



Escuela Técnica Superior de Ingenieros de
Caminos, Canales y Puertos



UNIVERSITAT
POLITÈCNICA
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Design project of the structure of a residential building in the city of Castellón street Paseo Ribalta nº1

ANNEX Nº3: ECONOMICAL AND ENVIRONMENTAL EVALUATION

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1. Analisis of the influence of the type of concrete on the economic cost and environmental impact of the structure

The analysis was carried out considering three solutions of the type of concrete applied to the structure. The following solution are showned in the table below:

Table 1.1 Concrete class in three solutions

	Solution 1	Solution 2	Solution 3
Slabs and beams	C25/30	C30/37	C30/37
Columns	C25/30	C25/30	C30/37

The investigation considers the influence of the type of concrete on the economic cost and environmental impact of the structure. The examined measurements are:

- kg of steel
- m³ of concrete
- m² of formwork
- kg of CO₂ emitted during the construction

The goal is to find which solution of these three is the most economical and has the least impact on the environment. We considered that the dimensions of the slabs and beams are immutable in all the proposals and the dimensions of the columns and the amount of reinforcement may vary rely on the forces.

The solutions do not include the costs of foundation because it will be calculated depends of the choosen solution.

1.1. Solution 1

Table 2.1 List of m³ of concrete and kg of steel bars of Solution 1

Element	Formwork (m ²)	Surface (m ²)	Volume (m ³)	Bars (kg)
Flat slabs	3934.05	3934.05	1201.11	47649
Slab base reinforcement				26697
Beams	512.94	321.56	136.3	10225
Columns	1010.15	-	88.41	16660
Stairs		71.17	12.42	1030
Total	5457.14	4326.78	1438.24	102261
Index (per m)	0.355	1.364	0.335	23.84

1.2. Solution 2

Table 3.1 List of m³ of concrete and kg of steel bars of Solution 2

Element	Formwork (m ²)	Surface (m ²)	Volume (m ³)	Bars (kg)
Flat slabs	3934.79	3934.79	1201.35	47114
Slab base reinforcement				26702
Beams	514.96	322.39	136.33	10118
Columns	996.8	-	84.37	16568
Stairs		71.17	12.42	1030
Total	5446.55	4326.78	1436.47	101532
Index (per m)	0.352	-	0.335	23.67

1.3. Solution 3

Table 4.1 List of m³ of concrete and kg of steel bars of Solution 3

Element	Formwork (m ²)	Surface (m ²)	Volume (m ³)	Bars (kg)
Flat slabs	3934.79	3934.79	1201.35	47183
Slab base reinforcement				26702
Beams	514.96	322.39	136.33	10138
Columns	996.8	-	82.37	12261
Stairs		71.17	12.42	1030

Element	Formwork (m ²)	Surface (m ²)	Volume (m ³)	Bars (kg)
Total	5446.55	4328.35	1436.47	97314
Index (per m)	0.352		0.335	22.69

2. Enviromental impact

The construction sector is one of the main sources of CO₂ emissions, representing one third of global greenhouse gas emissions. Residential and commercial buildings constitute 40% share in global energy consumption. We are responsible for searching for solutions that will reduce this number. One of the key solutions of CO₂ emissions is the efficient use and optimization of structural designs.

The kg of CO₂ emitted are considered based on the unit value of each materials. The following table taken from the article “CO₂-optimization of reinforced concrete frames by simulated annealing” show the emissions of CO₂ and the costs of each material:

Table 5.1 Unit prices and CO₂ emissions

Unit prices and CO ₂ emissions considered in the analysis (Ref. [12])			
Unit	Description	Cost (€)	Emissions (kg CO ₂)
kg	Steel B-400 in columns	1.00	2.99
kg	Steel B-400 in beams	1.13	3.01
kg	Steel B-500 in columns	1.05	2.99
kg	Steel B-500 in beams	1.14	3.01
m ³	Concrete HA-25 in beams	93.31	132.88
m ³	Concrete HA-30 in beams	99.70	143.48
m ³	Concrete HA-35 in beams	102.73	143.77
m ³	Concrete HA-40 in beams	105.58	143.77
m ³	Concrete HA-25 in columns	94.71	132.88
m ³	Concrete HA-30 in columns	101.09	143.48
m ³	Concrete HA-35 in columns	104.12	143.77
m ³	Concrete HA-40 in columns	106.97	143.77
m ²	Formwork in beams	20.82	3.13
m ²	Formwork in columns	13.55	8.90

The costs includes only the price of the material without the labor work costs.

3. Comparison

Table 6.1 Comparison of solutions part 1

	Solution 1	Solution 2	Solution 3
kg of steel	102261	101532	97314
m3 of concrete	1438.24	1434.47	1432.47
m2 of formwork	5457.14	5443.55	5443.55

Table 6.2 Comparison of solutions part 2

	Solution 1	Solution 2	Solution 3
Cost of concrete [€]	134325.9	142785.1	143336.1
Cost of steel [€]	115078.1	114255.4	109834.5
Cost of formwork [€]	106273.9	106150.4	106150.4
Total cost [€]	355678	363190.9	359321
CO2 emissions [kg]	509181.6	507582	509258

Table 6.3 Comparison of solutions part 3

	Solution 1	Solution 2	Solution 3
kg of steel per m ³ of concrete in beams	75.02	74.22	74.36
kg of steel per m ³ of concrete in columns	188.44	191.83	141.96
kg of steel per m ³ of concrete in slabs	61.90	61.44	61.50
cost of structure per m ² of floor [€]	90.41	92.25	91.22
kg of CO2 emitted per m ² formed	117.68	117.20	117.52

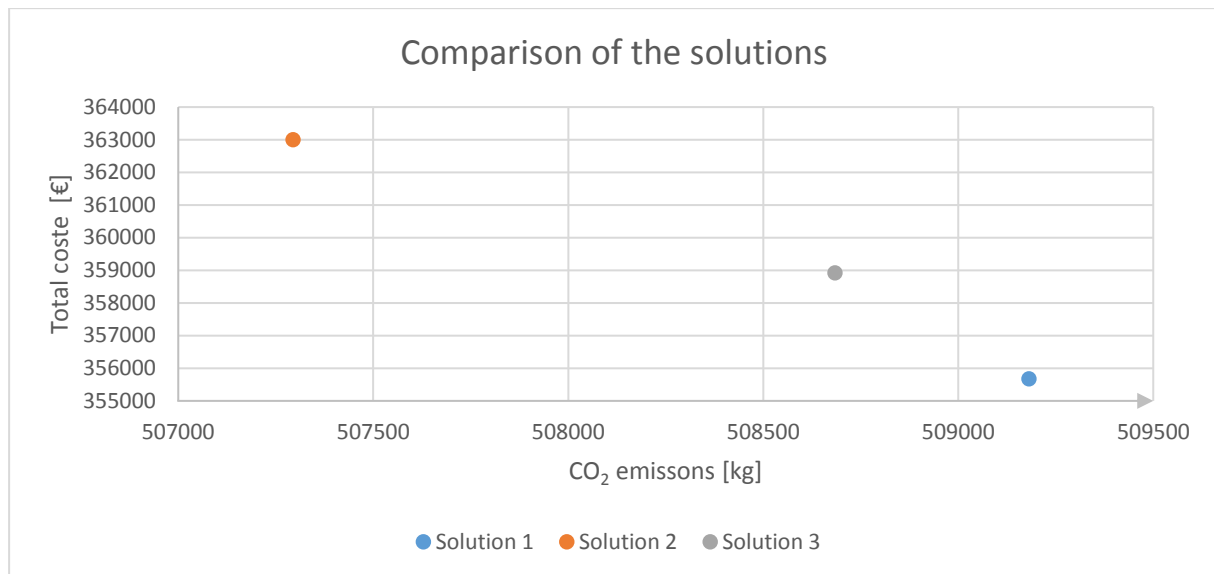


Figure 6.1 Grafical comparison of the solutions

The kg of CO₂ emitted per m² formed is almost the same in each solutions thus the price will be the decisive factor in choosing the solution. Solution 1 with the cost of 355678 € is the cheapest one and will be used for further calculations.

The Solution 3 need less kg of steel than Solution 1, but the cost of the higher class of concrete make the total price bigger.

The comparison of the three solutions shows that it is unjustified to use a higher class of concrete than C25/30 because the use of C25/30 concrete in all elements of the structure: beams, slabs and columns is the most economical and gives a comparable amount of kg of CO₂ emitted per m² formed as other solutions using higher classes of concrete.

4. Approximate evaluation of work units

All parts of the structure for Solution 1 of concrete C25/30 were evalauted including both the price of the material and the labor work price.

4.1. Foundations

4.1.1. m³ Basement excavation

Excavation of basements of more than 2 m deep, which in all its perimeter are below the natural slope, in sandy gravel soil, with mechanical means, and load to truck.

Total price per m³ 3,69 €

4.1.2. m² Mud slab

Mud slab of concrete layer C8/10 manufactured in central and poured from truck, 10 cm thick

Total price per m² 7,50 €

4.1.3. m³ Mat Foundation

Foundation slab of reinforced concrete, made with concrete C25/30 manufactured in central, and poured with pump, and steel UNE-EN 10080 B 500 S, with an approximate amount of 85 kg/m³; smooth surface finish by vibrating rule.

Total price per m³ 175,85 €

4.1.4. m² Formwork system for mat foundation

Assembly of metallic recoverable shuttering system, for foundation slab, formed by metal panels, amortizable in 200 uses, and subsequent disassembly of the shuttering system.

Total price per m² 17,56 €

4.1.5. m³ Basement wall

Reinforced concrete basement wall, made of C25/30 concrete manufactured in the central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 50 kg/m³.

Total price per m³ 152,35 €

4.1.6. m² Formwork system for basement wall

Assembly and disassembly of one-sided formwork system with industrial type finish for coating, made with modular metal panels, amortizable in 150 uses, for forming reinforced concrete wall, between 3 and 6 m high and flat surface, for containment of soils.

Total price per m² 25,31€

4.2. Reinforced concrete

4.2.1. m² Flat slab

Solid reinforced concrete slab, horizontal, with free height of plant up to 3 m, edge 30 cm, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 21 kg/m²; assembly and disassembly of continuous formwork system.

Total price per m² 81,68€

4.2.2. m³ Rectangular reinforced concrete pillar 35x35cm

Pillar of rectangular or square section of reinforced concrete, 35x35 cm of medium section, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with a approximate amount of 120 kg/m³; assembly and disassembly of formwork system.

Total price per m³ 433,26 €

4.2.3. m³ Rectangular reinforced concrete pillar 40x40cm

Pillar of rectangular or square section of reinforced concrete, 40x40 cm of medium section, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with a approximate amount of 120 kg/m³; assembly and disassembly of formwork system.

Total price per m³ 409,03 €

4.2.4. m³ Rectangular reinforced concrete pillar 45x45cm

Pillar of rectangular or square section of reinforced concrete, 45x45 cm of medium section, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with a approximate amount of 120 kg/m³; assembly and disassembly of formwork system.

Total price per m³ 390,30 €

4.2.5. m² Reusable formwork system for rectangular or square pillar

Assembly and dismantling of reusable formwork system for forming rectangular or square reinforced concrete pillar, with industrial type finish to coat in plant up to 3 m in free height.

Total price per m² 16,64€

4.2.6. m³ Reinforced concrete beam 30x30cm

Reinforced concrete beam, 30x30 cm, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 150 kg/m³; assembly and disassembly of the shuttering system, with industrial type finish for coating, in plant up to 3 m in free height

Total price per m³ 365,13 €

4.2.7. m³ Reinforced concrete beam 30x40cm

Reinforced concrete beam, 30x40 cm, made with concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 150 kg/m³; assembly and disassembly of the shuttering system, with industrial type finish for coating, in plant up to 3 m in free height

Total price per m³ 384,63 €

4.2.8. m² Formwork system for beam

Assembly and dismantling of formwork system for beam formation, straight, reinforced concrete, with industrial type finish to coat in plant up to 3 m free height.

Total price per m² 23,33 €

4.2.9. m² Exposed concrete staircase

Concrete staircase, with stair slab and reinforced concrete steps, made with 15 cm thick concrete C25/30 manufactured in central, and poured with cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 18 kg/m², leaving the concrete of the bottom and sides of the slab visible; Assembly and dismantling of formwork system, with a finished finish with a smooth texture on its lower face and sides, on a floor up to 3 m in free height.

Total price per m² 115,19 €

4.2.10. m² Formwork system for exposed concrete stair slab

Assembly and dismantling of formwork system for the formation of reinforced concrete staircase slab, with a finished finish with a smooth texture on its underside and sides, with concrete steps, up to 3 m in height.

Total price per m² 55,44€

5. Budget summary

	Amount (€)
1 Foundations	
1.1 Basement excavation	8.996,56
1.2 Blinding concrete layer	5.396,10
1.3 Foundation slab	103.229,04
1.4 Basement walls	24.767,75
Total 1 Foundation:	142.389,48
2 Structure	
2.1 Slabs	321.333,20
2.2 Pilars	55.122,25
2.3 Beams	61.734,11
2.4 Stairs	20.413,17
Total 2 Structure:	458602,73
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Budget of material and labor execution	600.992,22
13% de general costs	78.128,99
6% de industrial benefit	36.059,53
Contract execution budget	715.180,74
21% VAT	150.187,96€
Contract execution budget with VAT	865.368,69€

Increases the contract execution budget with VAT to the expressed amount of "EIGHT HUNDRED SIXTY FIVE THOUSAND THREE HUNDRED SIXTY EIGHT EURO AND SIXTY NINE CENTS".

6. Cost of the work per square meter

Once obtained the approximate budget, the cost of the work per m² can be calculated to have an order of magnitude of the cost:

- Contract execution budget with TAX = 865.368,69€
- Area of m² of the floor = 3934,05 m²

Therefore the cost per m² of the floor will be 219,97 €/m².

