. Drinking water supply network

Firstly, the initial cold water network supply of polybutylene piping, suffered a modification with the rebuilding process of the school. This modification was the replacement of polybutylene pipes by multilayered, achieving optimization and reaching better levels durability in the water supply network. Although this solution is more expensive, special attention was given to the improvement of the system, mainly due to its high usage. In this work, the initial project will be highlighted.

The analysis of the pipes supply water network for consumption led to several conclusions. It is important to refer that beyond the polypropylene and the high density polyethylene (used in the outside network), it was also used PEX piping in three sections of the kitchen. As represented in

Figure x, this system was the ideal solution to feed the island devices of this division, due to the need of making this type of installations on the floor.

5.3.2. Fire-fighting water supply network

RJSCIE [N1] impose that should be installed, in this school, a armed fire-fitghting network, because this building is susceptible to receive more than 200 people. Therefore many reels were installed throughout the school. To supply the reels was used a network composed by galvanized steel pipes.

The location of fire taps is one of the major concerns in projects where armed fire-fighting network is incorporated. An analysis of the network [M3] shows that the reels are installed in escape routes at a sufficient distance to cover all fire exposed areas. Still, there are some areas where it could have been installed fire taps to facilitate the fight by users, thereby increasing the effectiveness of fire-fighting.

Should also be noted that were taken into account the rules that optimize the design of the network, providing good economic and technical conditions.

6. Conclusions

The implementation of systems for cold water supply is made to obtain a solution that optimizes the ratio between the efficiency and ultimate cost, always meeting the legislative guidelines. In the studied buildings, it was verified that there is a greater concern with the price of the work than with the comfort that can be provided to users.

In [2] a study was done on the design methods contained both in RGSPPDADAR [N2], as in the European Standard EN806-3 [N4]. Through this analysis it can be concluded that the method proposed by RGSPPDADAR [N2], requires more time and is more complex, but delivers more rigorous solutions, with greater comfort level, while the use of European Standard [N4] allows a more practical way to obtain solutions with a lower level of comfort. It also should be noted that as the European standard [N4] leads to solutions with smaller diameters, it is more advantageous from an economic standpoint.

Concerning the water supply for fire fighting systems, it is possible to conclude by analising RTSCIE [N3], that the mean of combat which is more often required fire hose reel. This happens because armed fire-fighting network is the mean that provides, more rapid and effective fire fighting.

About the materials used in piping networks of cold water supply, a distinction between two main groups can be made: the metal and plastics. The metal pipes are most commonly used for fire fighting, while plastic pipes have limited its application to networks of water supply for drinking, and depending on their characteristics, can be used in hot water systems. The choice of the material should respect, besides the economic component, the applicability and characteristics of the material. Similar to what happens in materials, devices used in networks of water supply for consumption, are different from those applied in fire fighting networks, since they have distinct functions. Through the study made in this paper it is also possible to conclude that the pumping systems, despite having identical characteristics, are more rigorous in the combat systems, because a greater level rigor is demanded to prevent possible damage.

In the 3rd Chapter of this document an analysis was made to systems at work. It can be concluded that the durability of these systems is closely linked to the achievement of a performance with quality. It is also worth noting that the maintenance of the systems brings an increase in the durability of networks. It is also possible to conclude that the most evident pathologies are corrosion in metal pipes, and breakage due to impact on the plastic tubing.

During this work [1], a study on the sustainability of cold water supply chains was elaborated. This analysis showed that the adoption of sustainable networks enables reductions in water consumption, bringing financial and environmental advantages. Yet it is important to refer that these solutions may not be able to meet the requirements for which they were projected.

Through the examples discussed before, several noticeable differences in demand between different uses of buildings were identified, especially the supply water project for fire-fighting. Therefore, it was concluded that both the warehouse, and the school building are fitted with a more complete a combat system. This difference may be justified depending on specifications of the building. In the warehouse there is a higher fire risk, since some dangerous materials can be stored there. The school is also an accident risk place because it can be used by a large number of people. In both cases a fire fighting fleet network was used, decreasing the menace of an accident.

Another significant aspect in the analysis of such buildings has to do with the choice of material to be used in plumbing. As seen in the studied projects, the choice to use the tubing does not follow a rigid rule, which is consistent with the preferences of the designer. Yet there is a noticeable trend towards the use of galvanized steel pipes forming the network of fire fighting.

7. References

[1] AFONSO, A. S.; RODRIGUES, C. - "A qualidade na construção ao nível das instalações prediais de águas e esgotos. Situação e perspectivas em Portugal." Congresso Construção 2007 - 3º Congresso Nacional. Coimbra: Universidade de Coimbra, 2007.

[2] BAPTISTA, F.P. - "Sistemas prediais de abastecimento de água fria." Lisboa: IST, 2011.

[3] PEDROSO, V. M. R. – "Manual dos sistemas prediais de distribuição e drenagem de águas." 3ª Edição. Lisboa: LNEC, 2007.

[N1] Regime Jurídico da Segurança Contra Incêndios em Edifícios (Decreto-Lei n.º 220/2008). Lisboa, 2008.

[N2] Regulamento Geral dos Sistemas Públicos e Prediais de Distribuição de Água e de

Drenagem de Águas Residuais (Decreto Regulamentar Nº 23/95). Lisboa, 1995.

[N3] Regulamento Técnico de Segurança Contra Incêndios em Edifícios (Portaria n.º1532/2008). Lisboa, 2008.

[N4] Specifications for Installations Inside Buildings Conveying Water for Human Consuption - Part 3: Pipe Sizing - Simplified method (EN 806-3:2006). Bruxelas: CEN, 2006

[I1] INSTITUTO BRASILEIRO DE DESENVOLVIMENTO DA ARQUITECTURA - Forum da Construção (www.forumdaconstrucao.com.br) consulted at 16-11-2010.

[I2] SECOI LTDA (www.secoi-ltda.com) consulted at 15-7-2010.

[M1] MINISTÉRIO DO AMBIENTE E DO ORDENAMENTO DO TERRITÓRIO, INSTITUTO DA ÁGUA – Programa nacional para o uso eficiente da água.

[M2] Project of the mixed-use building - Seixal

[M3] Project of the Secondary School Josefa de Óbidos - Lisboa

[M4] Project of the warehouse - Seixal