Taller de Proyectos de Tecnología
Individual project

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Goals & Global description:

The project of "The floating forest" arises from the need of the NGO "Apadrina un olivo", to have a headquarters, so we are looking for a headquarters that can serve both as an expository of the work they do, as an office in which to finally establish. This NGO is fundamentally looking to save the trees that are in unpopulated areas and that due to the negligence of the human being do not have the care they need and end up dying.

Spain is the country in the world that has more olive trees, and has almost the total representation of more than 1800 species of olive trees discovered today. Yet only 24 types of them are cultivated for oil. The province that has more olive trees is Jaen. Although olive trees can survive drought, it is highly recommended that they do not fall below 8 degrees centigrade, as it slows their growth. If the temperature drops below -7 degrees, the trees die.

The olive tree is a thousand-year-old tree, which rarely reaches 10 m in height and which has neither deep nor aggressive roots. When it reaches 5 years of age, it usually measures about 150 cm. Nature has always been threatened by human action, at first in total freedom, then he was protected in botanical gardens and greenhouses and finally the project raises the olive trees from the ground, as if it were a cloud.

Within this floating forest we find up to 80 species of olive trees. In which a similarity with mountain rivers and clouds is created through the project itself, the surrounding topography and the adjacent fountain. The project has a double ventilated facade of Etfe, with 4 sheets for each cushion in which between the first and second and the third and fourth is a gel that when activated with an electric current, changes the properties of the plastic facade and allows or not to enter the light as appropriate.

The space is divided into two zones, the headquarters of the NGO, which corresponds to a smaller space as it is still growing, and the northern and largest part which is a coworking space which can be rented,. The building has the versatility that if the NGO becomes much larger the second space can be annexed simply by moving the olive trees, which are suspended in gardens hanging from the main structure.

Summary of gross/net building area

-Basement: 950 m2
-Plan +7.60m: 340 m2
-Plan +10.90m: 1700 m2

Cost estimation:

URBANIZACIÓN Y OBRA CIVIL 3.512.146,11€ (21,59%)
2 MAQUINARIA Y MEDIOS AUXILIARES 298.019,40€ (1,83%)
3 EDIFICACIÓN 12.453.888,64€ (76,57%)
TOTAL EJECUCIÓN MATERIAL 16.264.054,15€
TOTAL PRESUPUESTO GENERAL 25.583.357,17€ (Ejecución + G.G. + B.I. + IVA)

*See Annex for full bill of quantities.

Envelope:

I have chosen a double ventilated facade made out of ETFE, because one of my main goals was to achieve a building with a cloud look like. The facade, is composed by 18500 ETFE cushions, with 4 layers each. This ETFE cushions are held by the carpentry attached to the main steel structure, that works as a mesh. The double skin facade separated 1 meter maximum from one to another, acts like a highly insulated greenhouse. This separation is due to locate the main mep ducts through the facade. Moreover, many lights are places inside this double skin and when they are turned on, they also heat this cavity. The warm air is either expelled towards the outside by the cushions that open or recovered for the air-conditioning of the building.

In orther to make it more efficient I have decided to spend more of the budget on placing a gel between the layers of the etfe cushions that allows when an electric current is applied to change its properties, allowing more or less solar radiation and light to enter the building.

Furtheremore I wanted a very transparent facade because 80 species of olive trees live inside the building and they need as much solar light as possible.

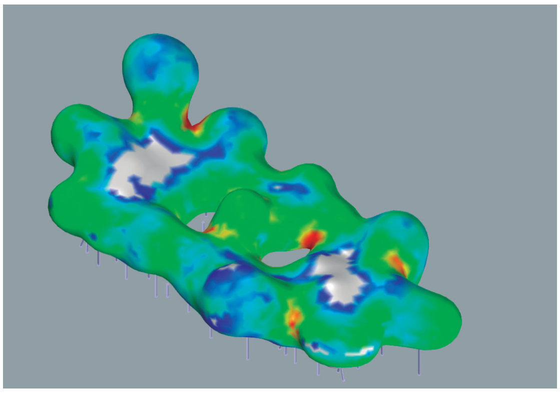
Construction process:

The construction process of the building begins with the preparation of the land and subsequent excavation of the land on which it will be built. After that, the foundations are set out and the concrete is poured, afterwards the reinforcement of the footings is placed. After that the retaining wall (basement wall) and the concrete pillars are built. The ceiling of the basement is done by waffle slab with recoverable cassettes. Tie beams are constructed, joining the upper part of the concrete pilar with the upper part of the retaining wall, in order to wihstand the incline forces.

Later on, trucks come and fill the empty space that was done for the part of the building below the ground. Three cranes are mounted and pilars, beams and joist are placed, cranes bring the olive tree pots and hang them from beams and joist. The outter structure is constructed and scafolding placed surrounding the building so ETFe cushions can be set in place.

Structural system:

The main structural system is a mesh of steel supported by pillars, resting on fotings and in the basement retaining wall. There are some incline pillars in order to brace the building and withstand wind forces. Incline pillars inside the mesh hold the upper part. Joist grab the mesh in the points where the middle curvature is located, helping the incline pillars to resist the forces and the mesh working as a dome from that point on. Predimensioning worked at the beggining but then a more precised software needed to be used because of the loads of the olive trees.



Structure analysis of the mesh

Energy design and performance:

Etfe values:		Transmittance	Solar factor:
	2 layer cushion	2.9 W/m2K	0.8-0.22
	3 layer cushion	1.9 W/m2K	0.8-0.22
	4 layer cushion	1.4 W/m2K	0.8-0.22

1. See Energy Analysis 1. the building complies with the energy regulation of Spain, but it is not very efficient, even though we are using the double facade of 4 layer cushion of Etfe each one.

Qh= 46.7 (kWh/ (m2·a))
Qc= -30.1 (kWh/ (m2·a))
Qhc= 76.8 (kWh/ (m2·a))

U value= 1.4 W/m2K
G value= 0.5

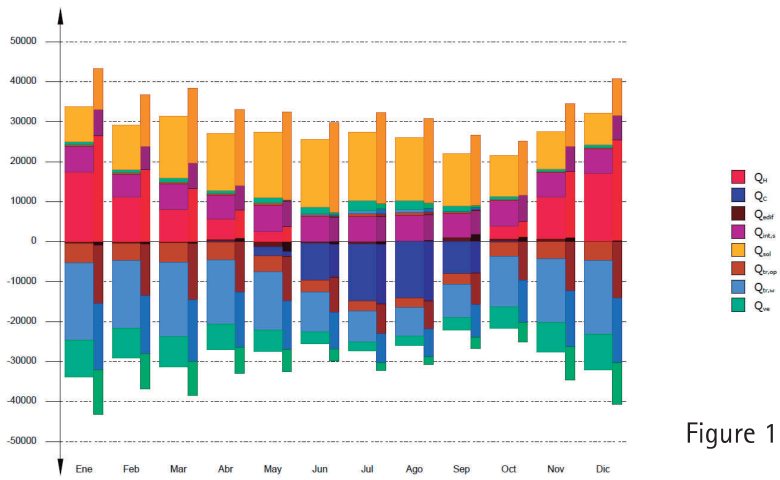


Figure 1

2. However by adding an electric current to a gel that is placed between the first and second layers and the third and fourth layers, we can control the opacity of the material and therefore the solar factor. Cype does not allow us to calculate for different seasons, different types of facades, so the Figure 2 would be the one during winter months (Qh) with a big solar factor.
(See Energy Analysis 2)

Qh= 13.5 (kWh/ (m2·a))
Qc= -142.8 (kWh/ (m2·a))
Qhc= 156.3 (kWh/ (m2·a))

U value= 1.4 W/m2K
G value= 0.8

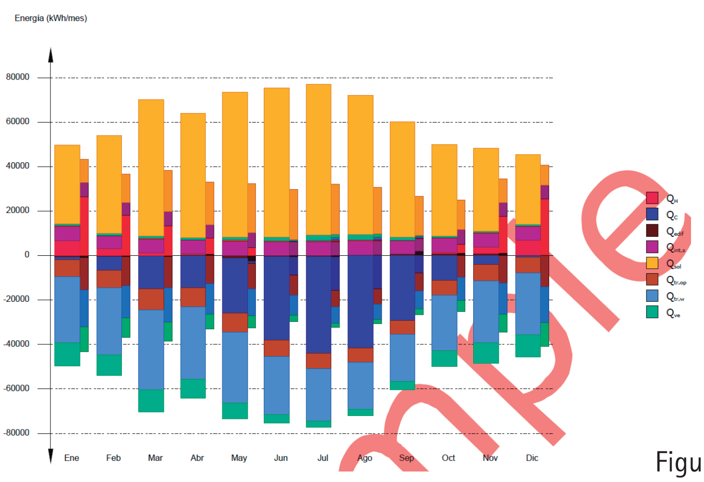


Figure 2

3. Figure 3 would be the one during summer months, with a low solar factor when most of the skin would be translucent letting very little sunlight inside.

Qh= 43 (kWh/ (m2·a))
Qc= -31 (kWh/ (m2·a))
Qhc= 74.1 (kWh/ (m2·a))

U value= 1.4 W/m2K
G value= 0.22

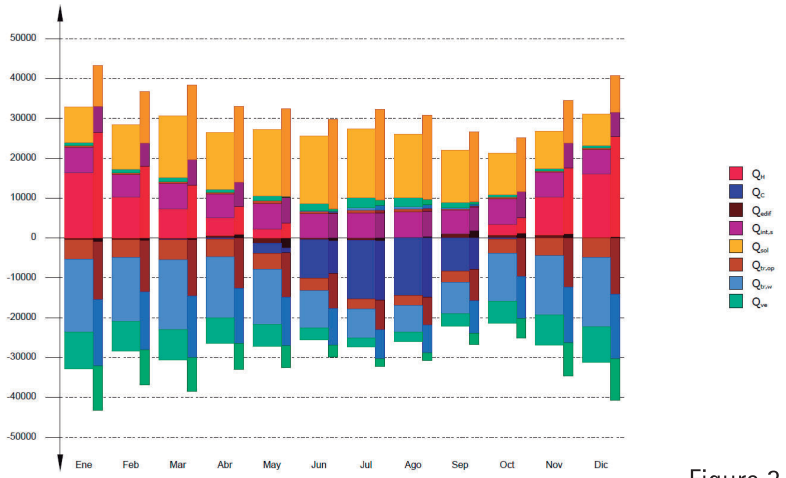


Figure 3

Some calculation, with the number of people that could be inside the building (office) we get the renovation of air per hour:

q vent	3750	l/s	3,75	m3/s	4 velocidad
q vent	13500	m3/h	0,9375	m2	
Volume	73138,05	m3			
Renov/h	0,18458244				

We need 59.86 m3/s in order to heat and cool down the building. (Our demand is 484KW). We Also get 3.75 m3/s from the exterior. If we have 6 Air treatment unit (UTA) and each one with 4 air conducts going to the building (each one 2.5 m3/s). The section of the conduct is 0.75x0.75 that is enough to go inside the facade. (Air conducts go from the MEP room in the basement to the building by fake steel columns, and the air goes from the air conduct in the facade to the interior space by a special cushion with an air difusser.

Air conditioning			
484	kw	416165	kcalh
		247717,262	
		215514,018	m3/h
		59,865005	m3/s

Lighting is designed to have 300 Lux in storage and circulation areas, and to have 500 lux in the conffErence and meeting rooms. Also 200 lux for the bathrooms are required.

To sum up the building is placed on the north south axis, so the south facade is the smallest, and good perfomance is achived with more investement for the ETFE with the gel that can change its properties.

Table of loads

Floor +7.40 m	gk kn/m2	qk kn/m2	gk + qk kn/m2	Specific weight m	Thickness m	Surface weight kn/m2
Use load office building (category: B)		3				
Steel structure	0,5					
Composite slab, EUROPERFIL HAIRCOL 59, H = 10cm	2.9					
Inner partitions	1					
Ceramic flooring	1,50					
Total	5,9 kn/m2	3 kn/m2	9,9 kn/m2			

Floor +10,9 m	gk kn/m2	qk kn/m2	gk + qk kn/m2	Specific weight m	Thickness m	Surface weight kn/m2
Use load office building (category: B)		3				
Steel structure	0,5					
Steel pannel	0,15					
Lightweight soil				6 kn/m3	0.35	2,1
Stone pavement	2,50					
Total	5,25 kn/m2	3 kn/m2	9,25 kn/m2			

Olive trees	gk kn/m2	qk kn/m2	gk + qk kn/m2	Specific weight m	Thickness m	Surface weight kn/m2
Olive trees	7					
Lightweight soil (Pots)				6 kn/m3	1.5	9
Total	16 kn/m2		16 kn/m2			

Floor +10,9 m & Olive trees	gk kn/m2	qk kn/m2	gk + qk kn/m2	Specific weight m	Thickness m	Surface weight kn/m2
Use load office building (category: B)		3				
Steel structure	0,5					
Steel pannel	0,15					
Lightweight soil				6 kn/m3	0.35	2,1
Stone pavement	2,50					
Olive trees	7					
Lightweight soil (Pots)				6 kn/m3	1.5	9
Total	21,25 kn/m2	3 kn/m2	24,25 kn/m2			

Perimeter wall	gk kn/m2	qk kn/m2	gk + qk kn/m2
Steel structure	0,5		
ETFE	0,03		
Total	0,53kn/m2 →		4m = 2,12 kn/lm

Roof	gk kn/m2	qk kn/m2	gk + qk kn/m2
Steel structure	0.5		
ETFE	0,03		
Snow load	0,5		
Total	1,03kn/m2		

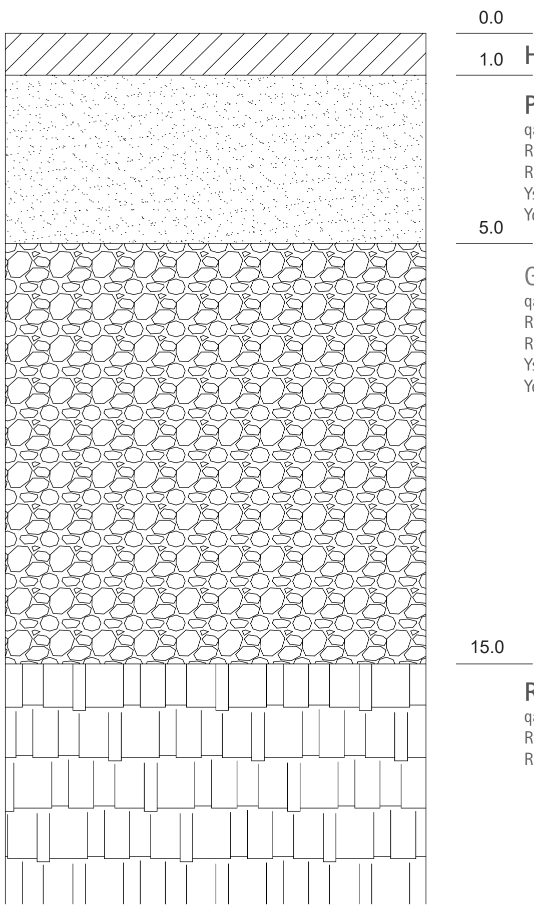
Tributary area calculation. Areas of floorplan +10.90

P1 Area = 11.75 m2
P2 Area = 8.65 m2
P3 Area = 19.30 m2
P4 Area = 20.10 m2
P5 Area = 18.10 m2
P6 Area = 19.25 m2
P7 Area = 9.60 m2
P8 Area = 8.45 m2
P9 Area = 7.50 m2
P10 Area = 6.90 m2
P11 Area = 16.75 m2
P12 Area = 15.10m2
P13 Area = 9.15 m2
P14 Area = 6.50 m2
P15 Area = 8.40 m2
P16 Area = 5.90 m2
P17 Area = 3.75 m2
P18 Area = 5.25m2
P19 Area = 4.35 m2
P20 Area = 4.00 m2
P21 Area = 3.50 m2
P22 Area = 4.00 m2
P23 Area = 11.00 m2
P24 Area = 7.25 m2
P25 Area = 5.00 m2
P26 Area = 3.25 m2
P27 Area = 34.15 m2
P28 Area = 23.50 m2
P29 Area = 5.60 m2
P30 Area = 5.75 m2
P31 Area = 5.50 m2
P32 Area = 21.0 m2
P33 Area = 6.20 m2
P34 Area = 8.15 m2
P35 Area = 11.10 m2
P36 Area = 16.00 m2
P37 Area = 18.00 m2
P38 Area = 4.60 m2
P39 Area = 7.00 m2
P40 Area = 7.50 m2
P41 Area = 6.20 m2
P42 Area = 7.35 m2
P43 Area = 3.30 m2
P44 Area = 11.20 m2
P45 Area = 10.00 m2
P46 Area = 25.00 m2
P47 Area = 4.15 m2
P48 Area = 17.40 m2
P49 Area = 14.80 m2
P50 Area = 8.30 m2
P51 Area = 26.40 m2

P52 Area = 6.90 m2
P53 Area = 3.10 m2
P54 Area = 6.90 m2
P55 Area = 13.60 m2
P56 Area = 7.60 m2
P57 Area = 4.40 m2
P58 Area = 10.60 m2
P59 Area = 9.30 m2
P60 Area = 18.10 m2
P61 Area = 6.60 m2
P62 Area = 3.90 m2
P63 Area = 6.30 m2
P64 Area = 7.00 m2
P65 Area = 11.00 m2
P66 Area = 12.60 m2
P67 Area = 8.25 m2
P68 Area = 5.20 m2
P69 Area = 4.00 m2
P70 Area = 23.15 m2
P71 Area = 10.15 m2
P72 Area = 4.45 m2
P73 Area = 9.30 m2
P74 Area = 9.15 m2
P75 Area = 4.60 m2
P76 Area = 11.05 m2
P77 Area = 11.90 m2
P78 Area = 11.00 m2
P79 Area = 6.10 m2
P80 Area = 9.00 m2
P81 Area = 9.65 m2
P82 Area = 11.00 m2
P83 Area = 12.00 m2
P84 Area = 13.05 m2
P85 Area = 9.20 m2
P86 Area = 11.10 m2
P87 Area = 10.10 m2
P88 Area = 13.50 m2
P89 Area = 11.40 m2
P90 Area = 13.55 m2
P91 Area = 9.30 m2
P92 Area = 12.05 m2
P93 Area = 9.85 m2
P94 Area = 21.00 m2
P95 Area = 9.50 m2
P96 Area = 13.00 m2
P97 Area = 16.30 m2
P98 Area = 8.75 m2
P99 Area = 13.50 m2
P100 Area = 11.40 m2
P101 Area = 11.05 m2
P102 Area = 11.85 m2
P103 Area = 11.65 m2
P104 Area = 12.10 m2

Tributary area calculation.Areas of floorplan +10.90

P105 Area = 6.80 m2
P106 Area = 6.80 m2
P107 Area = 12.70 m2
P108 Area = 12.40 m2
P109 Area = 7.80 m2
P110 Area = 7.80 m2
P111 Area = 20.70 m2
P112 Area = 22.00 m2
P113 Area = 20.35 m2
P114 Area = 21.50 m2
P115 Area = 6.15 m2
P116 Area = 6.15 m2
P117 Area = 11.55 m2
P118 Area = 11.40 m2
P119 Area = 6.95 m2
P120 Area = 6.95 m2
P121 Area = 19.85 m2
P122 Area = 25.20 m2
P123 Area = 20.50 m2
P124 Area = 23.60 m2
P125 Area = 21.50 m2
P126 Area = 17.50 m2
P127 Area = 21.00 m2
P128 Area = 16.50 m2



Main structural elements used (analysed with Sap 200):

Steel pillar
CHS 323.96 e=14.2mm

Steel beam
RHS 400x300 e=10mm

Steel joist
RHS 250x150 e=10mm

Steel Edge beam
RHS 400x400 e=12.5mm

f_y	275	MPa
f_{yd}	261,9	MPa
ε_y	0,9	
λ_E	86,81	

Resistance of the worst column (P'1)
P32+P41+P50+P51= 1501.075 KN

SECTION	N_{Ed}	$L_{k,y}$	$L_{k,z}$	A	CLASS			i_y	i_z	λ_y	$\bar{\lambda}_y$	α_y	χ_y	λ_z	$\bar{\lambda}_z$	α_z	χ_z	χ_{min}	$N_{b,Rd}$
	kN	m	m	cm2	f	w	tot	cm	cm										kN
CHS 323.9	1.502	7,00	7,00	154,7	1	1	1	13,0	7,6	53,9	0,62	0,34	0,83	92,3	1,06	0,49	0,50	0,50	1.968

Main structural elements used:

Steel pillar
CHS 323.96 e=14.2mm

Hierros leitza

	6	47,04	59,92	7572,47	11,24	467,58	606,43	15144,93	935,16	1,018	169,8
	8	62,32	79,39	9910,08	11,17	611,92	798,51	19820,16	1223,84	1,018	128,2
	10	77,41	98,61	12158,34	11,10	750,75	985,67	24316,68	1501,49	1,018	103,2
323,9	12	92,30	117,58	14319,56	11,04	884,20	1167,96	28639,12	1768,39	1,018	86,5
	12,5	95,99	122,29	14846,53	11,02	916,74	1212,78	29693,06	1833,47	1,018	83,2
	14,2	108,45	138,16	16599,08	10,96	1024,95	1362,93	33198,15	2049,90	1,018	73,7
	16	121,49	154,77	18389,93	10,90	1135,53	1518,20	36779,86	2271,06	1,018	65,7

Steel beam
RHS 400x300 e=10mm   Mannisipre.spa

Dimensiones	Espesor	Masa	Área de la sección	Momento de inercia J		Radio de giro I		Módulo de flexión elástico W		Módulo de flexión plástico Wp		Constantes de torsión		Área superficial por metro lineal	Largo (*)/
H x B mm	S mm	M kg/m	A cm^2	x - x cm^4	y - y cm^4	x - x cm	y - y cm	x - x cm^3	y - y cm^3	x - x cm^3	y - y cm^3	Jv cm^4	Wv cm^3	m^2/ m	aprox. por t (m)
400x300	6,3	67,7	86,2	20580	13260	15,5	12,4	1030	884	1210	994	24740	1400	1,38	–
	7,1	76,0	96,8	23020	14820	15,4	12,4	1150	988	1350	1110	27710	1570	1,38	–
	8,0	85,4	109	25710	16540	15,4	12,3	1290	1100	1520	1250	31010	1750	1,38	–
	8,8	93,6	119	28060	18040	15,3	12,3	1400	1200	1660	1360	33910	1910	1,38	–
	10,0	106	135	31520	20230	15,3	12,2	1580	1350	1870	1540	38180	2140	1,37	–
	11,0	116	148	34340	22020	15,2	12,2	1720	1470	2040	1680	41680	2320	1,37	–
	12,5	131	167	38450	24610	15,2	12,1	1920	1640	2300	1880	46810	2590	1,37	–
	14,2	148	189	42950	27440	15,1	12,1	2150	1830	2580	2110	52470	2890	1,36	–
	16,0	166	211	47540	30310	15,0	12,0	2380	2020	2870	2350	58290	3180	1,36	–

Steel joist
RHS 250x150 e=10mm   Mannisipre.spa

250x150	6,3	38	48,6	4178	1886	9,27	6,23	334	252	405	284	4049	413	0,786	26,2
	7,1	42,6	54,2	4610	2080	9,22	6,19	368	277	449	315	4520	457	0,782	–
	8,0	47,7	61,1	5167	2317	9,19	6,16	413	309	505	353	5014	506	0,783	20,9
	8,8	52,2	66,5	5550	2490	9,13	6,12	444	331	545	381	5460	547	0,777	–
	10,0	58,8	75,5	6259	2784	9,10	6,07	501	371	618	430	6082	606	0,779	16,9
	11,0	64,3	81,9	6670	2970	9,03	6,02	534	396	663	462	6600	652	0,772	–
	12,5	72,3	93,0	7518	3310	8,99	5,97	601	441	751	520	7317	717	0,773	13,7
	14,2	81,1	103	8140	3580	8,87	5,88	651	477	823	570	8100	784	0,763	–
	16,0	90,3	117	9089	3943	8,83	5,82	727	526	924	635	8863	851	0,766	11,0

Steel Edge beam
RHS 400x400 e=12.5mm   Mannisipre.spa

400x400	6,3	77,5	98,8	25460	16,1	1270	1460	38760	1890	1,58	–
	8,0	97,9	125	31860	16,0	1590	1830	48690	2360	1,58	–
	10,0	122	156	39350	15,9	1968	2272	60028	2896	1,58	8,20
	12,5	151	193	48190	15,8	2409	2800	73815	3530	1,57	6,58
	16,0	191	245	59910	15,7	2995	3514	92310	4363	1,57	5,21
	20,0	235	302	72396	15,5	3620	4292	112324	52,40	1,56	4,22

Footing calculation:

N= 1501.075
1501x1.1/200= 8.25m2
Square root of 8.25m is 2.87m (width and length of the footing)
2.87/2= 1.435
1.435/2= 0.7m the thickness of the footing
64 pillars x 8.25 m2 = 528m2, so footings is a good solution.

Retaining wall calculation:

e= 25cm + 5 planta = 45cm thickness of the wall
7 pillars x 1501.075 kn = 10507.525
10507.525/ 48 m= 218kn
218x1.1/200 = 1.20m2 (With of the footing of the retaining wall)
e= 0.275 it is too small, we will use 0.4m but I used 0.7 because the footing were very close to the retaining wall and with that I could unify the excavation.