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Waterproofing of foundations of buildings and special structures

Extended abstract

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1. Introduction

This dissertation aims to contribute to increase the knowledge on waterproofing membranes used in building foundations and special structures. The work carried out through this dissertation is focused on the study of the methods used to make these structural elements impermeable, as well as the study of the most adequate materials for each situation.

Even though the use of waterproofing membranes in building foundations improves the durability of these important structural elements, in Portugal they are only used in a small percentage of the buildings. This fact relates to the increase of the initial costs that their utilization implies, and the lack of information concerning this subject. The use of waterproofing protection is even more important when the groundwater level is close to the foundation of the buildings, where the water can be absorbed by capillarity. The fact that these structural elements are underground makes them hard to reach if it is necessary to proceed with any repair. Therefore, the repair of these elements is almost impossible, and thus the waterproofing of these structures must always be considered in the project.

In Portugal, waterproofing protection of foundations is only regarded in important projects with greater service life requirements. Two examples of these projects are mentioned throughout this work: the Building of the Champalimaud Foundation and the Portuguese National Bank.

However, not every foundation type, or every part of the foundation can be covered with a waterproofing membrane. Only foundation footings (isolated, linear or connected by lintels), mat-slab foundations and the pile heads or pile cap blocks are able to receive waterproofingt. The mentioned types of foundations are presented on Figure 1.

Figure 1 - Types of foundations that can be protected with waterproofing: isolated foundation footings, mat-slab foundations and pile heads [3] [w_1][w_2]

2. General aspects concerning the waterproofing of building foundations

Since its discovery in the nineteenth century, concrete is used in buildings everywhere around the world. This material was considered impermeable during a long time after its discovery, and therefore waterproofing protection was never required. After some time, it was discovered that concrete was not impermeable after all, and that water absorption was responsible for some performance problems in concrete structures, i.e. permeability of concrete could not be disregarded.

After this discovery, the need for waterproofing of structural elements made of concrete became imperative, especially in more susceptible structural elements: foundations, underground walls and roofs. It was therefore necessary to find solutions that would exhibit a good performance in protecting the structures, but did not interfere with its construction processes or the material's physical and mechanical properties.

The types of waterproofing that proved to be more effective and thus most popular are prefabricated membranes. They were developed sometime between the 1960's and 1970's in Central Europe. Bitumen appeared in the 1950's, and only in the next decade became a part of the membranes. The types of membranes available currently are summarized in Table 1. They can be divided in three different categories: bitumen; synthetic thermoplastic polymers or synthetic elastomeric polymers.

Table 1 - Prefabricated waterproof membranes

<table>
<tr><td rowspan="3">Bitumen based membranes</td><td colspan="2">Modified bitumen</td></tr>
<tr><td colspan="2">Styrene-butadiene-styrene resins (SBS)</td></tr>
<tr><td colspan="2">Atactic polypropylene (APP)</td></tr>
<tr><td rowspan="13">Synthetic polymer based membranes</td><td rowspan="7">Thermoplastic</td><td>Plasticized polyvinyl chloride (PVC-P)</td></tr>
<tr><td>High-density polyethylene (HDPE)</td></tr>
<tr><td>Polyethylene high-density (PEHD)</td></tr>
<tr><td>Thermoplastic polyolefin (TPO)</td></tr>
<tr><td>Ethylene propylene rubber (EPR)</td></tr>
<tr><td>Chlorinated polyethylene (CPE)</td></tr>
<tr><td>Polyisobutylene (PIB)</td></tr>
<tr><td rowspan="2">Thermoplastic-elastomeric</td><td>Ethylene/propylene copolymer (E/P)</td></tr>
<tr><td>Chlorosulfonated polyethylene (CSM)</td></tr>
<tr><td rowspan="4">Elastomeric</td><td>Ethylene-propylene-diene monomer (EPDM)</td></tr>
<tr><td>Copolymer of isobutylene with isoprene (Butyl) (IIR)</td></tr>
<tr><td>Chloroprene rubber (CR)</td></tr>
<tr><td>Nitrile butadiene rubber (NBR)</td></tr>
</table>

Only some of the membranes presented in Table 1 are used in foundations, such as: modified bitumen, SBS, APP, PVC-P, HDPE, TPO and EPDM.

On the other hand, the bentonite geocomposite, a type of geomembranes, appeared only in the late 1980's. These materials were developed as a way of complementing the previous systems, providing leakproofness characteristic.

The developments and breakthroughs underwent by this industry enabled ensuring impermeability using only one of the mentioned systems, either membranes or geomembranes.

Another option might be the use of materials prepared in situ. Examples of this type of waterproofing are the bituminous emulsions, created in 1920, and the bituminous paint, developed afterwards to substitute the first in places where there was a concern about esthetic aspects.

The water that affects the foundations of a structure may present itself in different ways in the soil: infiltration water; accumulated water; suspending water; capillarity water; condensate water; groundwater; absorbed water and interstitial water.

The types of humidity that affect the building foundations considered in the dissertation were: construction humidity, ground humidity, humidity due to phenomena of hygroscopic, condensation humidity and humidity due to fortuitous causes. The construction humidity and the ground humidity proved to be the ones that have the biggest influence on foundations.

Finally, the other agents responsible for the deterioration of underground structures were: microorganisms, roots of vegetation, soil acidity (pH) and groundwater level.

3. Materials used in the waterproof protection

As mentioned before, the types of coating systems that are used in building foundations are prefabricated membranes and materials prepared in situ.

The types of waterproofing systems used in building foundations are summarized on Table 2, as well as their properties and performance concerning the following criteria: service life, aging, stretching, resistance to cold, flexibility, resistance to vegetation roots, environmental adaptability, application method and commercial dimensions. These features are graded using "plus" signals. A greater quantity of plus signals means a higher performance, except on the aging process, in which the increase of "plus" signs corresponds to a higher deterioration velocity.

After careful analysis, it is concluded that the materials with higher service life period are the HDPE membrane, with a service life of 150 years, and the bentonite geocomposite, with 100 years. Next come the polyvinyl chloride, the polyolefin, the polypropylene and the polyethylene (PVC, TPO, PP e PE, respectively) and the ethylene-propylene-diene (EPDM) membranes, with an average service life of 50 years. The blown bitumen and all the materials manufactured in situ (emulsions, bituminous paint and cement based coating) are the ones that show the lowest service life.

Analyzing the other properties reported in Table 2, it is found that the EPDM membranes demonstrate the best overall performance. However, they exhibit low flexibility, which makes them hard to handle. The PVC and TPO membranes prove to be advantageous from this point of view.

Also indicated on Table 2 are the application methods for each type of waterproof protection: welding or mechanical fixation are used on the prefabricated materials, and by roll; brush or trowel on the in situ manufactured materials.

Table 2 - Characteristics of the products used in waterproofing systems

		Service life (years)	Stretching	Aging	Resistance to cold	Flexibility	Resistance to vegetal roots	Environmental adequacy	Aplication method	General characteristics
Type of material	**Modified bitumen**	1 a 2	+	+ +	-	-	0	Innocuous	Weld	Thickness from 3 to 5 mm Length from 1 to 10 m
Prefabricated	**Bitumen -polymer APP**	30	Polyester (+) Glass fiber(-)	-	+	+	+	Innocuous	Weld	Thickness from 3 to 5 mm Length from 1 to 10 m
	Bitumen -polymer SBS	30	Polyester (+) Glass fiber(-)	-	+	+	+	Innocuous	Weld	Thickness from 2 to 5 mm Length from 10 to 20 m
	High-density polyethylene (HDPE)	150	+	- - -	+	+	+	Innocuous	Mechanical	Thickness from 0.40 to 0.60 mm Length of 20m
	Polyvinyl chloride (PVC)	50	+	- -	+	+	+	Innocuous	Weld; mechanical	Thickness from 1.2 to 1.5 mm Length from 15 to 20 m
	Thermoplastic polyolefin (TPO)	50	+	- -	+	+	+	Innocuous	Weld; mechanical	Thickness from 1.2 to 2.5 mm Length from 20 to 25 m
	Polypropylene and polyethylene (PP and PE)	50	+	- -	+	0	0	Innocuous	Weld; mechanical	Thickness from 1.2 to 1.5 mm Length from 20 to 100 m
	Etileno-propileno-dieno (EPDM)	40 a 50	+ +	-	+ +	+ +	+	Innocuous	Weld	Thickness of 1.5 mm Length from 15 to 40 m
	Bentonite geocomposite	100	+	-	+ +	+	+	Innocuous	Mechanical	Thickness of 6.4 mm Length from 2.5 to 5 m
Manufacturated in situ	**Bituminous emulsions**	1 a 2	-	+	+	- -	- -	Normal	Roll, brush, trowel	-
	Bituminous paint	1 a 2	-	+	+	- -	- -	Innocuous	Roll, brush, trowel	
	Cement base coating	1 a 2	0	+	-	-	-	Innocuous	Trowel	

The dimensions of the membranes and their nominal thicknesses vary according to the brand. While choosing a type of coating for a specific situation, the characteristics of the material should be carefully studied, to ensure the adequacy to the situation and/or type of foundation. For instance, in the case of foundations footing, the most important characteristic is the membrane's easiness to handle, given that it must cover all the elements.

In Table 3 the materials can be applied in multiple layers are specified (one membrane on top of the other). Bituminous membranes can be applied in multiple layers, as well as materials manufactured in situ. The multiple layers are especially important in the last ones, because they provide a reinforcement of the system.

Table 3 - Materials able to be applied in multiple layers

Type of coating system	Name	One layer	Multilayer
Prefabricated	Modified bitumen	x	x
	Bitumen-polymer APP	x	x
	Bitumen-polymer SBS	x	x
	HDPE	x	
	PVC-P	x	
	TPO	x	
	PP	x	
	PE	x	
	EPDM	x	
	Bentonite geocomposite	x	
Manufactured in situ	Bituminous emulsions		x
	Bituminous paint		x
	Cement base coating		x

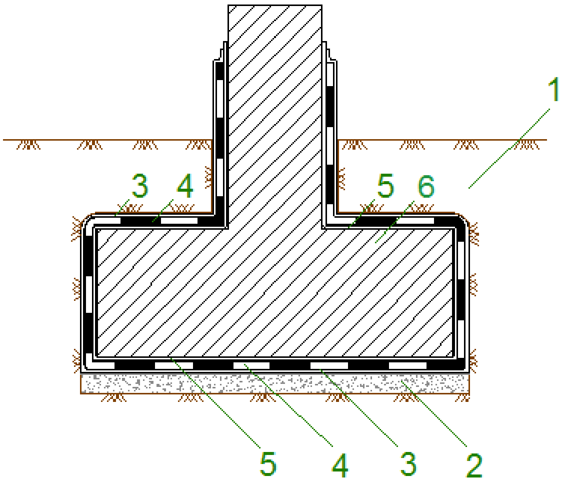
4. Waterproofing systems formed, techniques and application fields

For each type of foundation, different waterproofing systems can be used. However, for each case, there are types of coating that perform better than the others. Therefore, the main properties of the protection system should all be considered to ensure the best solution for the situation is used.

In foundation footings (both isolated and connected by reinforced concrete beams), the best waterproofing solution is to apply a protection geotextile layer and drainage material, followed by a waterproofing membrane and a new layer of geotextile to protect the membrane, after the element is built (Figure 2).

However, protecting foundations footing connected by lintels is very difficult and expensive, due to its geometry that requires several finishing details that have to be done in the membrane. These finishing details prove to be critical points in any coating system, and thus must be avoided.

One solution to this problem might be changing the project and choose a mat-slab foundation. This change allows overcoming problems with the aplication of the membrane, since it is applied horizontally (reducing the number of finishing details on the membrane), besides implying an easier construction process.



Legend

1 - Soil
2 - Blinding concrete
3 - Geotextile layer (mechanical protection layer and drainage material)
4 - Waterproof membrane (anyone of the prefabricated membranes mentioned on Chapter 3, especially PVC, TPO and EPDM membranes)
5 - Geotextile layer (mechanical protection layer)
6 - Isolated foundation footing (reinforced concrete)

Figure 2 – Waterproofing protection on an isolated foundation footing [personal archive]

The coating system presented in Figure 2 can be altered, removing one of the geotextile layers. However, there is a higher chance that the membrane is damaged without the geotextile layer protection. This may allow the degradation agents into the structural element and, in the worst case scenario, total loss of the system's waterproofing capacity, and therefore must be avoided.

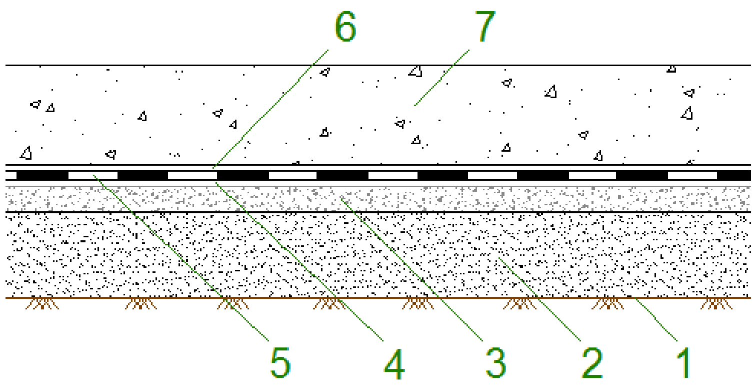
The PVC, TPO and EPDM membranes are the ones most commonly used by Portuguese technicians. They also suggest the use of bentonite blankets. The last ones show some advantages compared to the membranes mentioned before, that relates with the fact that the geotextile is already present in its constitution and, therefore, there is no need to add any other layer of geotextile. The presence of bentonite in its composition gives the membrane a capacity to self-heal.

On a mat-slab foundation, the waterproofing can be applied either on top or at the bottom of the concrete slab. If the groundwater level is close to this structural element, it is imperative that the membrane is applied at the bottom surface, in order to prevent the deterioration of the element. When the groundwater level is located deep in the ground, the waterproofing system can be placed on top of the concrete slab.

Applying the coating system at the bottom plate is advantageous, since it is easier to do the finishing details and to apply the material, unlike the application of the waterproofing protection on top of the mat-slab foundation.

For the mat-slab foundation, Portuguese technicians recommend, once more, the use of PVC, TPO and EPDM membranes, as well as of bentonite blankets. The in situ manufactured materials can also be applied on top of the levelling concrete, as reinforcement to the main system. However, they shall not be used alone, since they do not provide complete watertightness.

Figure 3 illustrates a coating system in a mat-slab foundation, applied to the bottom surface.

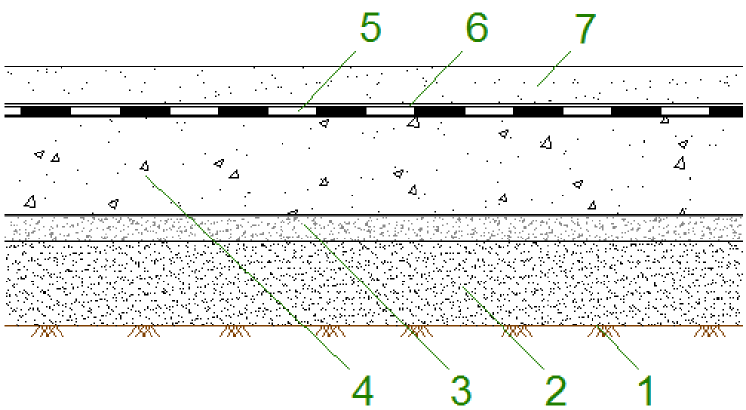


Legend

1 - Soil
2 - Riprap
3 - Blinding concrete
4 - Geotextile layer (mechanical protection layer and drainage material)
5 - Waterproof membrane
6 - Geotextile layer (mechanical protection layer)
7 - Mat-slab foundation

Figure 3 - Coating system applied at the bottom of a mat-slab foundation [personal archive]

When the waterproofing system is applied on the top surface of the concrete slab (Figure 4), the geotextile layer under the membrane can be dismissed. However, the removal of the geotextile layer implicates the use of a concrete slab on top of the membrane in order to protect it and act as base for the pavement, and therefore dismissing the membrane might not be the cheaper choice.



Legend

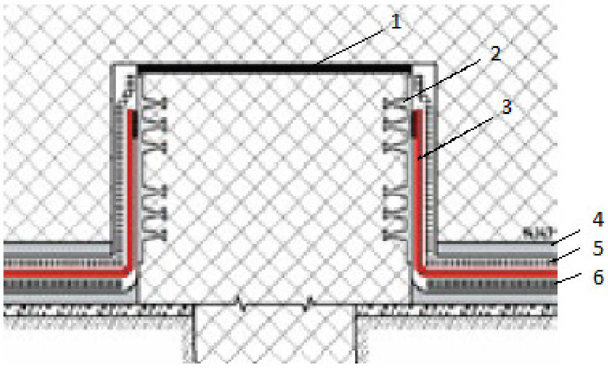
1 - Soil
2 - Riprap
3 - Blinding concrete
4 - Mat-slab foundation
5 - Waterproof membrane
6 - Geotextile layer (mechanical protection layer)
7 - Concrete slab

Figure 4 – Waterproofing system on the top surface of a mat-slab foundation [personal archive]

In this type of system all products mentioned above can be used but materials manufactured in situ must be complemented with prefabricated membranes to ensure watertightness.

For foundations using piles, there are two case scenarios: isolated piles and a rigid piles head, named cap pile block, which connects multiple piles. As it is impossible to apply a waterproofing system around foundation piles, it must be applied in the contact surface between the foundation and the structural elements above.

Figure 5 presents a scheme of the waterproofing system at the top of a pile that provides impermeability. In this system, a “waterstop” is placed to block the water flow. This piece must be carefully placed, ensuring that the whole pile head is covered. A faulty application of this system can make it into a leakage point.



Legend

1 - Cement base mortar, grout
2 - PVC waterstop
3 - Waterproof membrane
4 - Mat-slab foundation
5 - Geotextile layer (mechanical protection layer)
6 - Geotextile layer (mechanical protection layer and draniage material)

Figure 5 - Scheme of the waterproofing system in a pile head [2]

Figure 6 shows a scheme of the coating system of a pile cap block. The lower membrane and the upper membrane are made of the same material, and are connected.

The solution presented next aims to contribute to avoid the gaps on the lateral coating between the pile head and the “waterstop”. In order to do so, a one component cement-based mortar with compensated shrinkage named grout is used to create a waterproofing barrier. After sanitation of the pile’s head, which provides a rough surface, it must be cleaned to eliminate sediments that hinder the connection between the “old” concrete and the grout. The application of the mortar requires the use of a formwork, to give the desired shape to the concrete and the required consistency to the product. Since the grout is a very resistant material, this solution is appropriate for critical zones like the one illustrated in Figure 7.

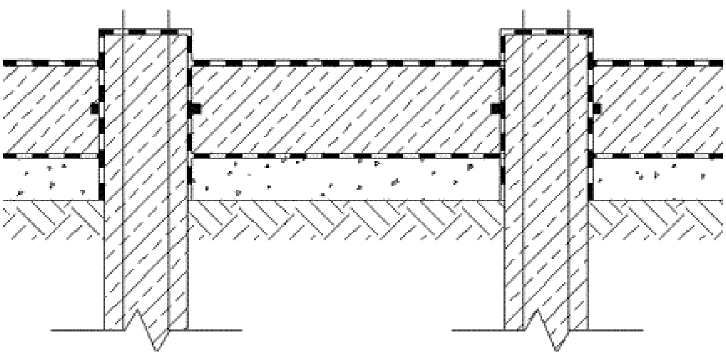
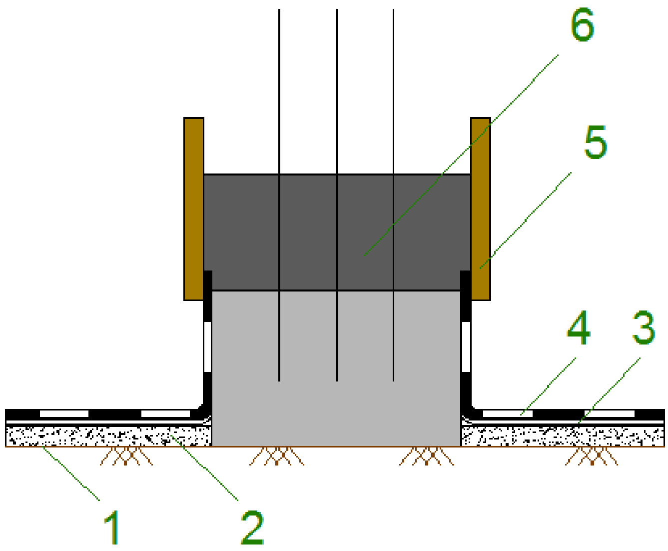


Figure 6 - Scheme of the waterproofing system of a pile cap blocks [w_3]

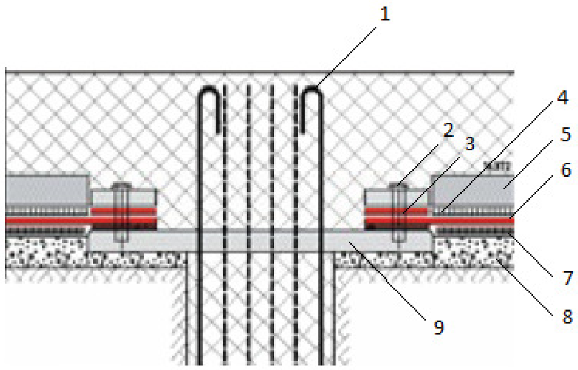


Legend

1 - Soil
2 - Blinding concrete
3 - Geotextile layer (mechanical protection layer)
4 - Waterproof membrane
5 - Formwork
6 - Cement base mortar, grout

Figure 7 - Waterproofing system of a pile cap using grout [personal archive]

Finally, the solution presented next ensures continuity between the pile head and the concrete slab of the pavement. This system was developed by the Sotecnisol company, and features a surface of galvanized steel with steel bars thermo welded that provide watertightness. The scheme of this solution is presented on Figure 8, as well as the materials used in it.



Legend

1 - Reinforcement welding thermo to the system of continuity
2 - Welding thermo screws
3 - Round waterproof membrane, between the continuation plate and the plate that holds the screw connection
4 - Geotextile layer (mechanical protection layer)
5 - Pavement slab
6 - Waterproof membrane
7 - Geotextile layer (mechanical protection layer)
8 - Blinding concrete
9 - System of the continuity of the pile's head

Figure 8 – Scheme of the waterproofing system developed by the Sotecnisol company [2]

This solution requires a reinforcement of the plate with screws in the pile head and a new squared waterproofing membrane. The new membrane must be connected to the first one by welding. The next step is to screw the plate and the steel bars to the pile head. Holes are drilled in the pile head to receive the steel bars that will ensure the connection with the concrete.

After that, a ring shaped membrane is applied, with holes only where the thermo welded screws will be placed, in order to enable the application of the membrane between the plates. Finally, the plate is fastened. Figure 9 exhibits this system before its placement on the foundation.

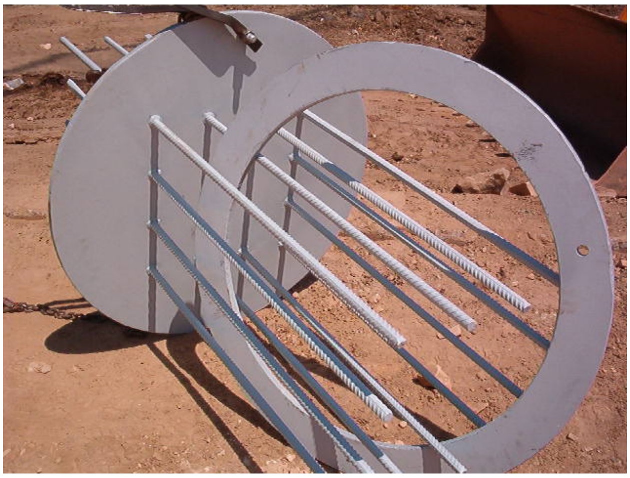


Figure 9 - Waterproofing solution developed by the Sotecnisol company [4]

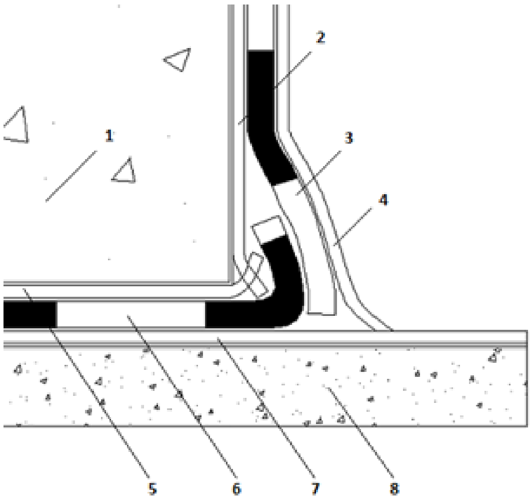
For the mentioned waterproofing solutions, except for the grout system, it is advised to use only the membranes that can be applied by welding: PVC, TPO and EPDM. Bentonite geocomposites may also be used in this solution, due to its flexibility and its great waterproofing properties.

In the solution using grout, the coating is applied in a similar way to the coating of the top of a mat-slab foundation, except for the connection between the two materials, which is ensured by the drying of the grout over the membrane.

The prefabricated membrane used in this process can be any of the mentioned before to waterproof building foundations.

There is also the possibility of finishing the horizontal and vertical membranes using two different types of welding. The welding is naturally used in the finishing details in foundations footing with a coating system formed by membranes applied by welding, as well as in the connection between the waterproofing membranes of the underground walls, reaching the lower waterproofing membrane of the foundation. This situation occurs only in foundation footings and mat-slab foundations. Figure 10 illustrates the welding of the membrane applied vertically, where the lower waiting-membrane is placed in the interior surface of the vertical waiting-membrane. This method prevents the accumulation of water on the weld, which could damage the connection. The geotextile layer splicing might be applied or not, since it is placed on the interior part of the weld.

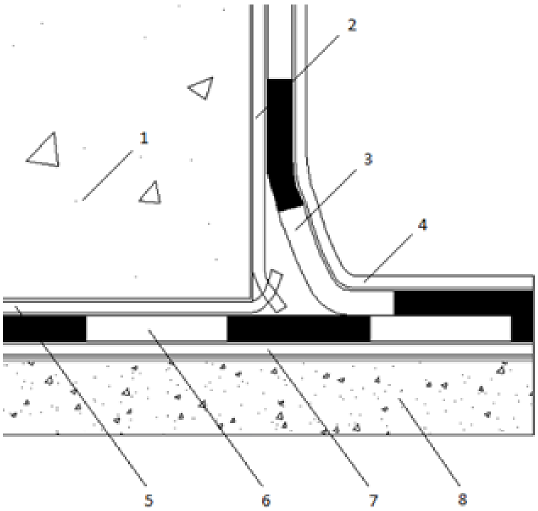
Figure 11 shows the weld of the membranes applied horizontally, to avoid the deterioration of the weld when the system is placed underground. In the solution presented in Figure 10, the weld was applied vertically, which might lead to its damage when subjected to the weight of the soil. This solution must be used only in situations that ensure enough space to accommodate the weld.



Legend

1 - Mat-slab foundation
2 - Geotextile layer (mechanical protection layer, near the vertical surface)
3 - Waterproof membrane
4 - Geotextile layer (mechanical protection layer)
5 - Geotextile layer (mechanical protection layer and drainage material)
6 - Waterproof membrane
7 - Geotextile layer (mechanical protection layer and drainage material)
8 - Blinding concrete

Figure 10 - Splicing of the geotextile layer and the weld on the vertical membrane [personal archive]



Legend

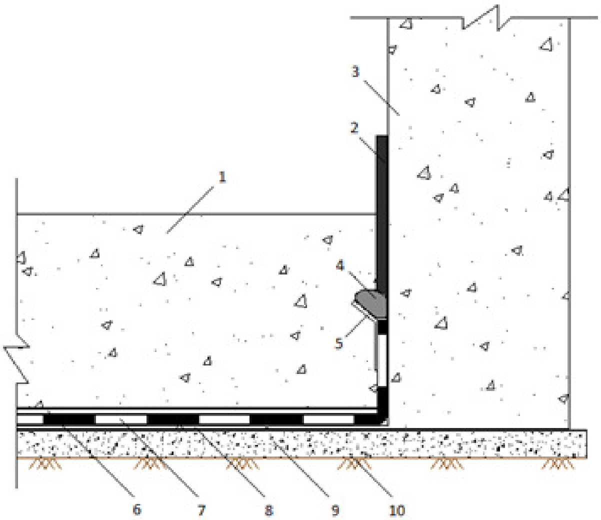
1 - Mat-slab membrane
2 - Geotextile layer (mechanical protection layer)
3 - Waterproof membrane
4 - Geotextile layer (mechanical protection layer and drainage material)
5 - Geotextile layer (mechanical protection layer)
6 - Waterproof membrane
7 - Geotextile layer (mechanical protection layer and drainage material)
8 - Blinding concrete

Figure 11 - Splicing of the geotextile layer and horizontal welding of the membrane [personal archive]

The last scheme presents the finishing detail of the membrane of a mat-slab foundation using vertical masonry. When the waterproofing system is applied to the mat-slab foundation, a piece of the membrane is left unapplied, and will afterwards be connected with the masonry. This solution must be finished with a cement-based coating. The finishing detail of the membrane, when applied vertically, must be accomplished using a stainless steel plate , where mastic is applied to ensure the connection between the foundation and the membrane. The connection between the mastic and the waterproofing membrane prevents the infiltration of water between the membrane and the wall.

Figure 12 shows a scheme of this method of coating placed on the lower surface of the concrete slab.

Table 4 summarizes the types of membranes used in different types of building foundation solutions and the elements where they can be applied: on the exterior of foundations footings, on the lower or upper surfaces of mat-slab foundations and on the pile cap blocks.



Legend

1 - Mat-slab foundation
2 - Cement based coating
3 - Vertical element (masonry)
4 - Mastic
5 - Stainless steel plate
6 - Geotextile layer (mechanical protection layer)
7 - Waterproof membrane
8 - Geotextile layer (mechanical protection layer and drainage material)
9 - Blinding concrete
10 - Soil

Figure 12 - Waterproofing system with finishing details of the membrane using stainless steel plate and mastic [personal archive]

Table 4 - Membranes used in different types of building foundations

	Foundation footing	Mat-slab slab foundation		Piles		
	Exterior	Lower	Upper	Top of the pile head	Lower pile cap block	Uper pile cap block
Bitumen			x			x
Bitumen-polymer APP			x			x
Bitumen-polymer SBS			x			x
HDPE		x	x		x	x
PVC	x	x	x		x	x
TPO	x	x	x		x	x
PP	x	x	x		x	x
PE	x	x	x		x	x
EPDM		x	x		x	x
Bituminous emulsions			x		x	x
Bituminous paint			x		x	x
Cement based coating			x	x	x	x
Grout			x	x		

5. Constructive anomalies and suggestions for its repair

Anomaly is a defect or a flaw on the system that could, in the cases studied in this dissertation, damage the esthetic aspect or deteriorate the structure. Buildings' pathology is the science that studies the four fundamental stages on the development of an anomaly: diagnosis, prognosis, agents that originate the anomaly and best solution for the problem.

The careful consideration of these four parameters indicates which methods should be chosen to eliminate or repair the anomaly. The options are: remove the anomaly, replace the affected elements and materials, protect against the deterioration agents and eradicate the causes of the anomalies. The best solution is, doubtlessly, to eradicate the cause. However, on building foundations this option might not be possible, since it is extremely difficult (and sometimes impossible) to access the affected area, which makes the repairs very expensive.

The most common anomalies that affect the building foundations are: imperfections of concrete (anomalies that occur during its execution), that increase its permeability, allowing the deterioration agents to infiltrate from the surface; anomalies of the waterproofing membranes and anomalies due to the wear of the waterproofing coating system over time.

Imperfections on concrete comprise the holes and porous zones and segregation of concrete (Figure 13). In this case, if there is no coating system, the deterioration agents do not have anything to prevent their infiltration into the element, and a lot of problems may arise. If a waterproofing solution is considered since the beginning of the project, this situation can be avoided, increasing not only the service life of the structural element, but also the service life of the membrane and the waterproofing products used.

Figure 13 - Anomalies during execution: voids and segregation of concrete [w_4][w_5]

During the service life of the foundation, the type of waterproofing system used might prove to be unsuitable for the situation, or show deficiencies in its application, which may lead to damages on the system and/or the element. These type of anomalies include cracking, corrosion of the steel reinforcement and sulfate attack (Figure 14).

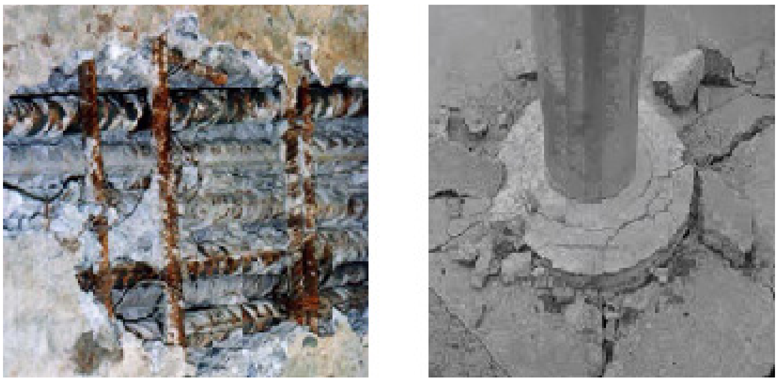


Figure 14 - Anomalies occured during the membrane's service life: corrosion of the steel reinforcement and sulfate attack

Even using the adequate waterproofing protection to each particular case, it can suffer some damages that allow the deteriorating agents to access the structural element, creating a weak point on the system. The most common anomalies exhibited by the membranes are: perforations, folds, swelling and cracking.

The methods available to solve the problems mentioned above are referred below, focusing essentially on the mat-slab foundations, since the repair of a pile is, if possible, very difficult and expensive as concluded before.

When the waterproofing system is placed on top of the mat-slab foundation, it might be possible to proceed to a full repair of the element, since it is easily reached by removing the slab of the pavement. On the other hand, when the system in placed at the bottom, its access is impossible. In this case it is advised to repair/hide the anomaly from within.

It is very important to choose wisely the waterproofing system that fits each situation, considering the factors that bring greater problems in each case: water, humidity, soil acidity (pH), microorganisms, and groundwater level), in order to avoid premature damage of the foundation.

The costs of all the systems referred on chapter 4 are summarized below.

6. Costs

After some research and inquiry to the producers and brands of the mentioned waterproofing systems and materials used, the average prices for each solution were calculated. These values are presented on Tables 5, 6, 7, and should not be considered the final and exact price for each solution, but only an estimation of the cost.

7. Conclusion

A quality waterproofing coating of the building foundations is easy to achieve, as long as it is considered right from the start (during the structural project). The foundations of a building are one of the most important structural elements, and therefore must be conserved in its ideal conditions, in order to extend its service life, and, therefore, the building's service life.

The lack of normative and technical information proves to be a great barrier to the companies, as there is no information about some execution parameters, such as experimental tests or most commonly used materials for each situation. Most info existent on this subject comes from the experience of producers and technicians that apply them.

The use of waterproofing membranes in the coating systems on building foundations proves to be a good solution, since it provides a barrier that prevents the water and other deteriorating agents to reach the structural element.

Table 5 - Types of waterproofing solutions used in foundation footings and their costs

Name	Cost
Foundation footing	
Waterproofing below foundation footing, using a membrane of polyvinyl chlorite, mechanically applied, and two polyester geotextile weighing 300 g/m^2 each	23,82 €
Waterproofing below foundation footing, using a membrane of polyvinyl chlorite, mechanically applied, and one polyester geotextile weighing 300 g/m^2	22,07 €
Waterproofing below foundations footing, using a membrane of polyvinyl chlorite, mechanically applied	20,31 €
Waterproofing below foundations footing, using a membrane of polyolefin, mechanically applied, and two polyester geotextile weighing 300 g/m^2 each	22,23 €
Waterproofing below foundations footing, using a membrane of polyolefin, mechanically applied, and one polyester geotextile weighing 300 g/m^2	20,48 €
Waterproofing below foundations footing, using a membrane of polyolefin, mechanically applied	18,72 €
Waterproofing below foundations footing, using a membrane of ethylene-propylene-diene, mechanically applied, and two polyester geotextile weighing 300 g/m^2 each	21,87 €
Waterproofing below foundations footing, using a membrane of ethylene-propylene-diene, mechanically applied, and one polyester geotextile weighing 300 g/m^2	20,11 €
Waterproofing below foundation footing, using a membrane of ethylene-propylene-diene, mechanically applied	18,34 €
Waterproofing below foundation footing, using a bentonite blanket, mechanically applied	15,11 €

Table 6 - Types of waterproofing solutions used in mat-slab foundations and their costs

Mat-slab slab foundations	
Waterproofing on top of a mat-slab foundation, using a membrane of modified bituminous, applied by weld	12,21 €
Waterproofing on top of a mat-slab foundation, using a membrane of bitumen-polymer atactic polypropylene, applied by weld	13,86 €
Waterproofing on top of a mat-slab foundation, using a membrane of bitumen-polymer styrene-butadiene-styrene, applied by weld	13,14 €
Waterproofing on top of a mat-slab foundation, using a membrane of polyvinyl chlorine, fixed mechanically	16,63 €
Waterproofing on top of a mat-slab foundation, using a polyolefin membrane, applied by weld	14,99 €
Waterproofing on top of a mat-slab foundation, using an ethylene-propylene-diene membrane, applied by weld	14,67 €
Waterproofing on top of a mat-slab foundation, using a bentonite blankets, fixed mechanically	12,62 €
Waterproofing on top of a mat-slab foundation, using a bituminous emulsions	4,54 €
Waterproofing on top of a mat-slab foundation, using a cement base coating	5,69 €
Waterproofing on top of a mat-slab foundation, using grout	10,66 €
Waterproofing on top of a mat-slab foundation, using a modified bitumen and a bituminous emulsion as a primer	13,15 €
Waterproofing on top of a mat-slab foundation, using a bitumen-polymer atactic polypropylene and a bituminous emulsion as a primer	14,81 €
Waterproofing on top of a mat-slab foundation, using a bitumen-polymer styrene-butadiene-styrene membrane and a bituminous emulsions as a primer	14,09 €
Waterproofing at the bottom of a mat-slab foundation, using a polyvinyl chlorite membrane, mechanically applied, and one polypropylene geotextile weighing 160 g/m^2	18,15 €
Waterproofing at the bottom of a mat-slab foundation, using a polyolefin chlorite membrane, mechanically applied, and one polypropylene geotextile weighing 160 g/m^2	16,49 €
Waterproofing at the bottom of a mat-slab foundation, using an ethylene-propylene-diene membrane, mechanically applied , and one polypropylene geotextile weighing 160 g/m^2	16,18 €
Waterproofing at the bottom of a mat-slab foundation, using a polyvinyl chlorite, mechanically applied, and one man-made fibers geotextile weighing 250 g/m^2	18,86 €
Waterproofing at the bottom of a mat-slab foundation, using a polyolefin membrane, mechanically applied, and one man-made fibers geotextile weighing 250 g/m^2	17,21 €
Waterproofing at the bottom of a mat-slab foundation, using an ethylene-propylene-diene membrane, mechanically applied, and one man-made fibers geotextile weighing de 250 g/m^2	16,89 €
Waterproofing at the bottom of a mat-slab foundation, using a polyvinyl chlorite membrane, mechanically applied, and one polyester geotextile weighing 300 g/m^2	18,40 €
Waterproofing at the bottom of a mat-slab foundation, using a polyolefin membrane, mechanically applied,	16,74 €

and one polyester geotextile weighing 300 g/m^2	
Waterproofing at the bottom of a mat-slab foundation, using an ethylene-propylene-diene membrane, mechanically applied , and one polyester geotextile weighing 300 g/m^2	16,43 €
Waterproofing at the bottom of a mat-slab foundation, using a polyvinyl chlorite membrane, mechanically applied, and two polyester geotextiles weighing 300 g/m^2 each	20,16 €
Waterproofing at the bottom of a mat-slab foundation, using a polyolefin membrane, mechanically applied, and two polyester geotextiles weighing 300 g/m^2 each	18,50 €
Waterproofing of the bottom of a mat-slab foundation, using an ethylene-propylene-diene membrane, mechanically applied , and two polyester geotextiles weighing 300 g/m^2 each	18,19 €
Waterproofing of the bottom of a mat-slab foundation, using a high-density polyethylene painel, a polyvinyl chlorite membrane, mechanically applied, and one polyester geotextile weighing 300 g/m^2	25,33 €
Waterproofing of the bottom of a mat-slab foundation, using a high-density polyethylene painel, a polyolefin membrane, mechanically applied, and one polyester geotextile weighing 300 g/m^2	23,68 €
Waterproofing at the bottom of a mat-slab foundation, using a high-density polyethylene painel, an ethylene-propylene-diene membrane, mechanically applied, and one polyester geotextile weighing 300 g/m^2	23,36 €

Table 7 - Types of waterproofing solutions used in piles and their costs

Piles	
Waterproofing of a cap pile (Ø 0,50 m), using a polyvinyl chlorite, welding, and one system of continuity	643,15 €
Waterproofing of a cap pile (Ø 0,50 m), using a polyvinyl chlorite membrane, one PVC waterstop and a cement base coating	28,45 €
Waterproofing of a cap pile (Ø 0,50 m), using a polyvinyl chlorite membrane, one PVC waterstop and grout	30,81 €
Waterproofing of a cap pile (Ø 0,50 m), using a polyvinyl chlorite membrane and grout	26,78 €

8. References

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