UNIVERSITAT POLITÈCNICA DE CATALUNYA

DEPARTAMENT DE CONSTRUCCIONS ARQUITECTÒNIQUES I

TECNOLOGIA DE L'ARQUITECTURA, EDIFICACIÓ I URBANISME

PREFABRICATED FOUNDATIONS FOR HOUSING APPLIED TO ROOM MODULES

APPENDICES

By:

ESTER PUJADAS GISPERT

Supervised by:

PROF. DR. JOSEP IGNASI DE LLORENS

Barcelona, November 2015

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1. Case studies

A1 - 1	Light / Point	Steel panels
1.66 kN/m^2	T2	2008

1 – The building

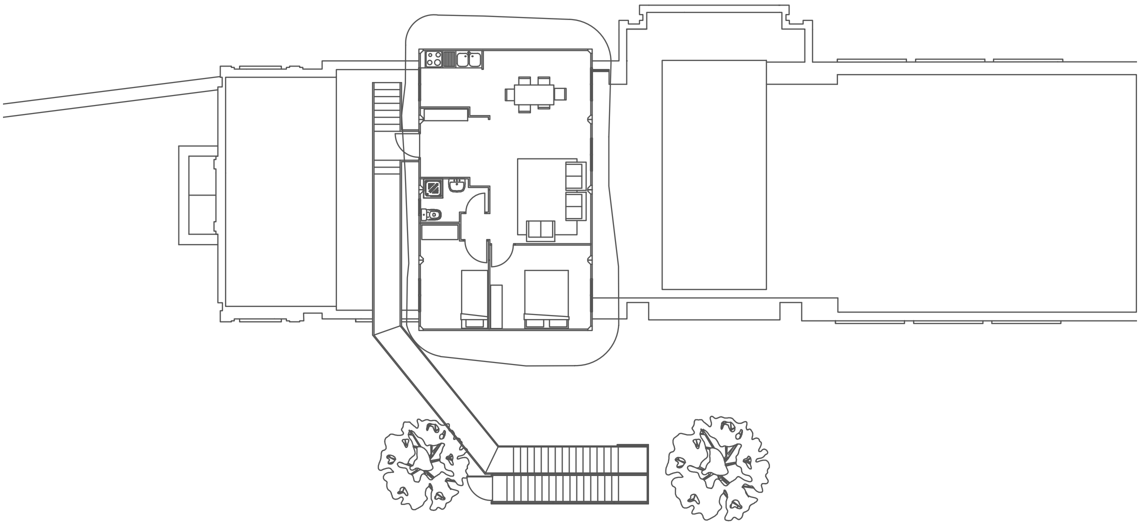


Figure 1. Ground floor plan.

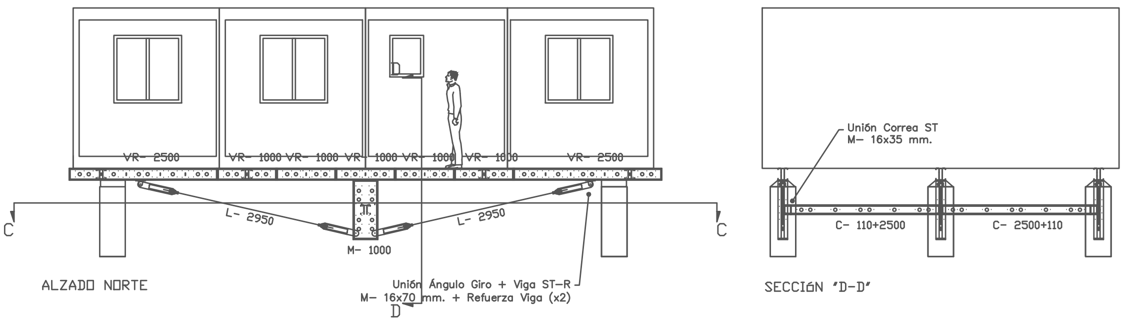


Figure 2. North elevation and cross section.

2 – Foundation design factors

1. Initial price. The structure was rented.
2. Initial constrains. Existing building to respect.
3. Temporary location.

3 – The foundation

The foundation consists of six recoverable steel isolated footings fixed to the parapets of the existing building by means of chemical anchors.

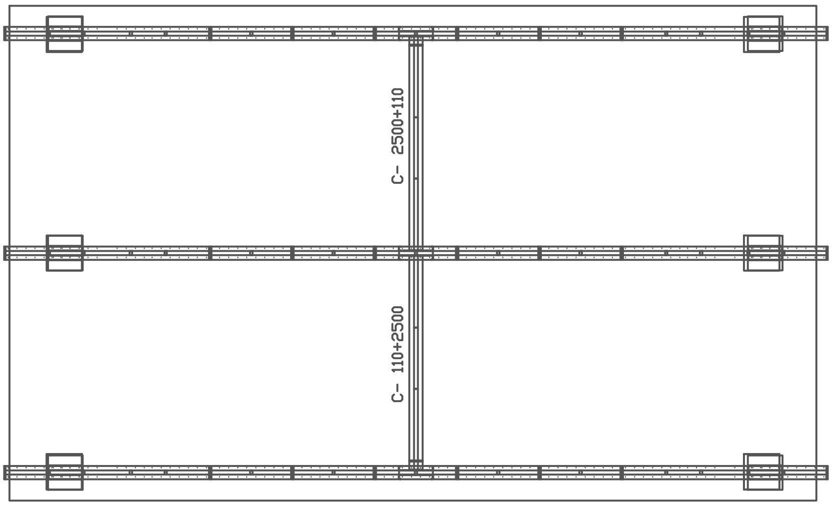


Figure 3. Foundation plan.

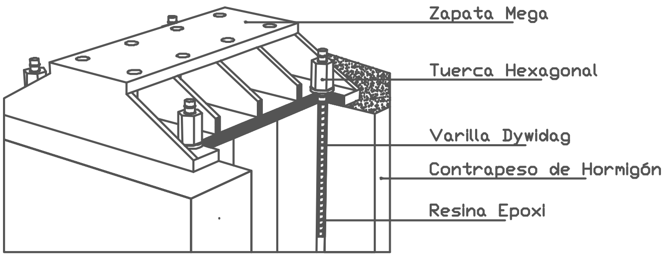


Figure 4. Footing detail.

Figure 5. Foundation image.

A1 - 2	**Light / Point**	**Steel-timber frames**
2.45 kN/m^2	**T1**	**2008**

1 – The building

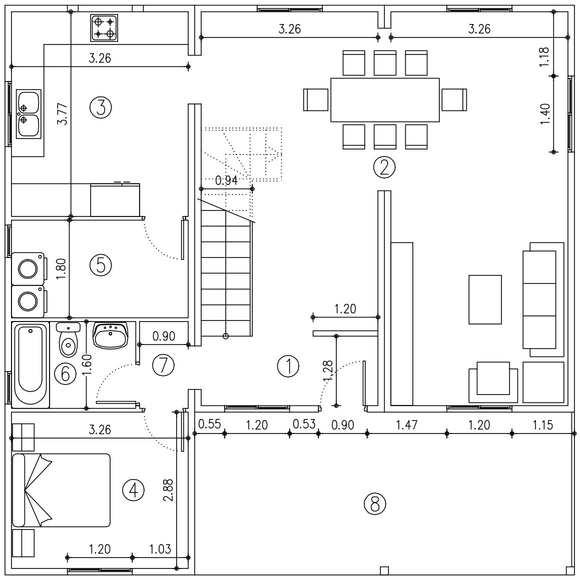


Figure 1. Ground floor plan.

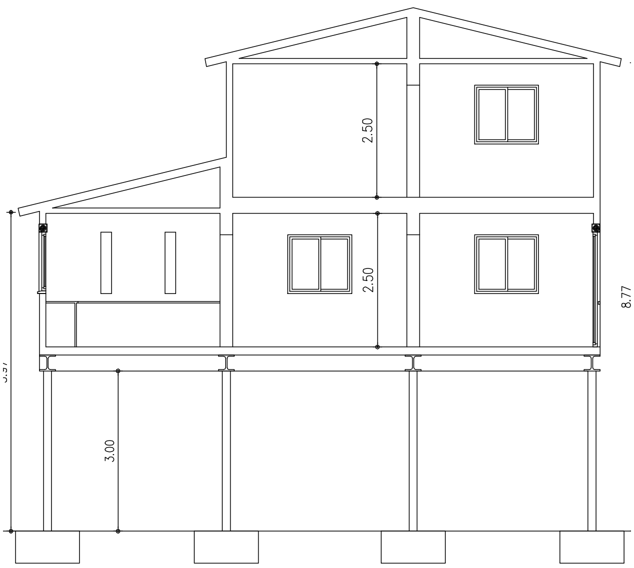


Figure 2. Cross section.

2 – Foundation design factors

1. Ground characteristics. The slope of the ground.

2. Initial constrains. There had to be a garage under the house.

3 – The foundation

The foundation consists of cast-in-place isolated footings and cast-in-place tie beams. Modules are placed over a metalic structure to take advantatge of the slope of the ground and to build the garage under the house.

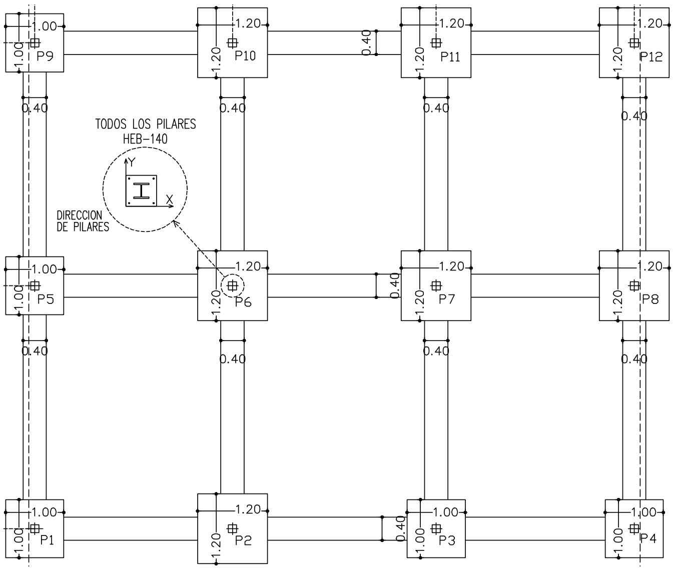


Figure 3. Foundation plan.

Figure 4. Modules are placed over a metalic structure to take advantatge of the slope of the ground and to build the garage under the house.

A1 - 3	**Light / Point**	**Steel panels**
1.77 kN/m^2	**T2**	**2009**

1 – The building

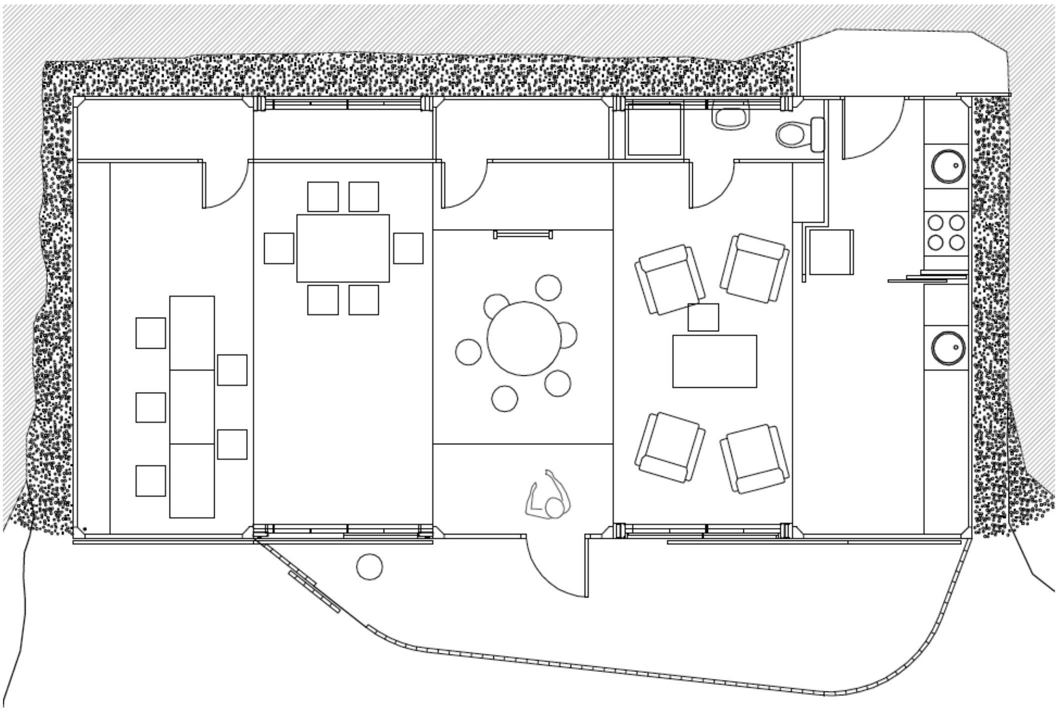


Figure 1. Ground floor plan.

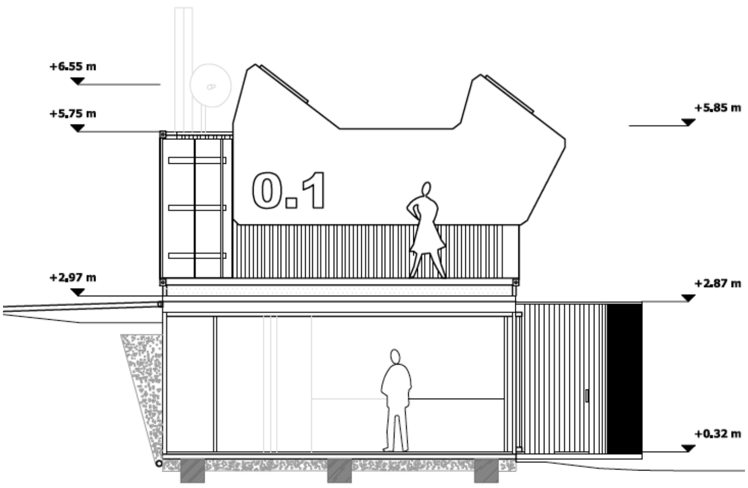


Figure 2. Cross section.

2 - Foundation design factors

1. Initial price. The budget to build the building was 30,000 €.
2. Simplify the construction. The hollow concrete block was used as a formwork.

3 - The foundation

The foundation consists of self-built semi-prefabricated isolated footings. They were built with concrete blocks and mass concrete. Some timber boards were nailed over the foundation in order to create a base for the modules.

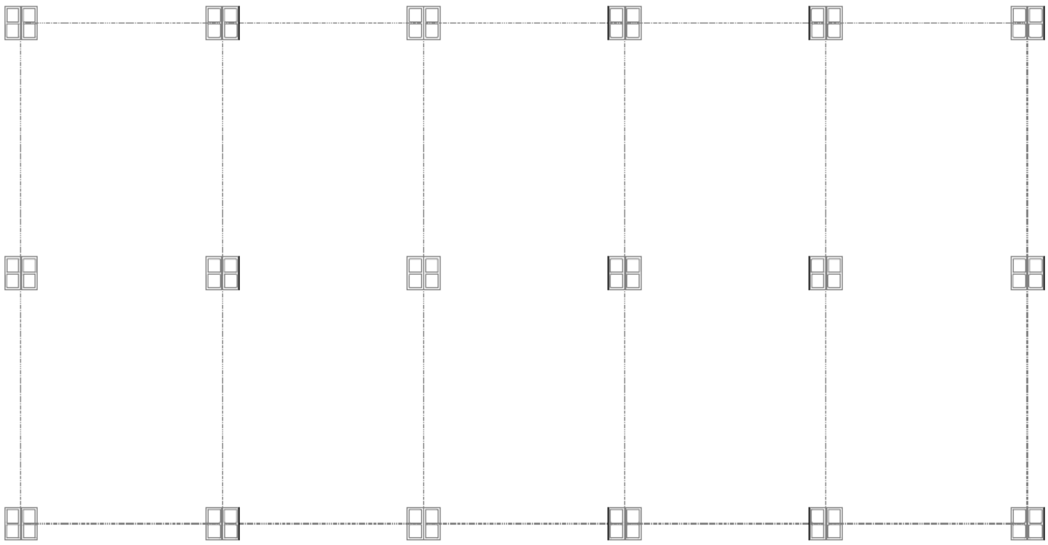


Figure 3. Foundation plan.

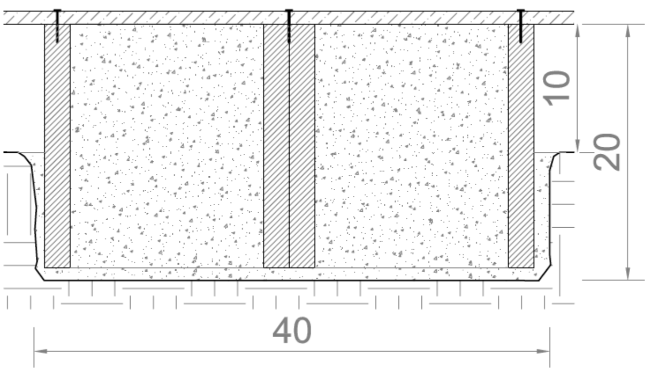


Figure 4. Isolated footing detail.

A1 - 4	Light / Point	Timber Frames
3.57 kN/m^2	T1	2009

1 – The building

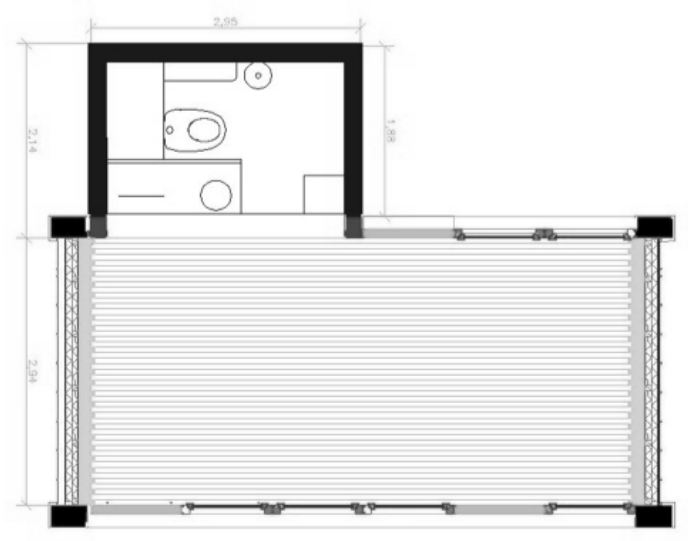


Figure 1. Ground floor plan.

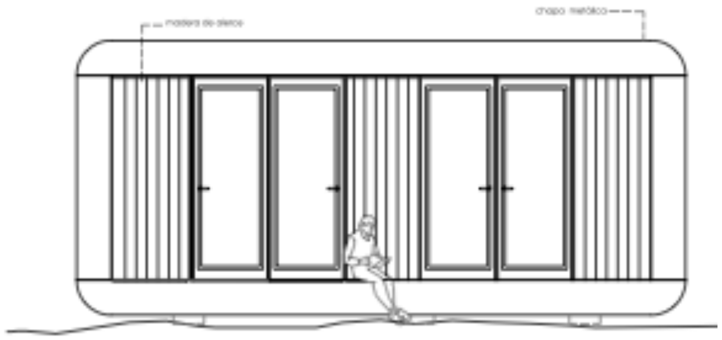


Figure 2. Elevation.

2 – Foundation design factors

1. Initial price.
2. Sustainability:
    a. Good life cycle materials.
    b. Minimal impact.
3. Temporary location.

3 – The foundation

The foundation consists of a cast-in-place ground slab. The module was placed over timber beams. The slope of paving was compensated by timber wedges.

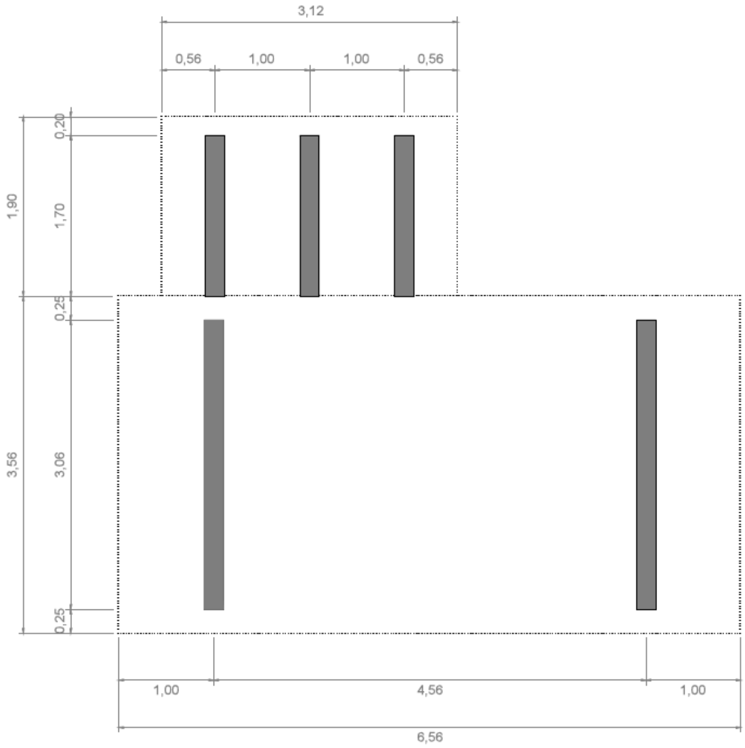


Figure 3. Timber beams distribution.

Figure 4. Timber wedges under the timber beams to compensate the slope of the ground slab.

A1 - 5	Light / Point	Timber frames
3.43 kN/m^2	**T1**	**2009**

1 – The building

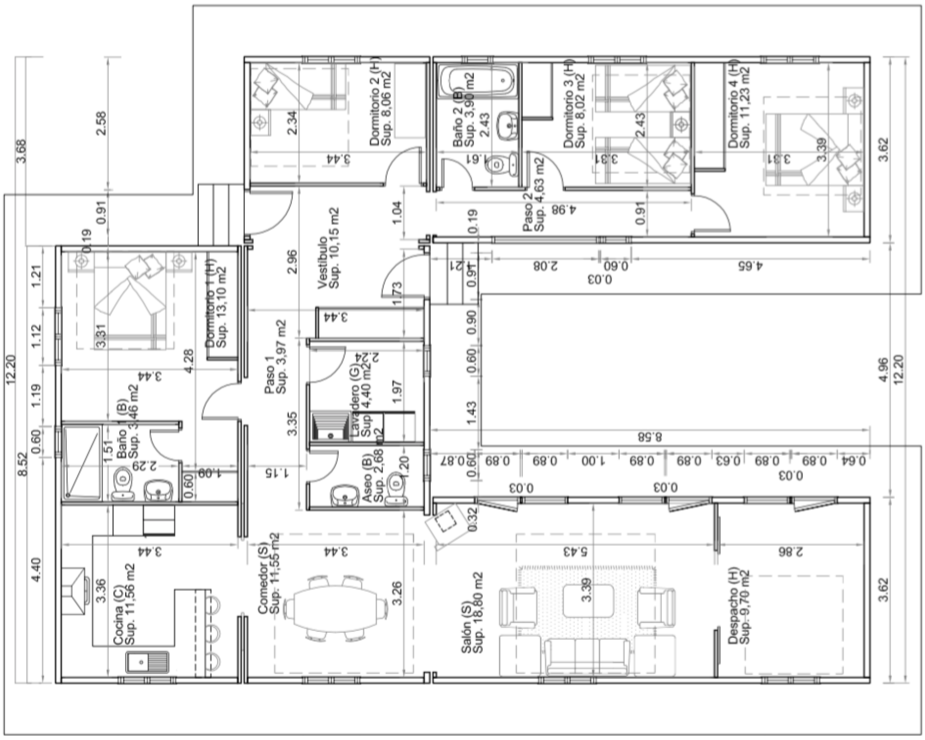


Figure 1. Ground floor plan.

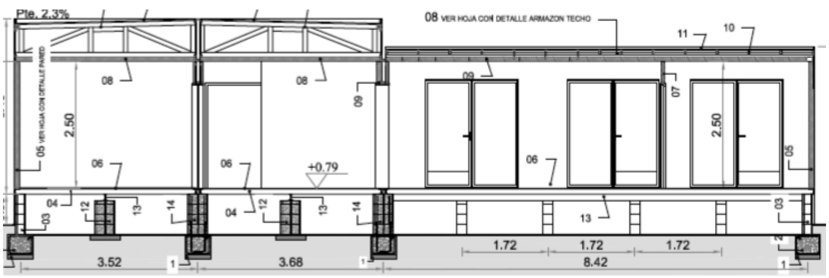


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. "*It is easy to do it*".

3 – The foundation

The foundation consists of cast-in-place isolated footings and cast-in-place strip footings. Modules are placed over concrete block walls to form the suspended floor.

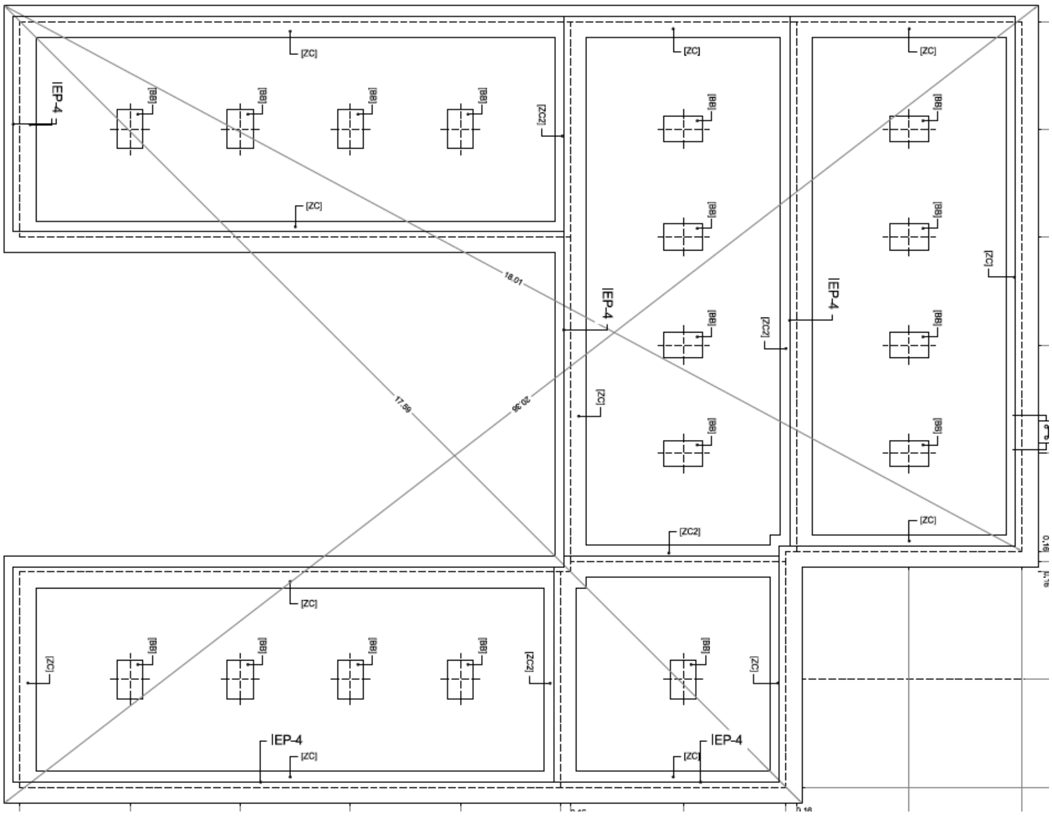


Figure 3. Foundation plan.

A1 - 6	**Light / Distributed**	**Timber panels**
3.57 kN/m^2	**T2**	**2009**

1 – The building (The left module is the dwelling)

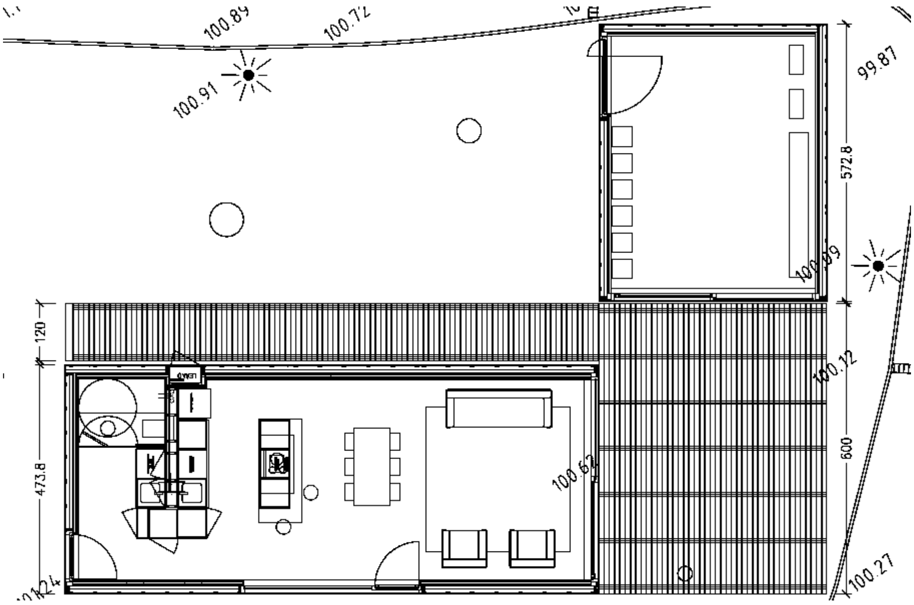


Figure 1. Ground floor plan.

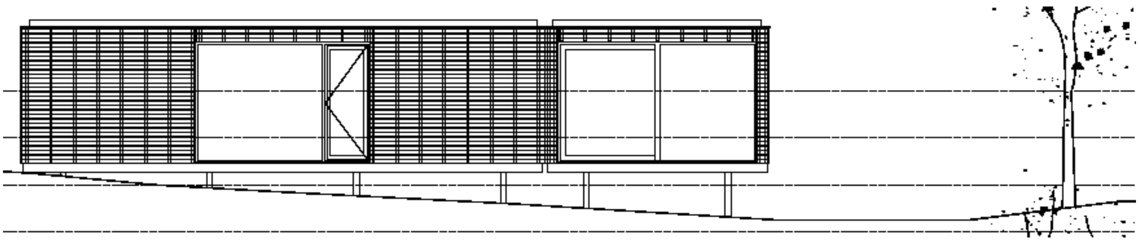


Figure 2. Elevation.

2 – Foundation design factors

1. Temporary location.
2. Sustainability reasons:
    a. Good life cycle materials.
    b. Minimal ecologic footprint.
    c. Dry construction.
3. Ground characteristics. It should adapt to the slope of the ground.

3 – The foundation

The foundation consists of steel screw piles. Metal plates were welded at the top of screw piles and timber beams were nailed over the metal plates.

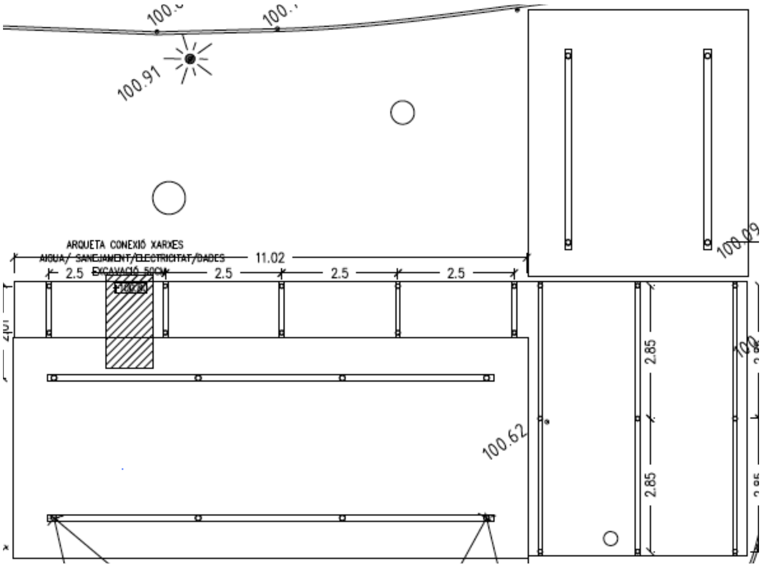


Figure 3. Foundation plan.

Figure 4. A metal plate was welded at the top of a screw pile.

A1 - 7	**Light / Point**	**Concrete-steel frames and panels**
3.23 kN/m^2	**T1**	**2009**

1 – The building

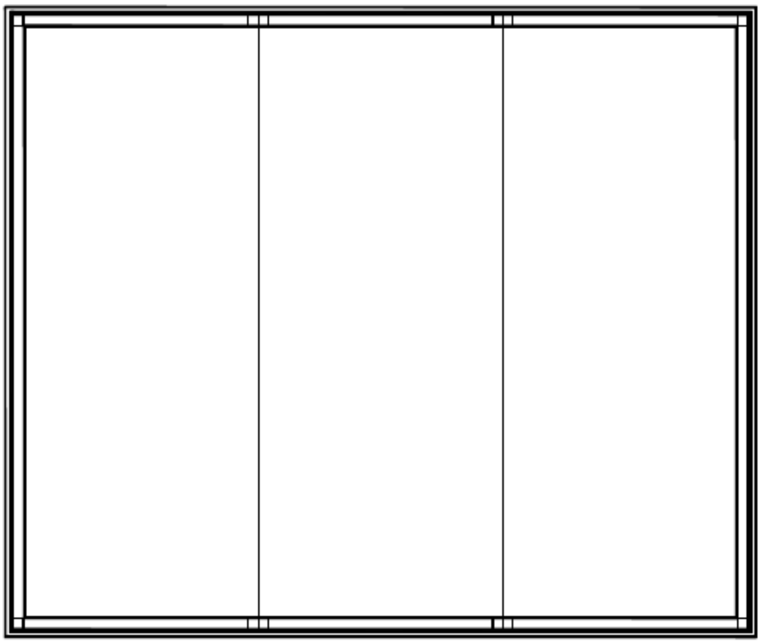


Figure 1. Ground floor plan.

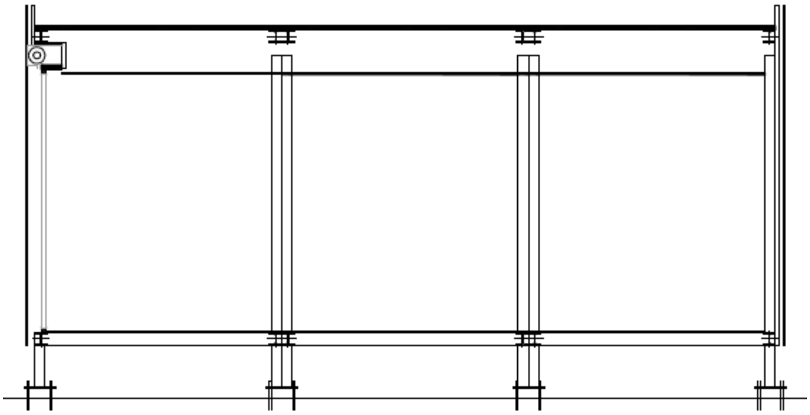


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. "*It is easy to do it*".

3 – The foundation

The foundation consists of a cast-in-place ground slab. Supports are fixed to the foundation by means rebars and vinyl ester resin.

Figure 3. Modules are placed over metal supports. Supports were fixed to the foundation by means rebars and vinyl ester resin.

A1 - 8	**Light / Point**	**Steel-timber frames**
2.45 kN/m^2	**T1**	**2009**

1 – The building

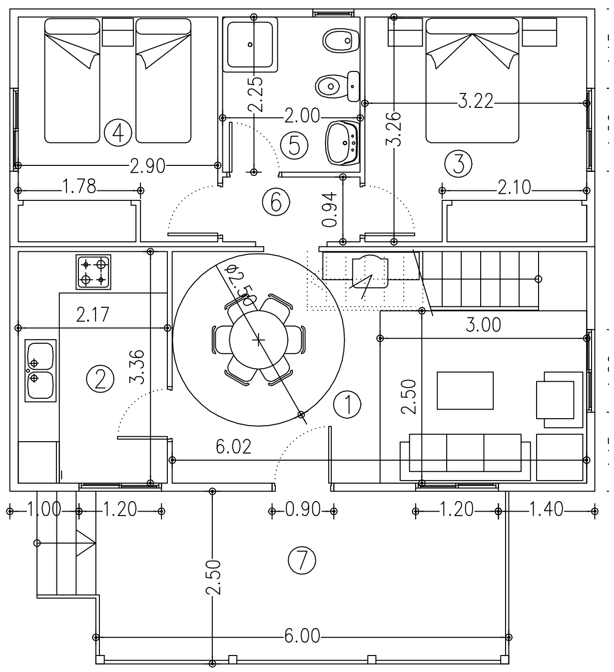


Figure 1. Ground floor plan.

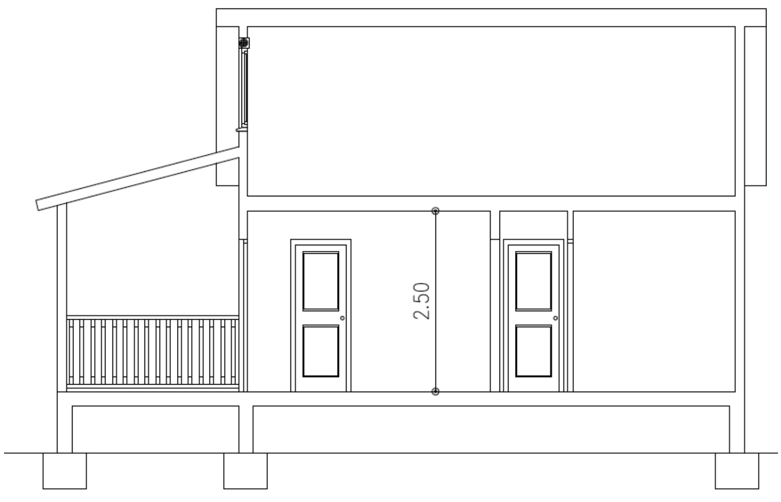


Figure 2. Cross section.

2 – Foundation design factors

1. Recommendations. Geotechnical study recommendations.

3 – The foundation

The foundation consists of cast-in-place strip footings. Modules are placed over concrete block walls to form the suspended floor.

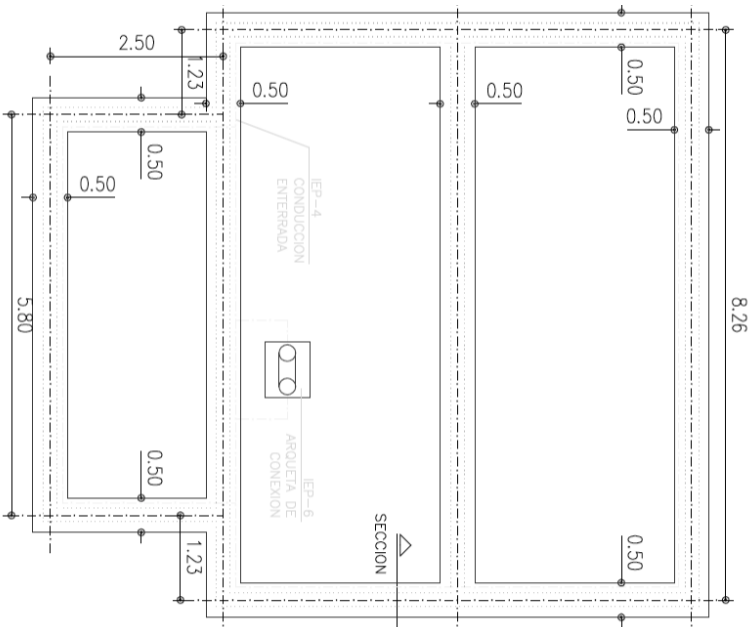


Figure 3. Foundation plan.

Figure 4. Concrete block walls were built over the foundation.

A1 - 9	**Heavy / Distributed**	**Concrete panels**
10.34 kN/m^2	**T2**	**2010**

1 – The building

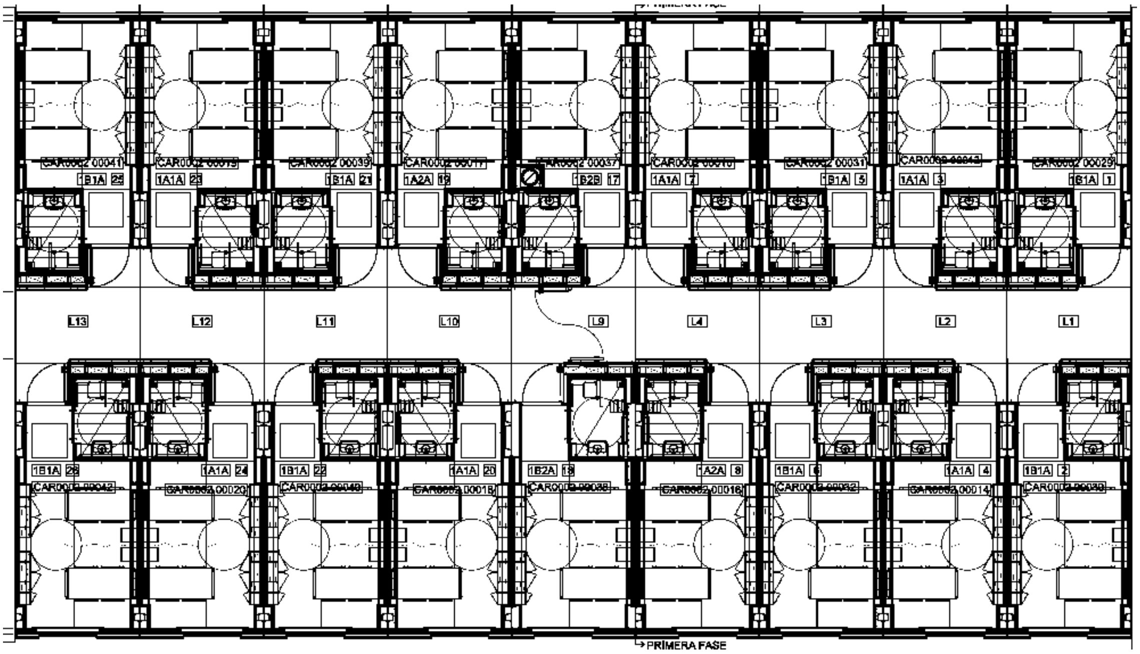


Figure 1. First floor plan.

Figure 2. Cross-section.

2 – Foundation design factors

1. Ground characteristics.
2. Initial constrains: The ground floor should be diaphanous that was the reason why basement and ground floor cast-in-place and the second and the third floor were industrialized.

3 – The foundation

The foundation consists of cast-in-place footings, ground slabs and tie beams.

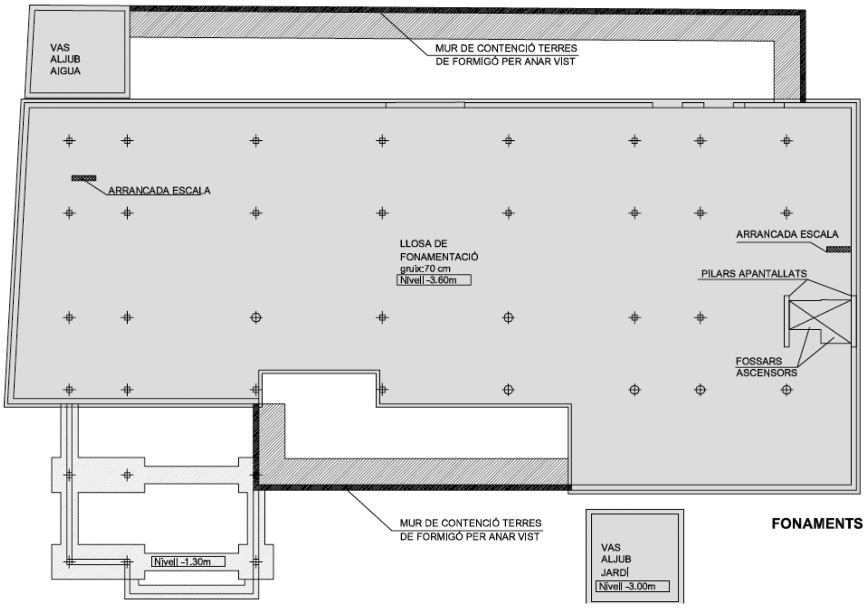


Figure 3. Foundation plan.

Figure 4. This metal template helped to position module connectors to the right position.

A1 - 10	**Heavy / Distributed**	**Concrete panels**
8.48 kN/m^2	**T2**	**2010**

1 – The building

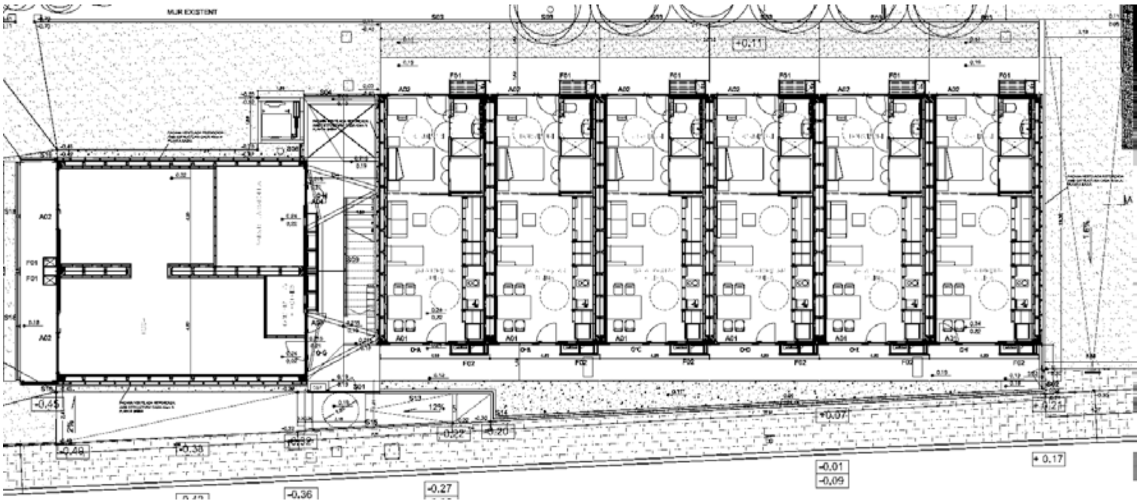


Figure 1. First and second floor plan.

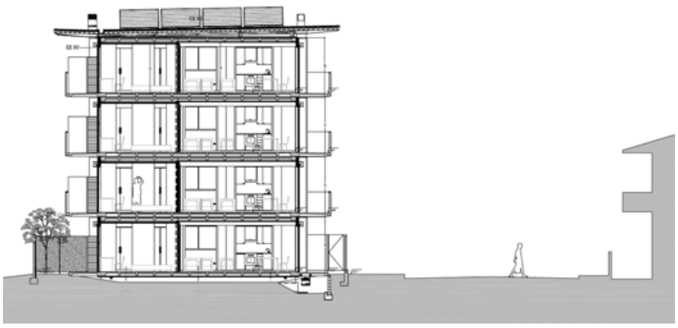


Figure 2. Cross-section.

2 – Foundation design factors

1. Initial price. Precasting the foundation was more expensive.
2. Recommendations. Geotechnical study pointed out:
    a. The presence of the water table.
    b. The low bearing resistance of surface layers.
    c. There were nearby buildings.
3. Difficulties in transport and manipulation.
4. To solve the union between prefabricated and cast-in-place construction.

3 – The foundation

The foundation consists of continuous fight auger piles (CFA), semi-prefabricated ground beams and cast-in-place tie beams.

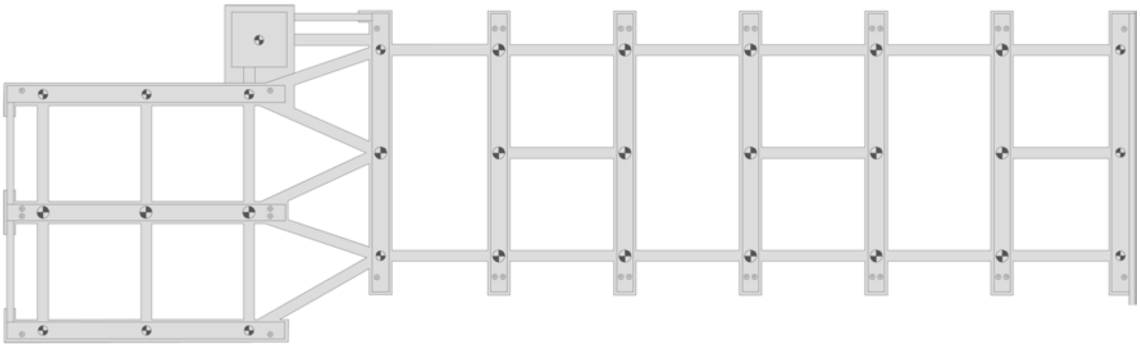


Figure 3. Foundation plan.

Modules were placed over prefabricated semi-beams that had laid out module connectors in order to avoid possible dimensional tolerance problems between the cast-in-place foundation and the prefabricated housing.

4 – Comments

Different mechanisms were used in order to position prefabricated semi-beams at the right location. It took time, and it consequently took money.

Figure 4. Mechanisms to position prefabricated semi-beams at the right position.

A1 - 11	Light / Point	Steel frames
1.96 kN/m^2	T1	2010

1 – The building

Figure 1. Ground floor plan.

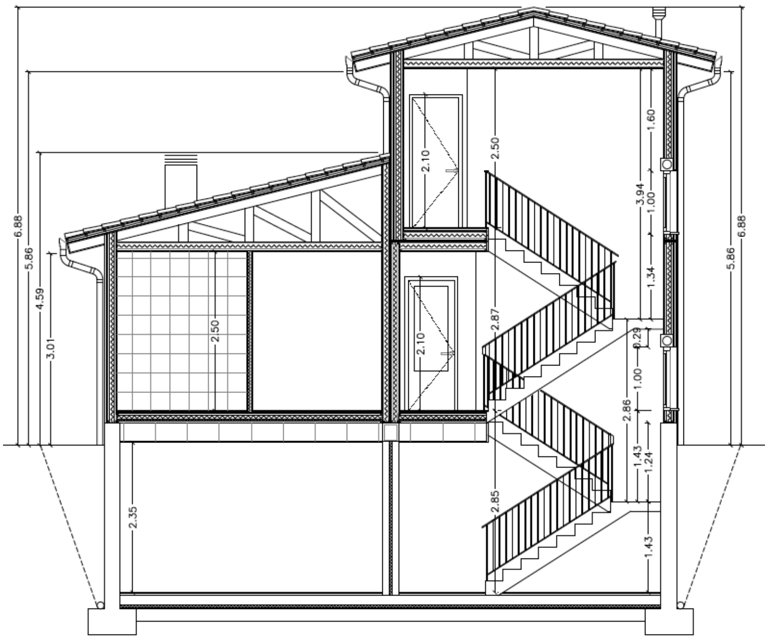


Figure 2. Cross-section.

2 – Foundation design factors

1. Comfort.”*It is easy to do it*”.

3 – The foundation

The foundation consists of cast-in-place ground slabs and cast-in-place strip footings under foundation walls.

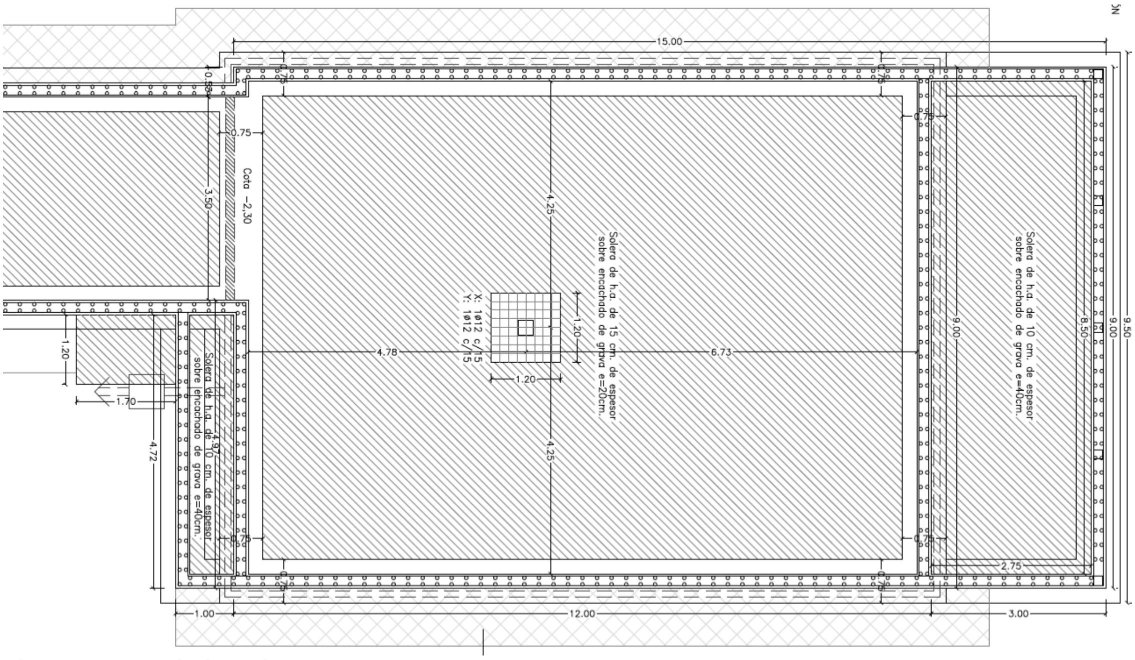


Figure 3. Foundation plan.

A1 - 12	**Light / Point**	**Steel frames**
3.43 kN/m^2	**T1**	**2010**

1 – The building

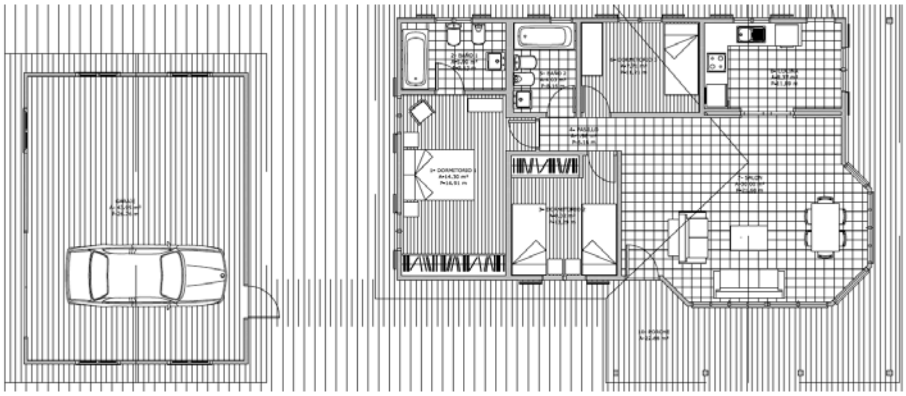


Figure 1. Ground floor plan.

2 – Foundation design factors

1. Initial price.
2. Comfort. "*It has always been done that way*." "*It is easy to do it*"

3 – The foundation

The foundation consists of two cast-in-place ground slabs.

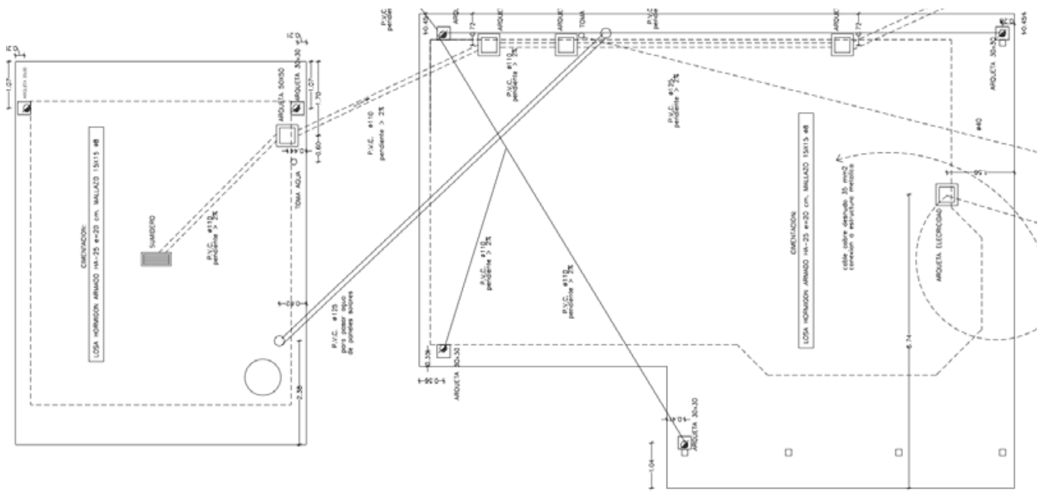


Figure 2. Foundation plan.

A1 - 13	Heavy / Point	Concrete-steel frames and panels
4.41 kN/m^2	T1	2010

1 – The building

Figure 1. Ground floor plan.

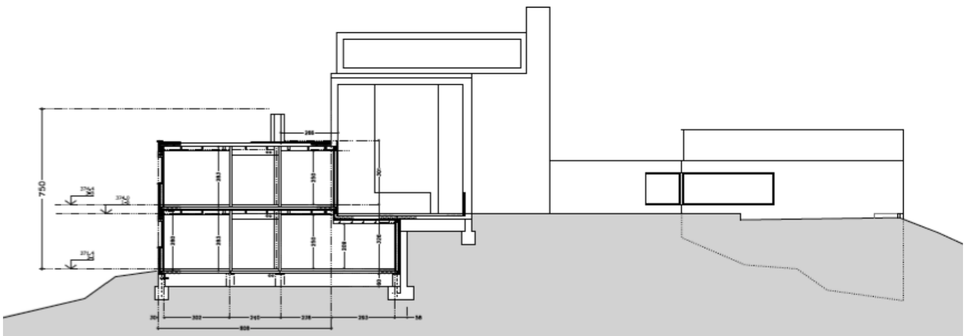


Figure 2. Section through the main room.

2 – Foundation design factors

1. Ground characteristics. The ground had different geotechnical features.

2. Regulations: Planning regulations. The project was built in a rural area and it had to respect the original topography.

3. Initial constrains. The crane could not place modules at the right position at once. Modules should be placed in a provisional position. They thought that only a cast-in-place foundation could allow this.

3 – The foundation

The foundation consists of cast-in-place footings and tie beams.

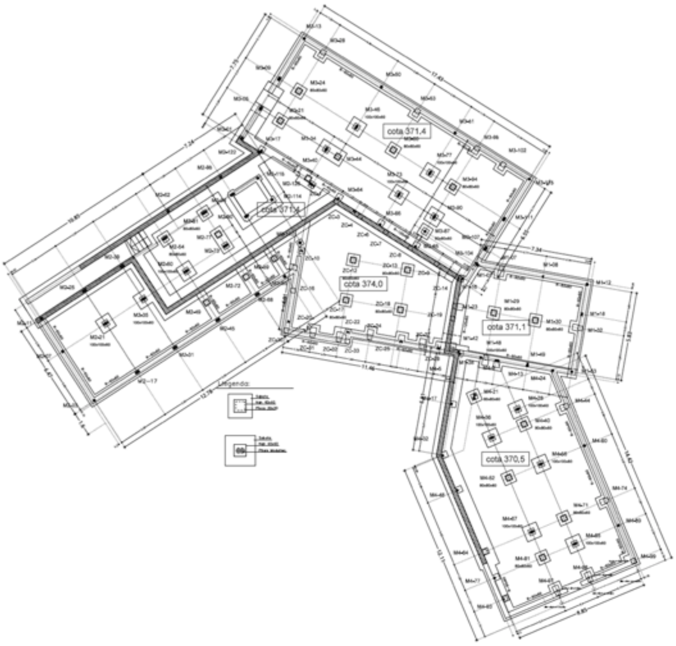


Figure 3. Foundation plan.

Figure 4. The foundation is prepared to place the modules.

A1 - 14	**Heavy / Point**	**Concrete-steel frames and panels**
4.41 kN/m^2	**T1**	**2010**

1 – The building

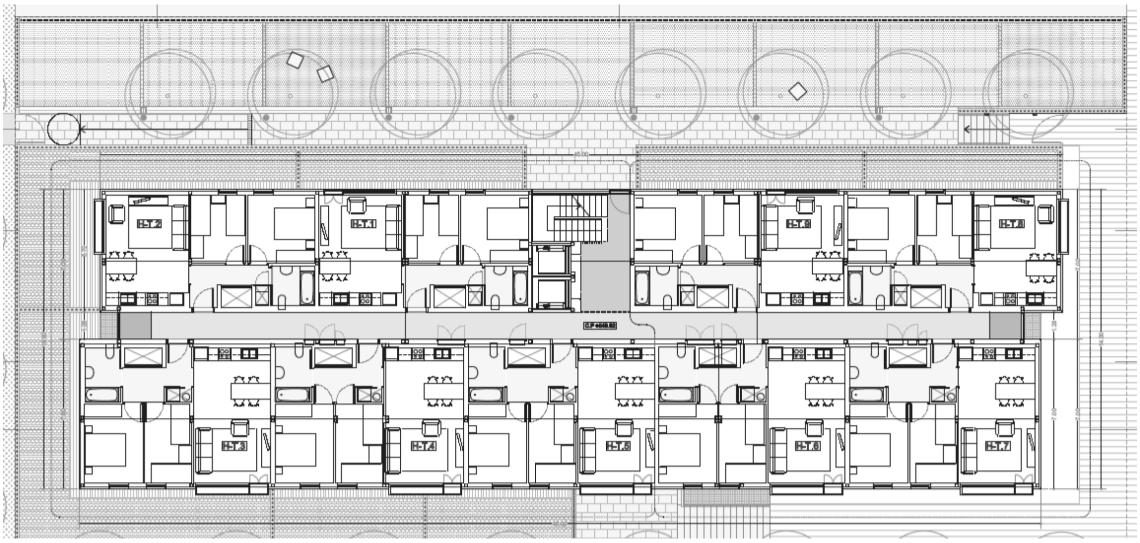


Figure 1. Ground floor plan.

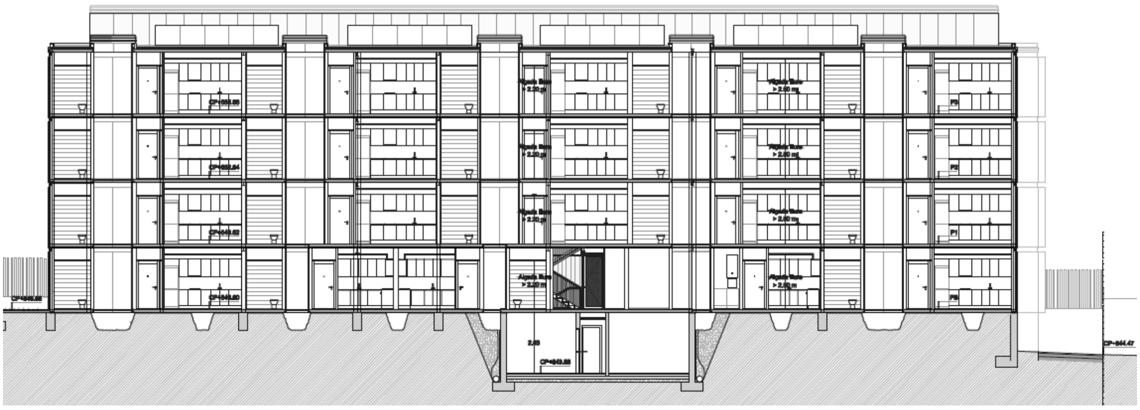


Figure 2. Longitudinal section

2 – Foundation design factors

1. Initial price.
2. They could not find a prefabricated construction company that could build all of the foundation.
3. Difficulties in prefabricating the foundation.

4. The geotechnical study gives values from 77.63 to 143.74 kg/cm^2 in the studied points. But on the conclusions of it, it is recommended an admissible load of 5 kg/cm^2 for isolated footings. This value oversizes the foundation.

3 – The foundation

The foundation consists of cast-in-place isolated footings, strip footings and tie beams.

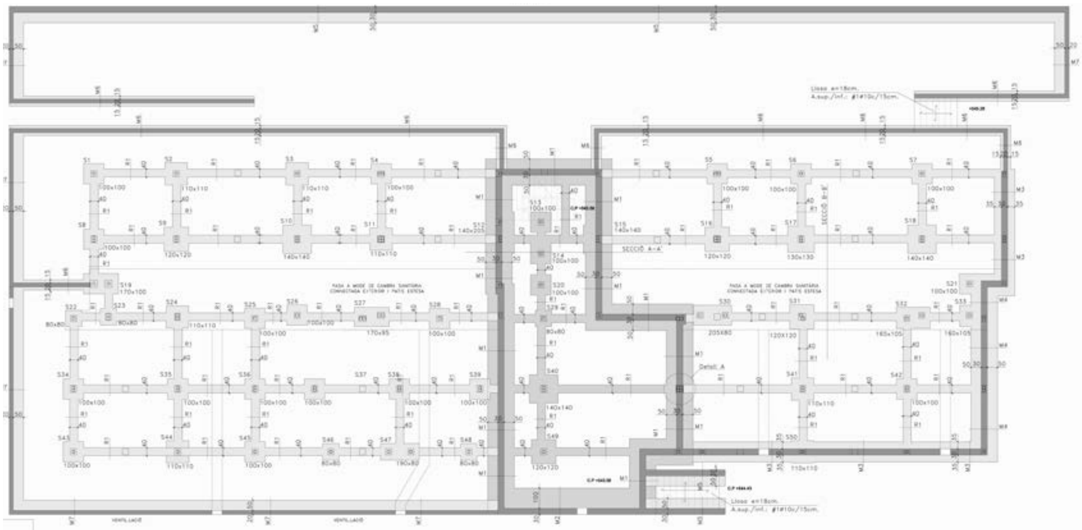


Figure 3. Foundation plan.

Figure 4. Cast-in-place isolated footings and tie beams. Steel plates were left in the top surface to weld the connectors or bolts that join the foundation with the overlying modules.

4 – Comments

One of the first unforeseeable conditions was the hardness of the subsoil. The geotechnical survey had already warned that the soil was of a rocky composition. But it was not expected to be so extreme. In some points the excavation exceeded four meters for the construction of a basement and lowered the site to the level of the street. In order to carry out the excavations, a tracked excavator was used, as well as equipment to drill and inject expansive mortar. This caused delays and increased project costs considerably.

Foundations were constructed cast-in-place. Steel plates were left on the top surface to weld the connectors or bolts that join the foundation with the overlying modules. When the modules arrived to the site, some did not match with the foundation bolts, so various solutions had to be improvised, depending on the location of the bolts. In general, bolts were cut and modules were directly welded to the plates.

Figure 5. The cutting of offset connector bolts with an angle grinder.

A1 - 15	**Heavy / Distributed**	**Concrete panels**
8.52 kN/m^2	**T2**	**2011**

1 – The building

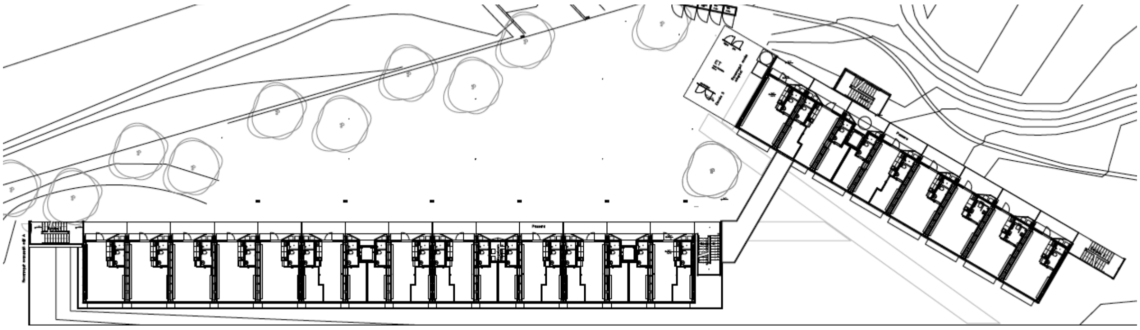
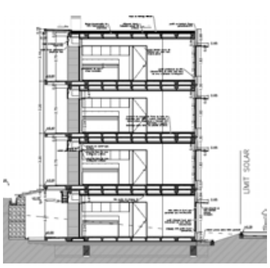


Figure 1. First floor plan (Building A and building B).



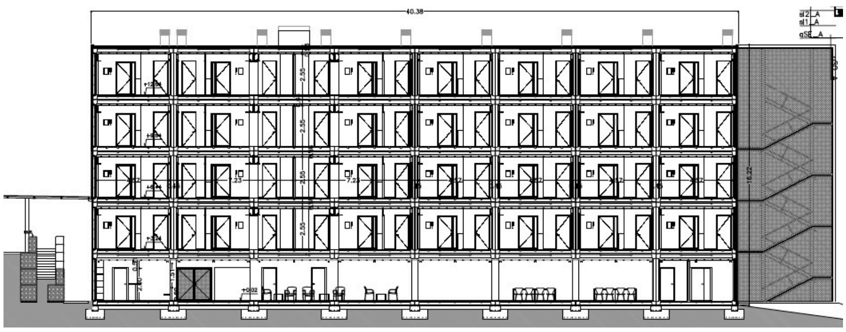


Figure 2. Cross-section (Building A). Figure 3. Longitudinal section (Building B).

2 – Foundation design factors

1. Ground characteristics. The ground had different geotechnical features.
2. Transport and manipulation problems.
3. To solve the union between prefabricated and cast-in-place construction.

3 – The foundation

The foundation consists of semi-prefabricated strip footings, cast-in-place tie beams and ground slabs. Modules were placed over prefabricated semi-beams that had laid out module connectors in order to avoid possible dimensional tolerance problems between the cast-in-place foundation and the prefabricated housing.

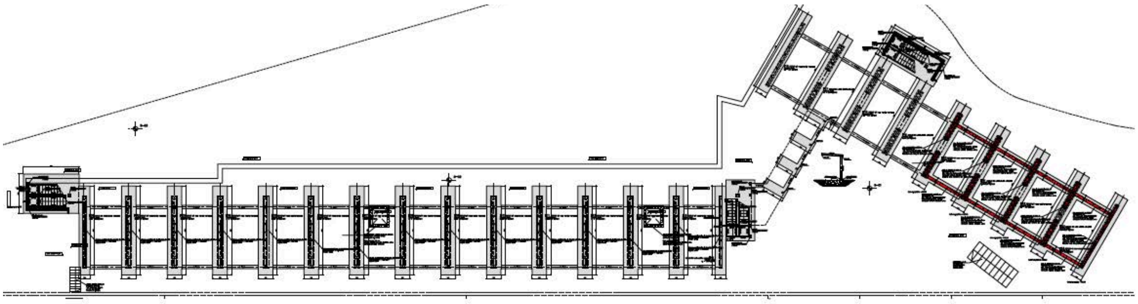


Figure 4. Foundation plan

4 – Comments

As in the A1-10 case, different mechanisms were used in order to position prefabricated beams at the right location. It took time and it took consequently money.

Figure 4. Mechanisms to place prefabricated beams at the right position.

A1 - 16	**Heavy / Distributed**	**Concrete panels**
7.53 kN/m^2	**T2**	**2011**

1 – The building

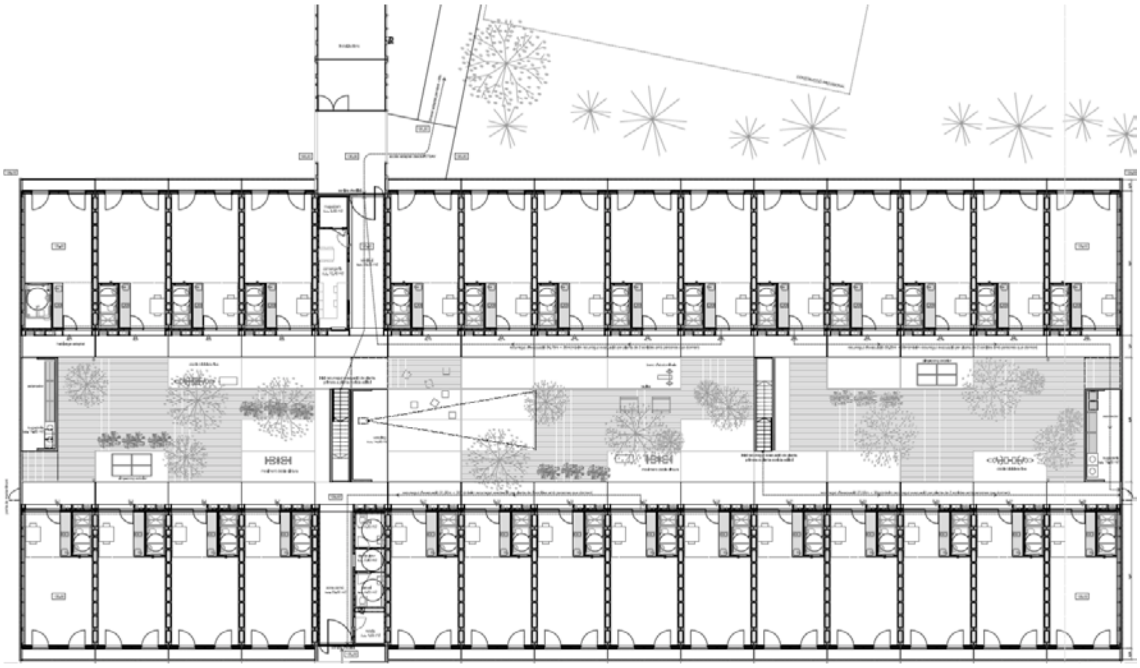


Figure 1. Ground floor plan.

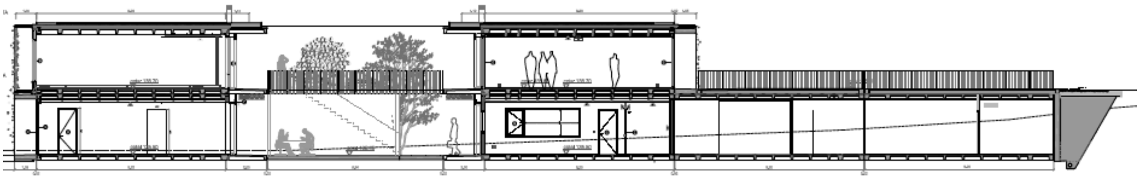


Figure 2. Cross-section.

2 – Foundation design factors

1. Initial price. Project design. As the building had only two floors and the ground was good, it was possible to change foundation scheme in order to save concrete, especially precast concrete that is initially more expensive.
2. Initial constrains. Module shape. The module has two double concrete ribs at opposite sides of the module. They collect and transmit main building loads to

the foundation. Foundation beams were built under double concrete ribs in order to collect these loads.

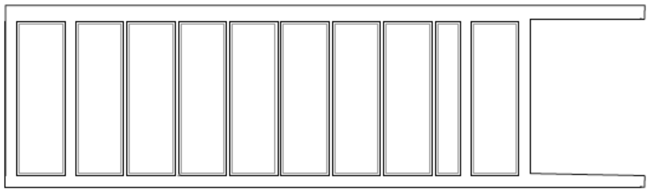


Figure 3. The module has two double concrete ribs at opposite sides of the module.

3 – The foundation

The foundation consists of cast-in-place continuous footings and cast-in-place tie beams, every three modules.

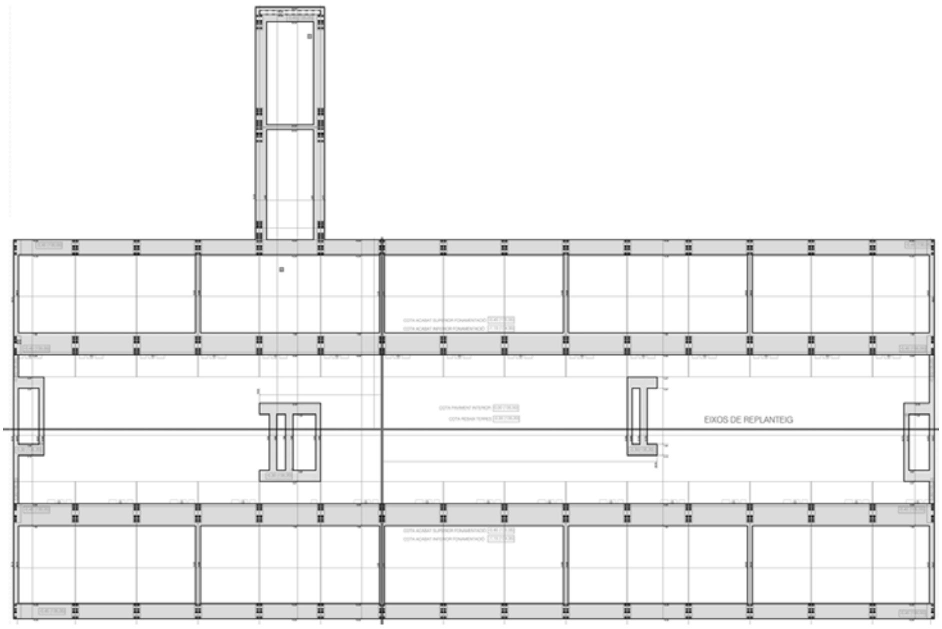


Figure 4. Foundation plan.

Modules were placed over precast concrete pads that had laid out module connectors in order to avoid possible dimensional problems between foundations and room modules.

4 – Comments

The lay out of the precast concrete pads took more time that it was expected. The delay in the foundation construction influenced the module company entrance and consequently the building timing and costs.

Figure 5. Mechanisms to position precast concrete pads over continuous footings.

A1 - 17	**Heavy / Distributed**	**Concrete panels**
7.53 kN/m^2	**T2**	**2011**

1 – The building

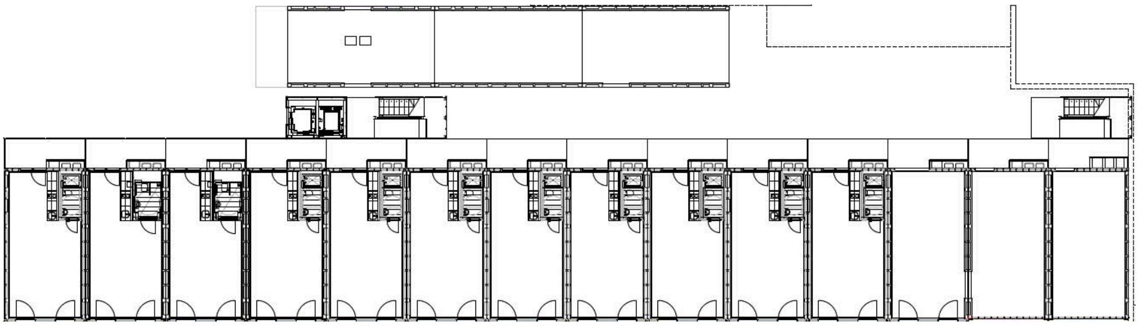


Figure 1. Ground floor plan (Building A and building B).

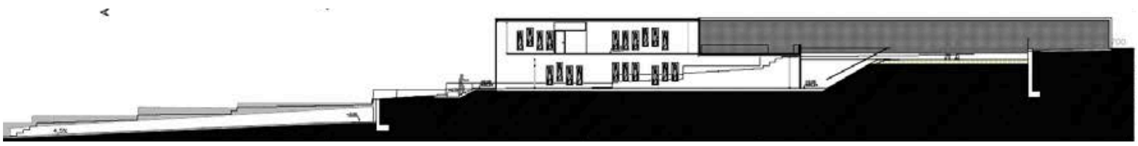


Figure 2. Longitudinal section. (Building A).

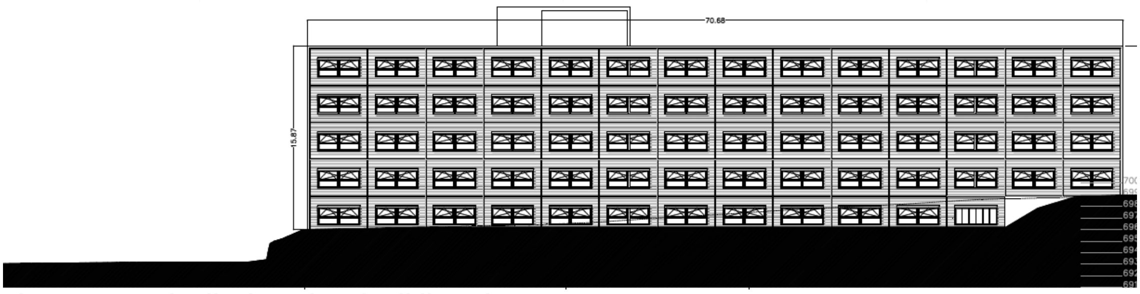


Figure 3. Longitudinal section. (Building B).

2 – Foundation design factors

1. Ground characteristics: the ground had different geotechnical features and a considerable slope.
2. Transport and manipulation problems.
3. Initial constrains: Project design. The building should have a certain number of parking spaces and there was not enough space. That is why the parking was extended under the foundation.
4. To solve the union between prefabricated and cast-in-place construction.

3 – The foundation

The foundation consists of semi-prefabricated strip footings and ground beams and cast-in-place drilled shafts, tie beams, strip footings and a ground slab.

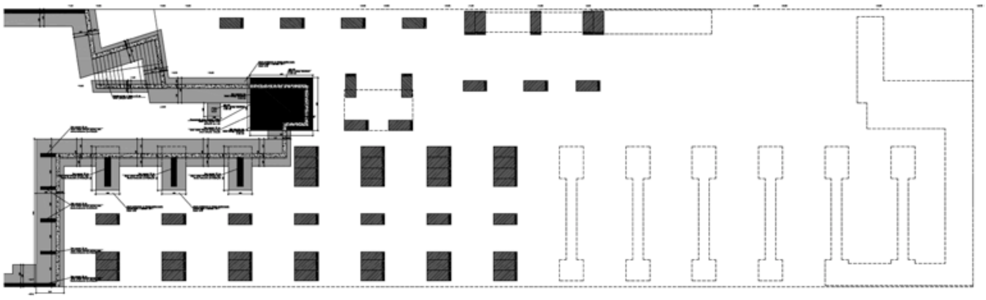


Figure 4. Foundation plan (lower level).

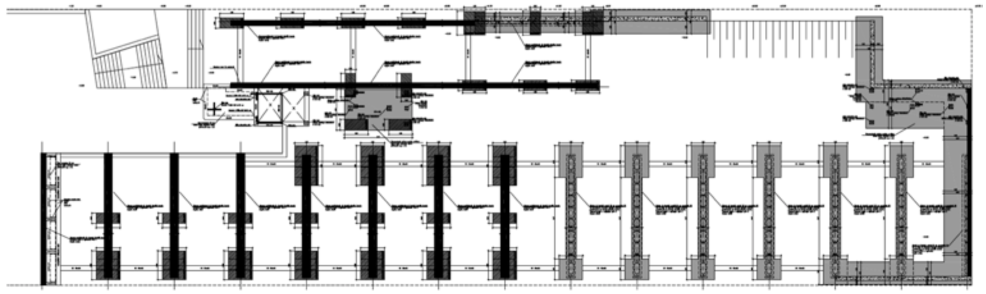


Figure 5. Foundation plan (upper level).

4 – Comments

As in previous projects, different mechanisms were used in order to position prefabricated semi-beams at the right location.

Figure 6. Mechanisms to place prefabricated semi-beams.

A1 - 18	**Light / Point**	**Steel panels**
3.26 kN/m^2	**T2**	**2011**

1 – The building

Figure 1. Ground floor plan.

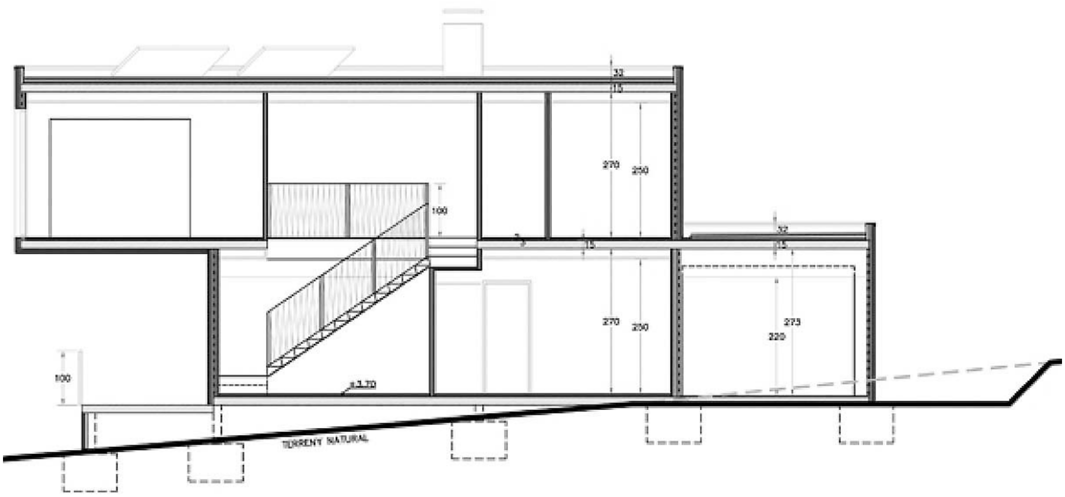


Figure 2. Longitudinal section

2 – Foundation design factors

1. Initial price. They mentioned that it was cheaper to build the foundation cast-in-place.
2. It was preferred to build the foundation cast-in-place with own personnel. Because then they do not have to subcontract.
3. Architect recommendations.

3 – The foundation

The foundation consists of cast-in-place isolated footings.

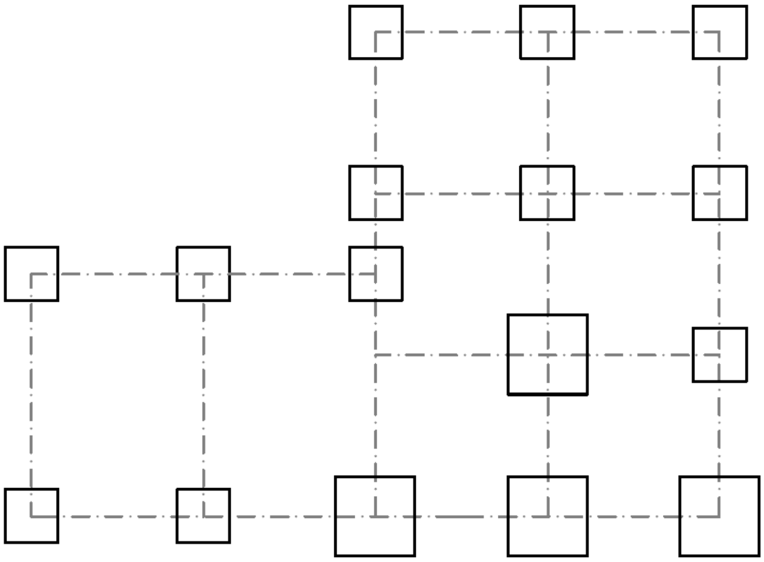


Figure 3. Foundation plan.

Figure 4. Isolated footing reinforcement before concreting.

A1 - 19	**Light / Point**	**Timber frames**
3.43 kN/m^2	**T1**	**2011**

1 – The building

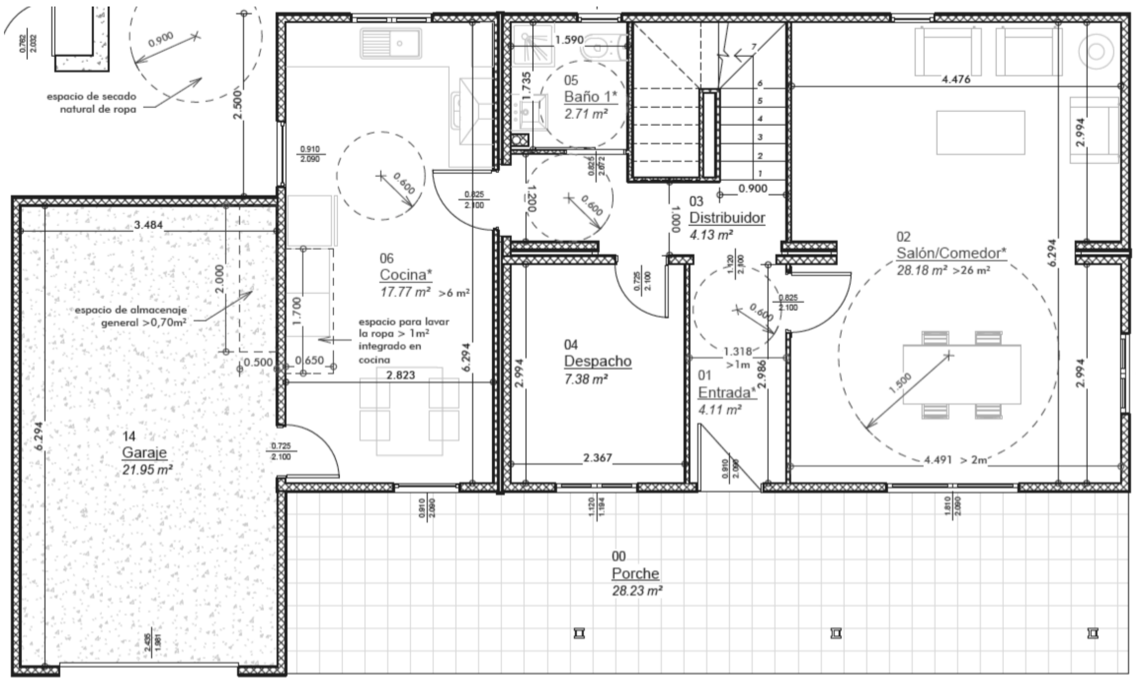


Figure 1. Ground floor plan.

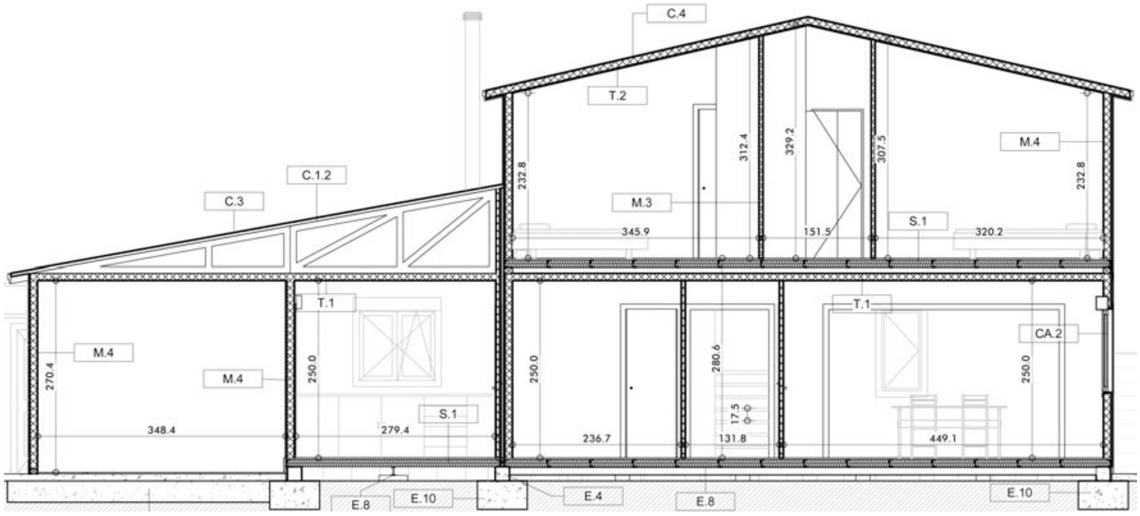


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. ”*It is easy to do it*”.

3 – The foundation

The foundation consists of cast-in-place isolated footings, strip footings and a ground slab. Modules are placed over concrete block walls to form the suspended floor.

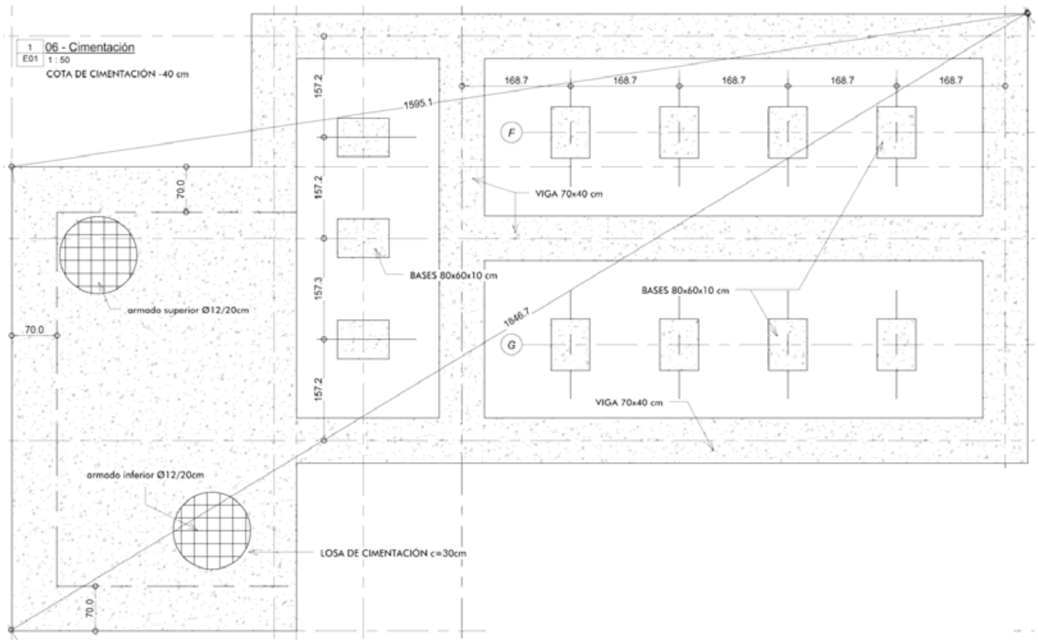


Figure 3. Foundation plan.

Figure 4. Positioning a module.

A1 - 20	**Light / Point**	**Concrete-steel frames and panels**
3.65 kN/m^2	**T2**	**2011**

1 – The building

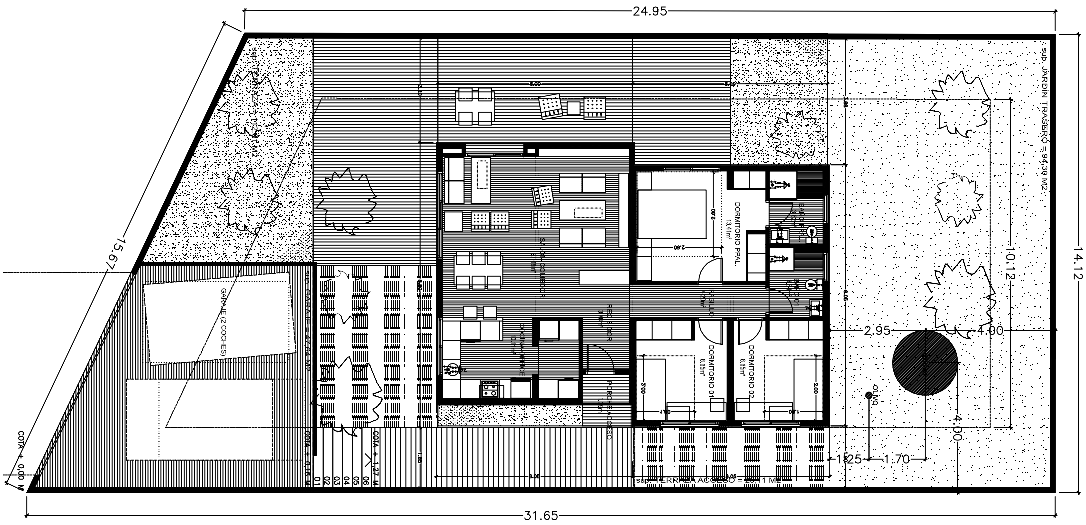


Figure 1. Ground floor plan.

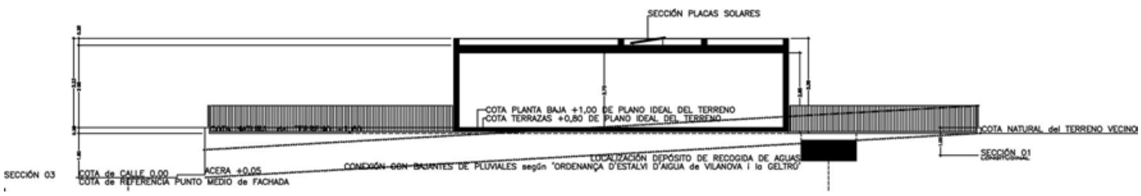


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Insecurity. "*New foundation system, new problems.*" The property chose the constructor. The architect designed a slab because most constructors in Spain know how to build it and then there is less chance of making a mistake.

3 – The foundation

The foundation consists of a cast-in-place ground slab with an extra reinforcement at the perimeter and bellow pillars.

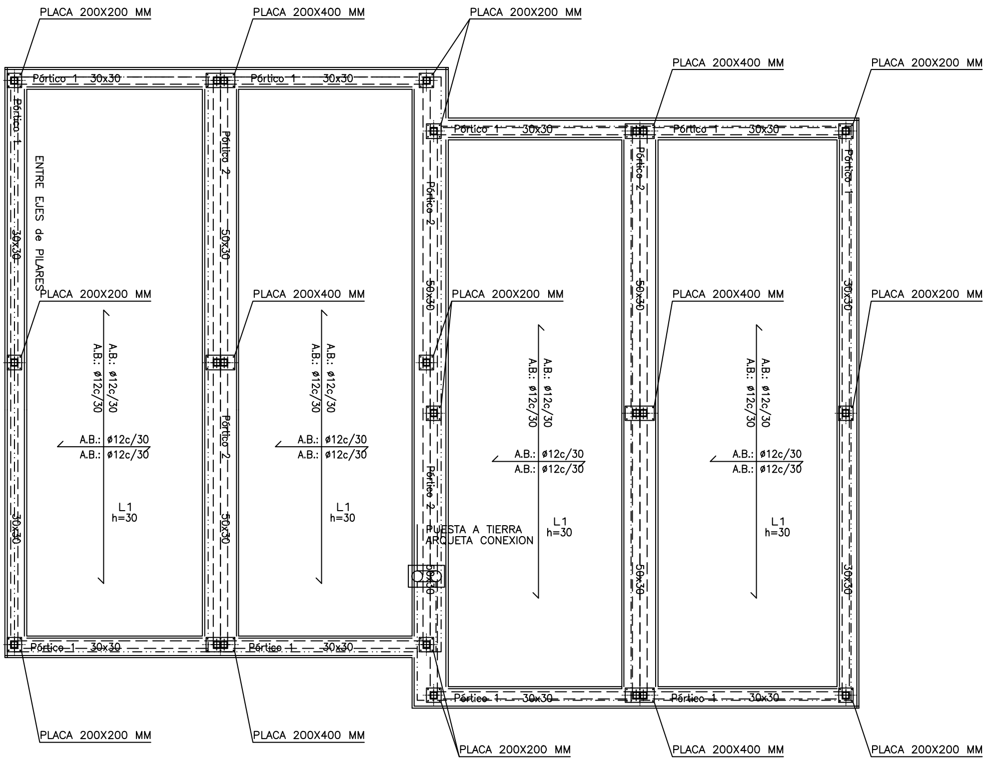


Figure 3. Foundation plan.

Figure 4. Ground slab reinforcement over a base course.

A1 - 21	**Light / Distributed**	**Steel-timber frames and panels**
1.96 kN/m^2	**T2**	**2011**

1 – The building

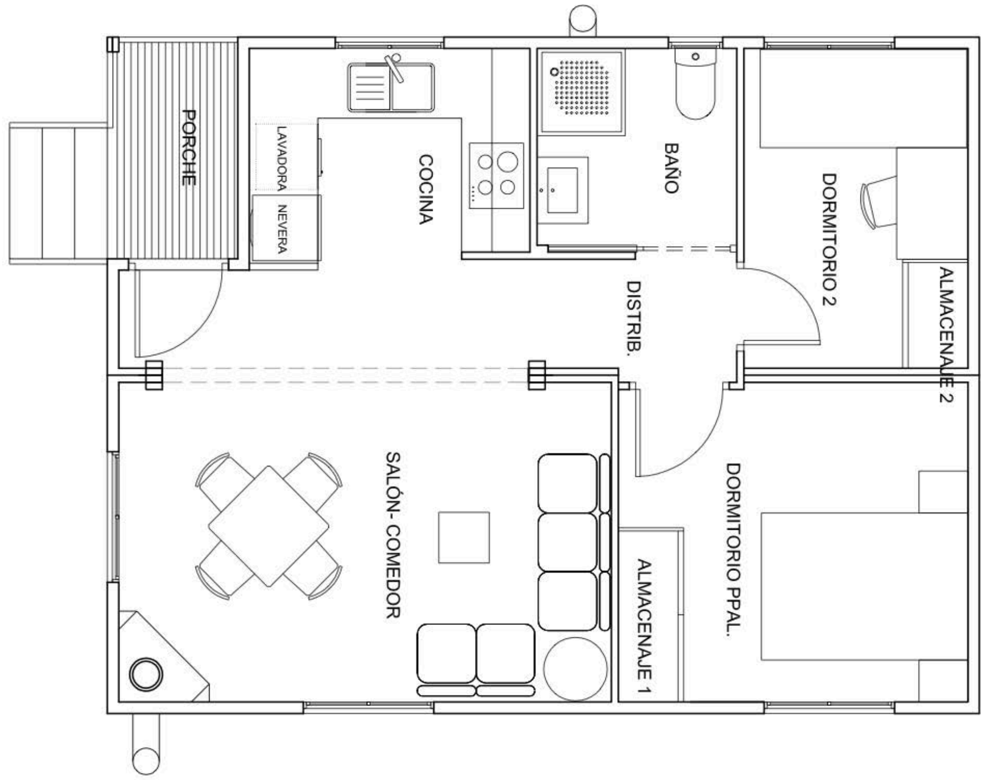


Figure 1. Ground floor plan.

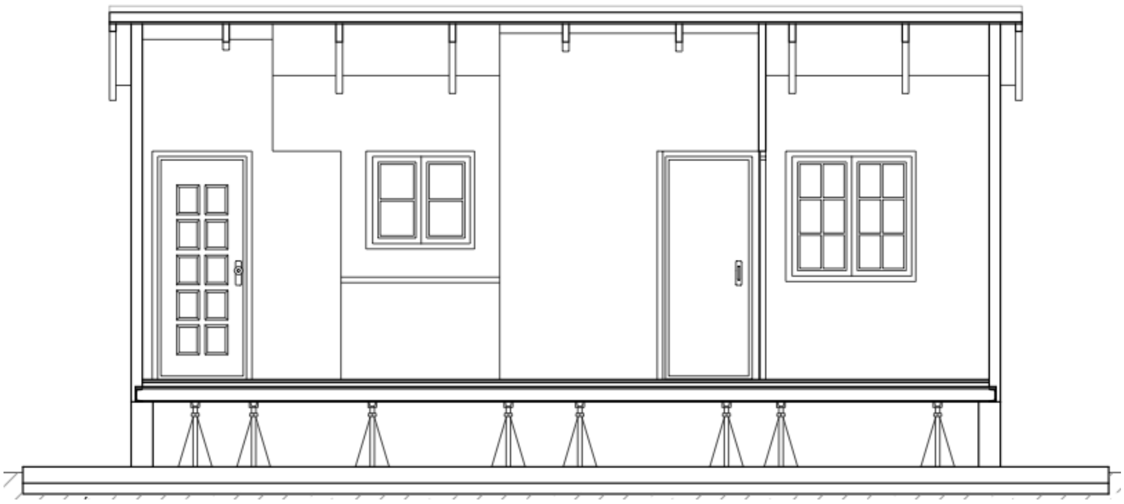


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. “*It is easy to do it*”.

3 – The foundation

The foundation consists of a cast-in-place ground slab of 15 cm. The house lays over metal piers and perimeter concrete blocks walls.

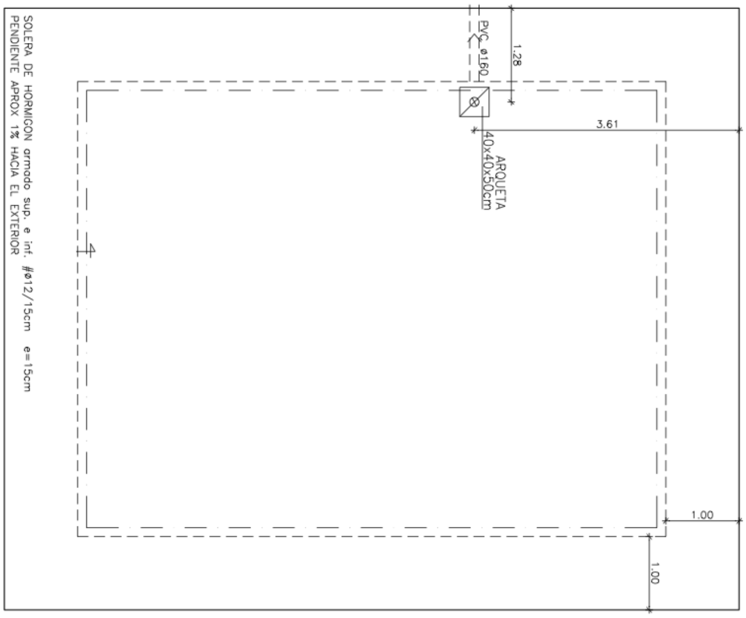


Figure 3. Foundation plan.

Figure 4. Ground slab reinforcement.

A1 - 22	**Light / Distributed**	**Steel-timber frames and panels**
1.96 kN/m^2	**T2**	**2011**

1 – The building

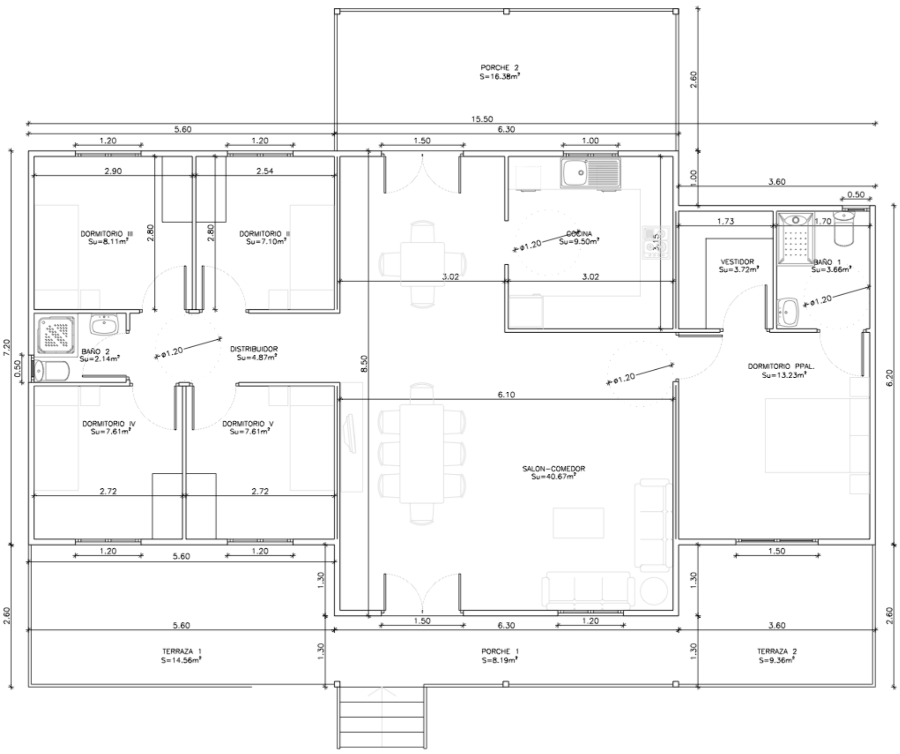


Figure 1. Ground floor plan.

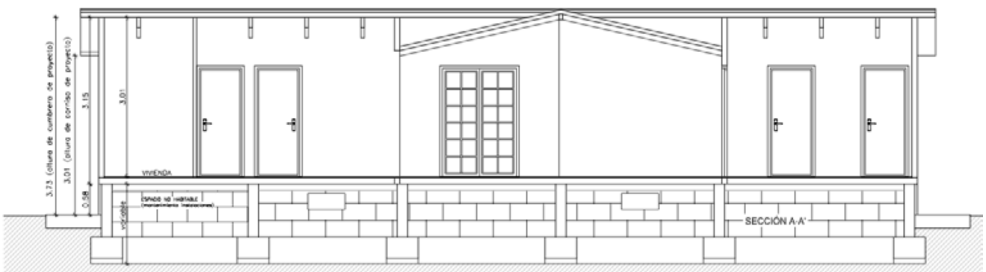


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. “*It is easy to do it*”.

3 – The foundation

The foundation consists of cast-in-place strip footings. Modules are placed over walls to form the suspended floor.

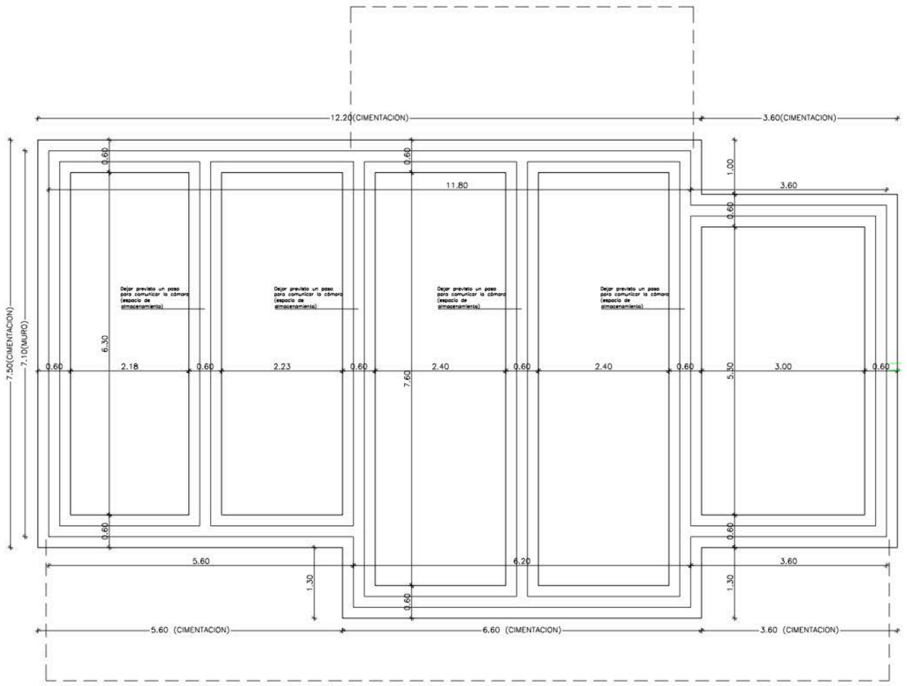


Figure 3. Foundation plan.

Figure 4. Suspended floor structure.

A1 - 23	Heavy / Point	Concrete-steel frames and panels
9.07 kN/m^2	T1	2012

1 – The building

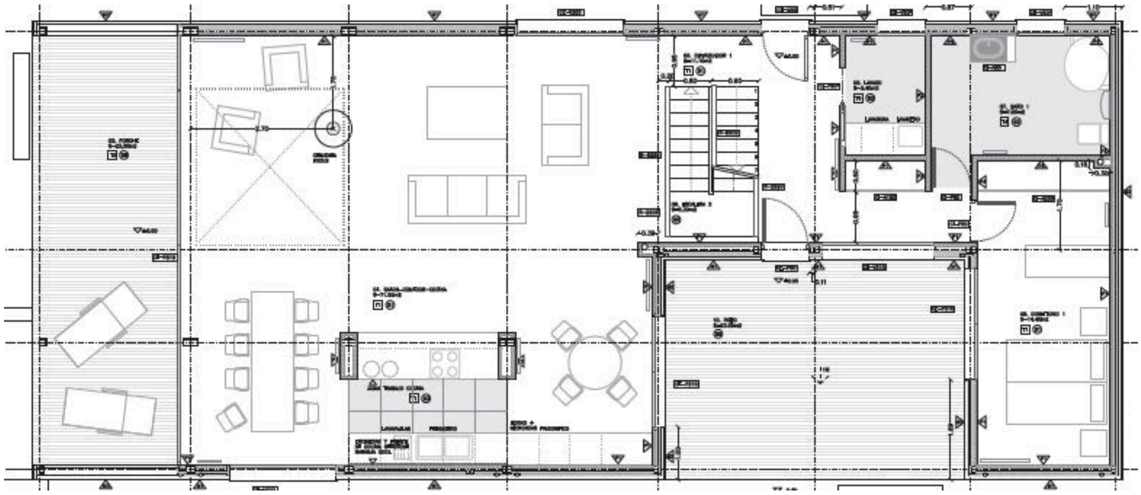


Figure 1. Ground floor plan.

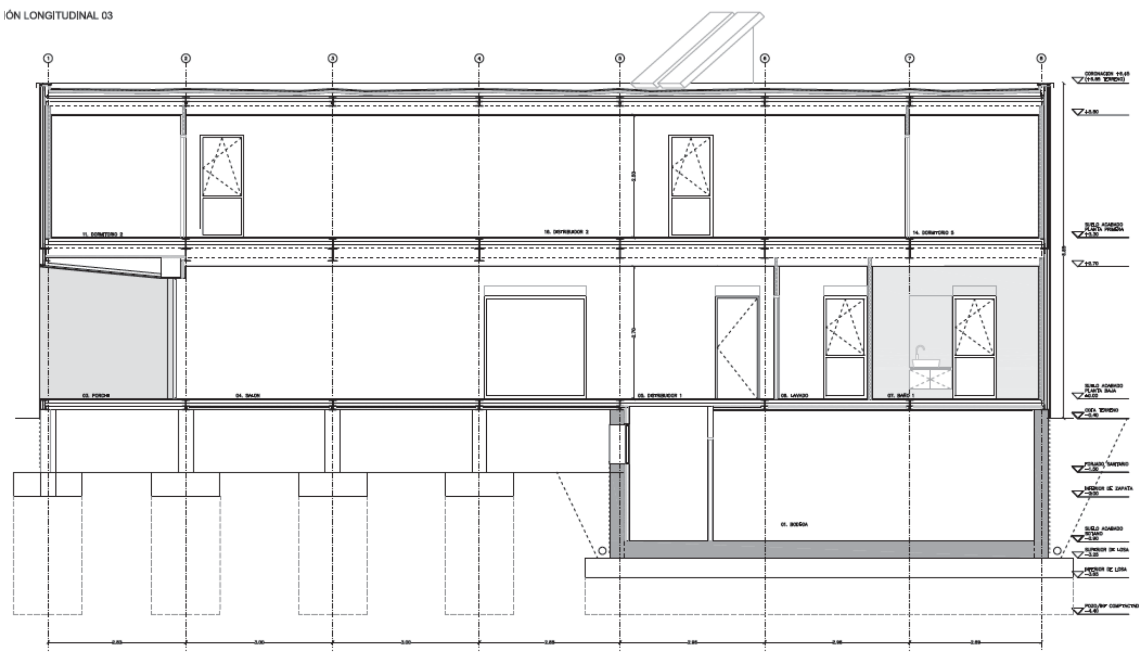


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.

2. Ground characteristics. The upper layers of the ground were not consolidated.

3 – The foundation

It consists of cast-in-place isolated footings over drilled shafts, cast-in-place tie beams and a ground slab. Modules are placed over metal plates, placed over concrete block walls and pillars.

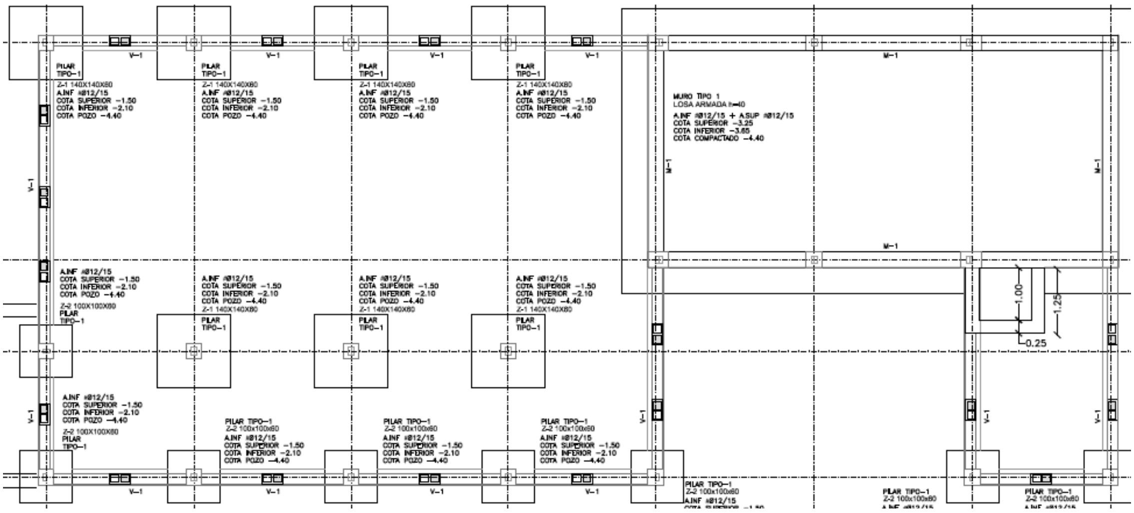


Figure 3. Foundation plan.

Figure 4. Modules are placed over metal plates, placed over concrete block walls and pillars.

A1 - 24	**Heavy / Distributed**	**Concrete panels**
7.99 kN/m^2	**T2**	**2012**

1 – The building

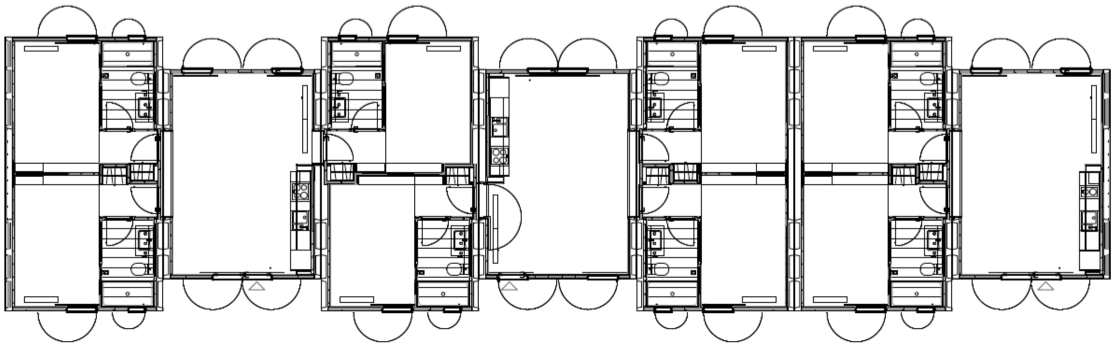


Figure 1. Ground floor plan.

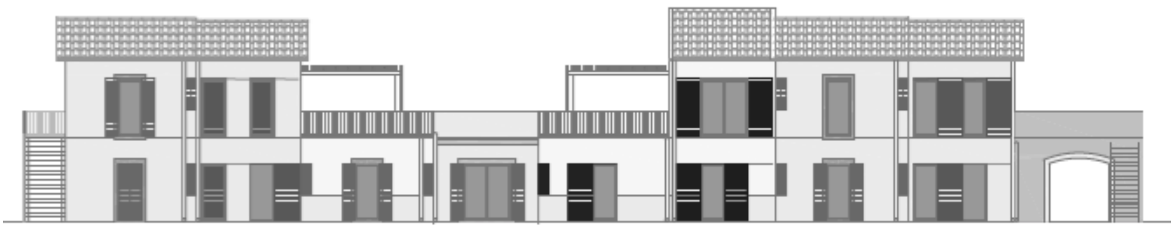


Figure 2. Elevation of this type of building. (There is no correspondence with the ground floor plan or the foundation plan)

2 – Foundation design factors

1. Initial price.
2. It was preferred to build them cast-in-place with own personnel. The construction company wanted to build the foundation.

3 – The foundation

The foundation consists of cast-in-place strip footings and tie beams. Connector holes were made by metal cylinders placed into the strip footings before concreting.

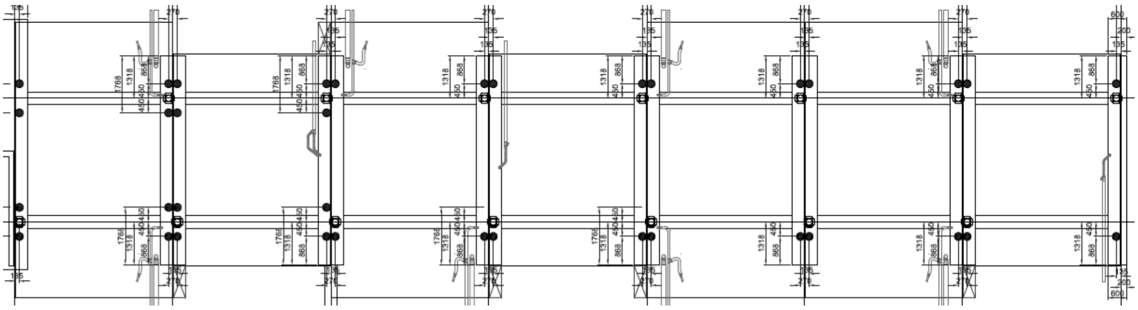


Figure 3. Foundation plan.

Figure 4. Metal template to position metal cylinders inside strip footings. Once the foundation was concreted, module connectors were placed inside holes.

4 – Comments

Another metal template was used to position module connectors inside foundation holes (metal cylinders). This mechanism set out the location of six connectors inside foundation holes at one time.

Comparing to previous foundations of this company, it was faster to set out connectors and working groups did not overlap.

Figure 5. This mechanism set out the location of six connectors at one time.

A1 - 25	**Light / Distributed**	**Steel-timber frames and panels**
1.96 kN/m^2	**T2**	**2012**

1 – The building

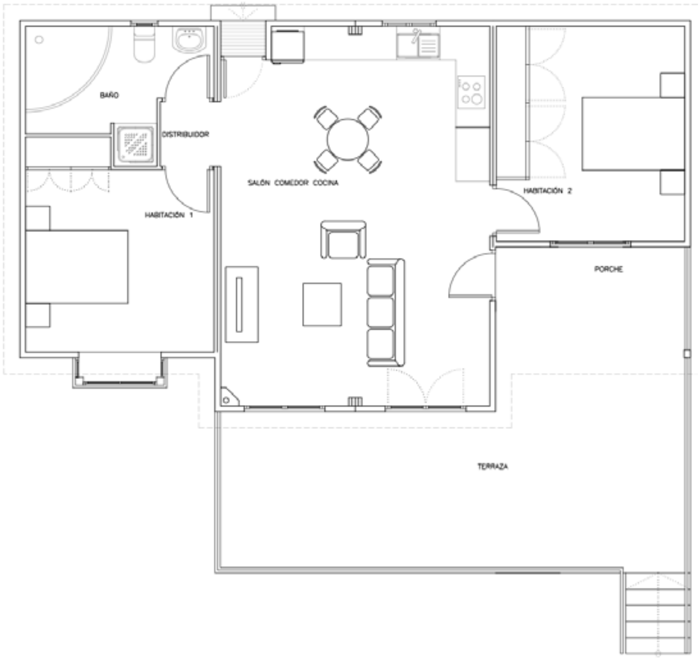


Figure 1. Ground floor plan.

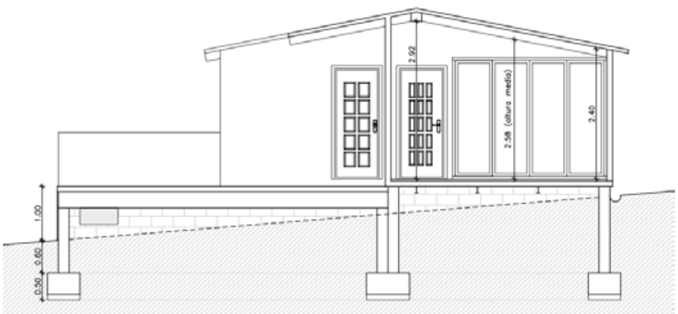


Figure 2. Cross section.

2 – Foundation design factors

1. Initial price.
2. Comfort. "*It is easy to do it*".

3 – The foundation

The foundation consists of cast-in-place strip footings. Modules are placed over concrete block walls to form the suspended floor.

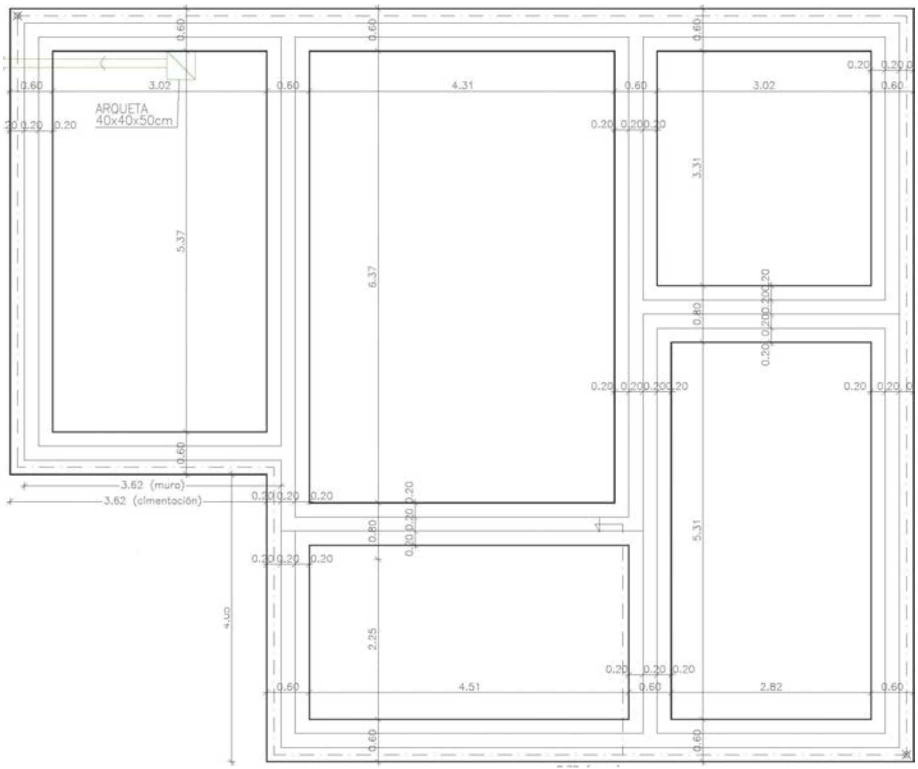


Figure 3. Foundation plan.

Figure 4. Modules are placed over concrete block walls to form the suspended floor.

A1 - 26	**Light / Point**	**Steel panels**
2.73 kN/m^2	**T2**	**2013**

1 – The building

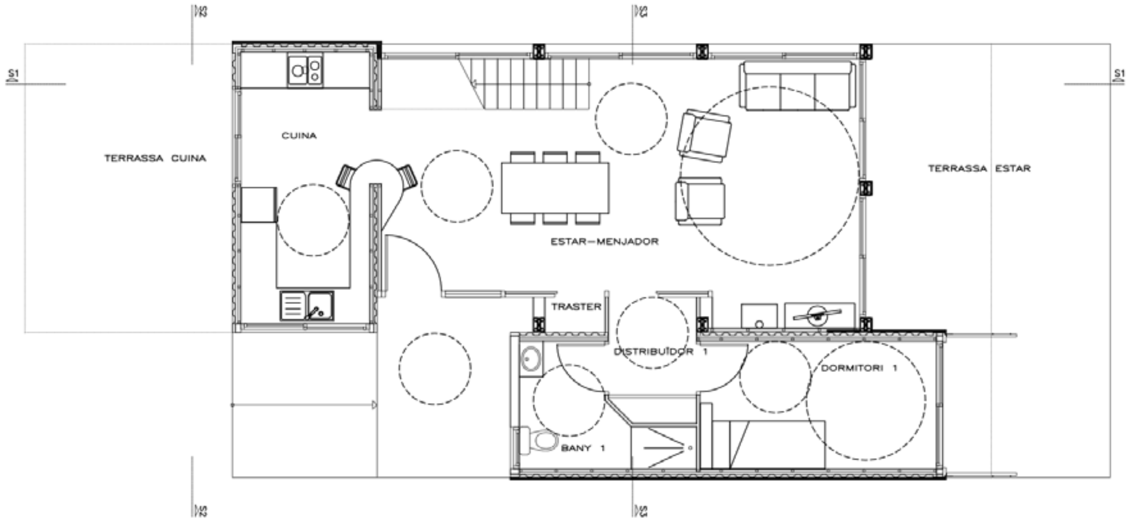


Figure 1. Ground floor plan.

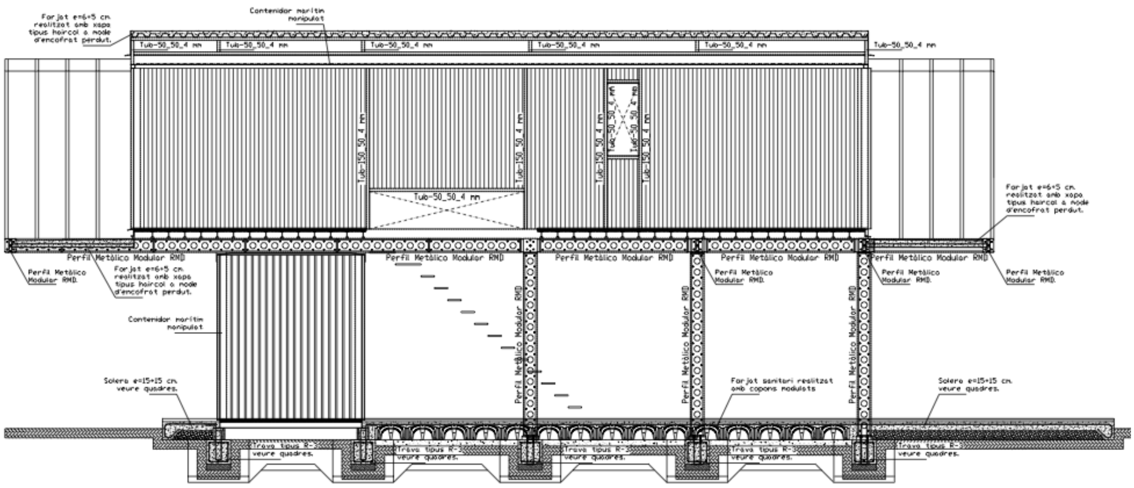


Figure 2. Longitudinal section

2 – Foundation design factors

1. Initial price.

3 – The foundation

The foundation consists of cast-in-place isolated footings and tie beams. Modules are placed over concrete block walls to form the suspended floor.

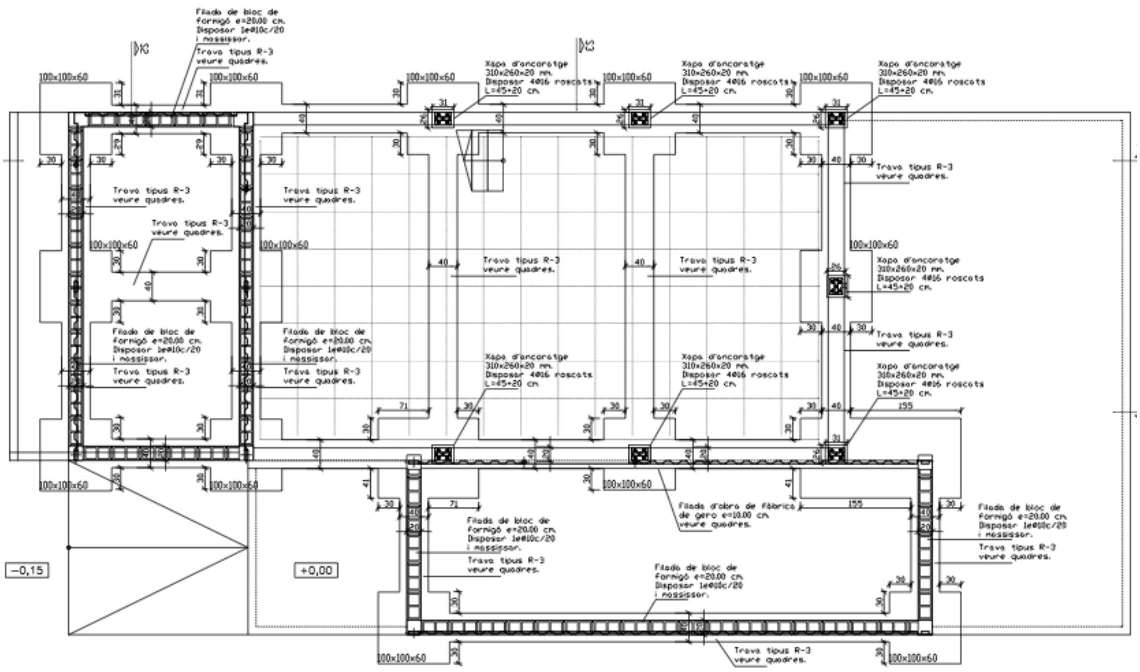


Figure 3. Foundation plan.

Figure 4. Cast-in-place strip footings and tie beams.

A1 - 27	**Light / Point**	**Steel-timber frames**
2.61 kN/m^2	**T1**	**2013**

1 – The building

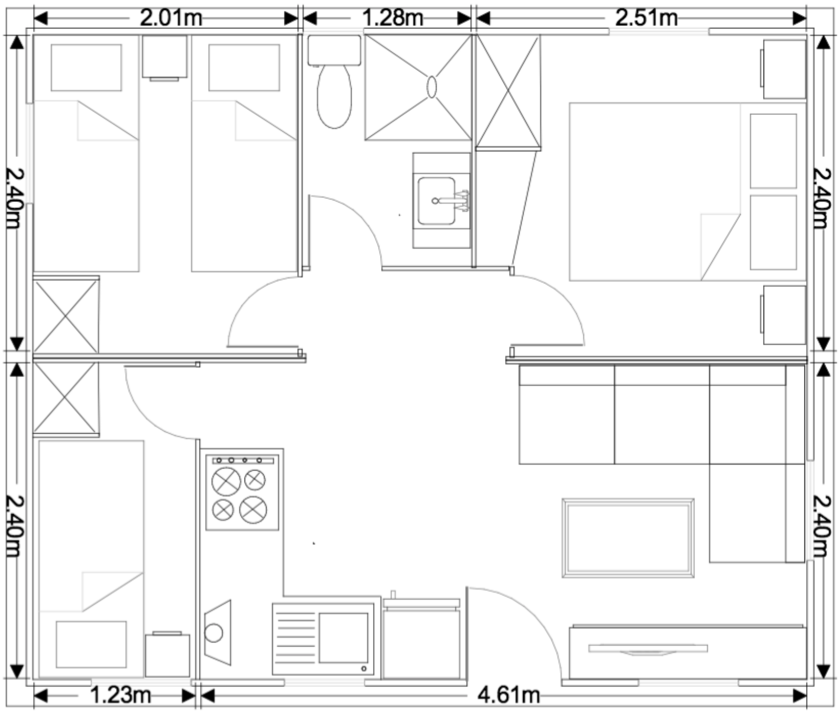


Figure 1. Ground floor plan.

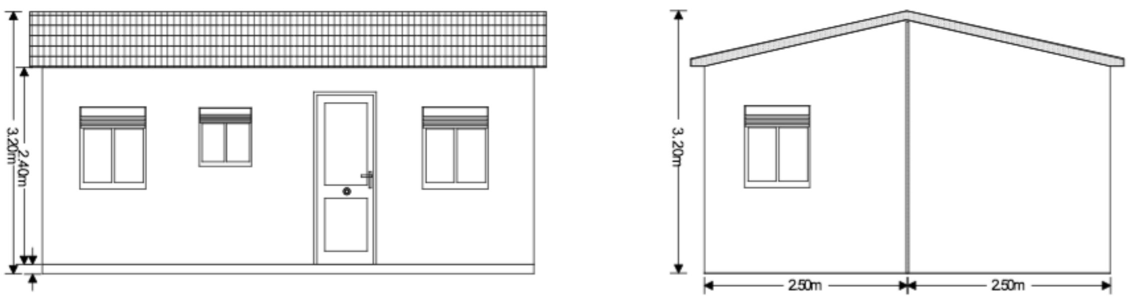


Figure 2. Elevations.

2 – Foundation design factors

1. Initial price.
2. Ground characteristics:
    a. The presence of water.
    b. The low consistency of the ground.

3 – The foundation

The foundation consists of a ground slab of 35 cm. The house lays over concrete blocks, placed over the ground slab.

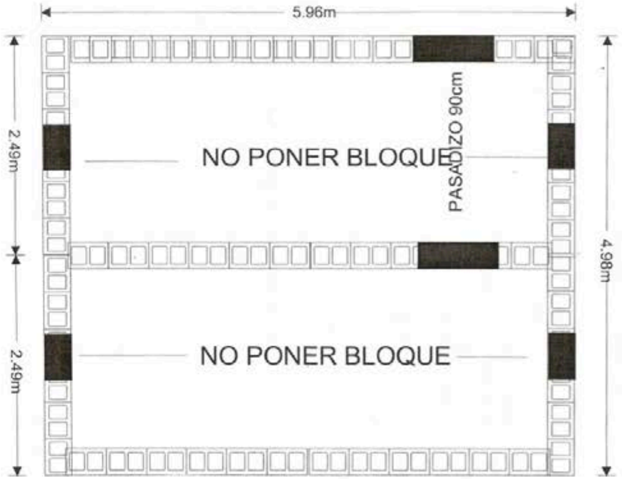


Figure 3. The house rests on concrete block walls over the foundation.

Figure 4. Half house is placed in the right position. It rests on concrete blocks.

A1 - 28	**Light / Distributed**	**Steel-timber frames and panels**
1.96 kN/m^2	**T2**	**2013**

1 – The building

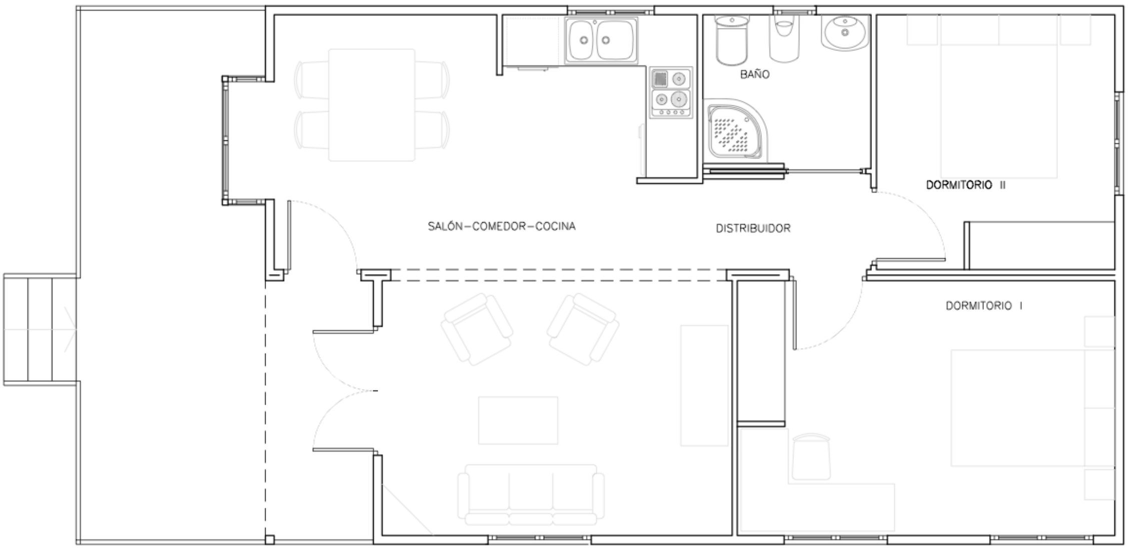


Figure 1. Ground floor plan.

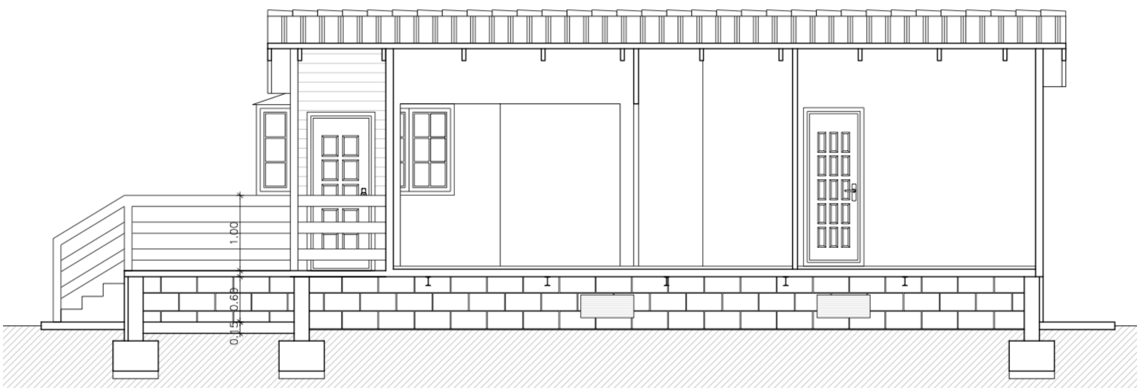


Figure 2. Longitudinal section.

2 – Foundation design factors

1. Initial price.
2. Comfort. '*It is easy to do it*'.

3 – The foundation

The foundation consists of cast-in-place strip footings. The house lays over concrete filled block walls placed over the foundation.

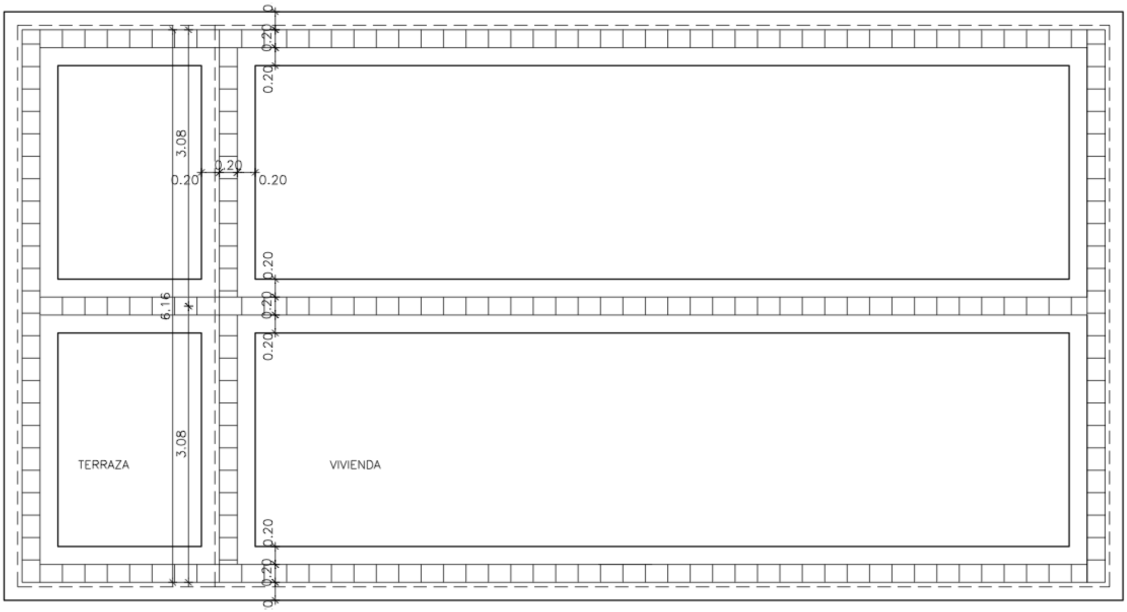


Figure 3. Foundation plan.

A1 - 29	**Light / Distributed**	**Steel-timber frames and panels**
1.04 kN/m^2	**T2**	**2014**

1 – The building

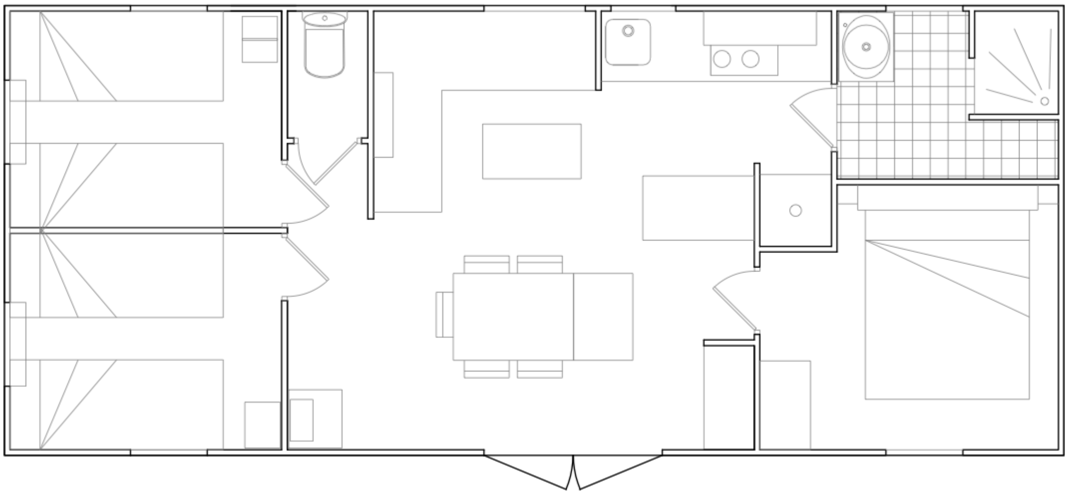


Figure 1. Ground floor plan.

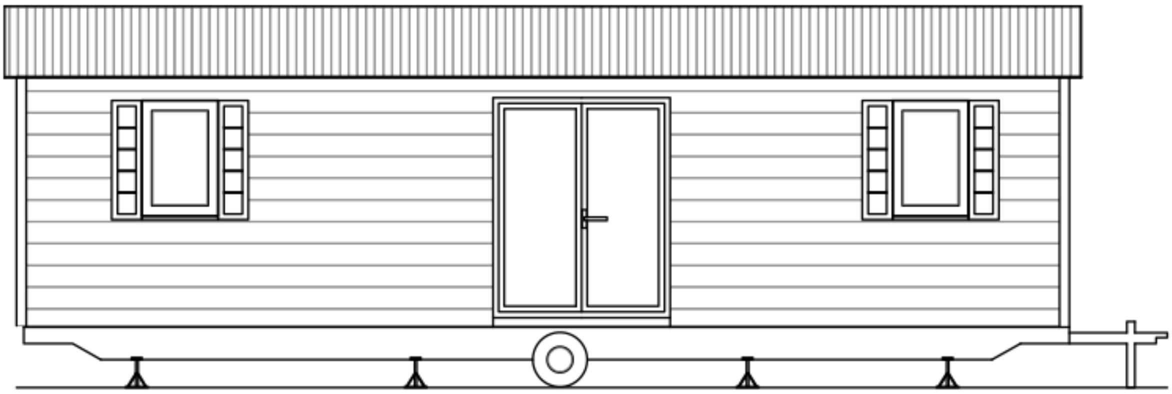


Figure 2. Elevation.

2 – Foundation design factors

1. Initial price.
2. Comfort. "*It is easy to do it*".

3 – The foundation

The foundation consists of cast-in-place ground slab. The house is placed over metal piers.

Figure 3. Metal piers support the mobile home over the cast-in-place ground slab.

A1 - 30	**Heavy / Distributed**	**Concrete panels**
13.83 kN/m^2	**T2**	**2014**

1 – The building

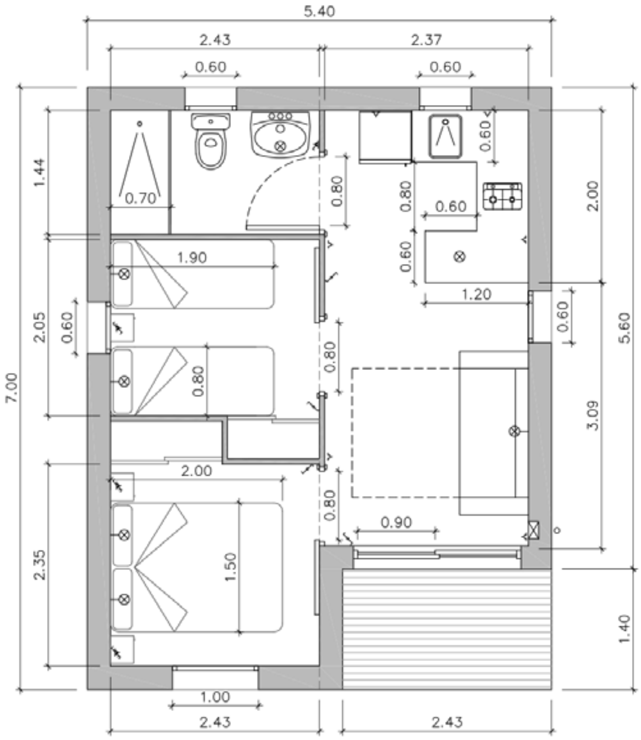


Figure 1. Ground floor plan.

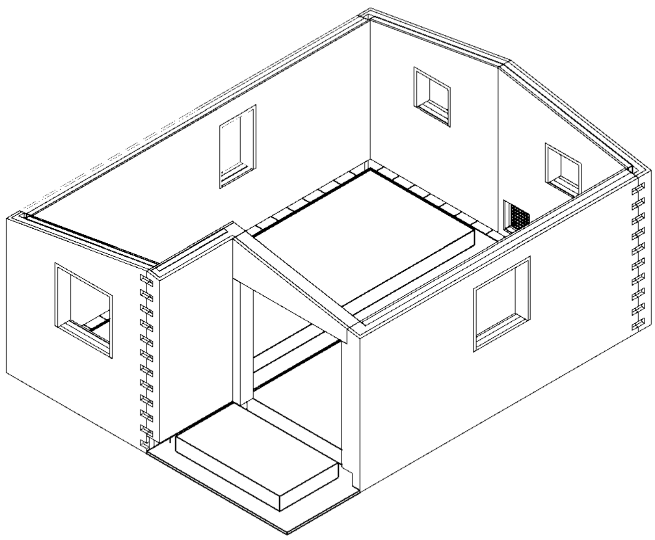


Figure 2. Axonometry perspective.

2 – Foundation design factors

1. Initial price.
2. Comfort. “*It is easy to do it”.*

3 – The foundation

The foundation consists of a cast-in-place perimeter strip footing.

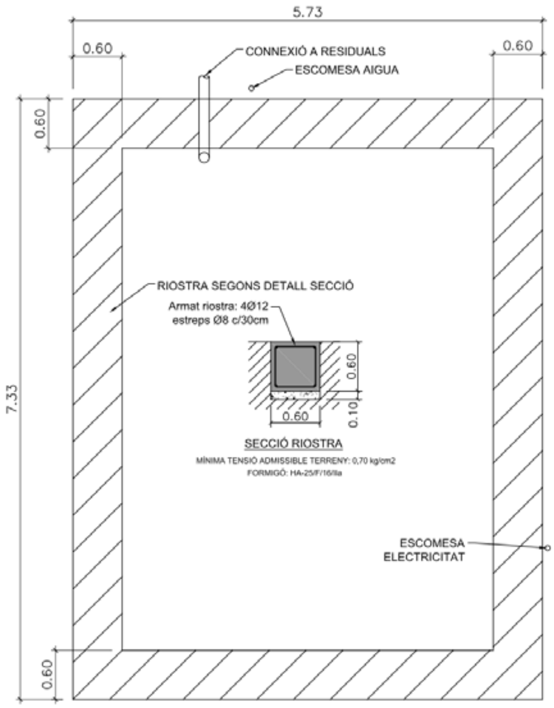


Figure 3. Foundation plan.

Figure 4. Foundation image.

2. Foundations

Precast concrete pile — A2 - 1. 1. 1

1

Description

It is a monolitic piece of precast reinforced concrete. Its section is round, octogonal or chamfered square. It is driven into the ground.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN)	Fc = 824 - 2393
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	X = Y = 235 - 400 L = 5000 - 12000[2]
Own weight (kN)	6.90 - 48[3]
Dimensional tolerances (mm)	H = 100
Phases of construction	1.Cleaning the site, leveling the ground and creating a platform to place the equipment 2.Setting out piles 3.Driving piles 4.Cutting down the heads of piles and remove them
Machinery required	A free-fall equipment, using a hammer raised either by a simple cable system or an hydraulic pile driver
Advantages	They can be used as end-bearing piles or friction piles. Fast. Clean. Compact the ground and reduce the amount of waste produced by excavation. Sections of piles and caps are smaller comparing with sections of cast-in-place concrete piles. They can be spliced to achieve greater lengths. Relatively inexpensive. They can be redriven if they are affected by ground heave. High load capacity
Disadvantages	High initial cost. Precast piles required specialized pile driving equipment and workers.They can not penetrate obstructions or desiccated clays. There can be problems with noise and vibration. Relatively difficult to cut. They can be damaged during driving. Piles can not be removed.They can not be driven with very large diameters or in condition of limited headroom

More information	The pile may be equipped with a pile shoe, which protects the pile tip during hard driving. Precast piles can have corrugations to help withstand tensile stresses.The head tip can have a drill to explore some meters below the tip and the subsequent injection of cement or mortar to fill holes or depressions
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / 1 / **>1**
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / No problems near buildings / **Problems near buildings**
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	**No** / No problems with precautions / Yes
Possible other problems	Damage or deviation of the pile
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figures 1. It is not always necessary to buid caps. The floor is mounted over precast pile caps.[4]

[1] http://fendermro.files.wordpress.com/2012/04/precast-reinforced-concrete-driven-pile-152836.jpg Accessed: 20/10/2015

[2] Piles can be spliced and achieve deeps bigger than 50 meters

[3] Calculated for piles: 0,235 x 0,235 x 5 m and 0,40 x 0,40 x 12 m

[4] http://www.theengineer.co.uk/system-first/1006268.article Accessed: 20/10/2015

Ground anchor	A2 - 1. 1. 2
	**Description** It consist of a rod driven into the ground designed to stabilize structures. There are different shapes and sizes.

1

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Steel
Allowable load (kN)	Ft = 2.2 - 26.7
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	X = 13 - 19 Y = 102 - 178 Z = 380 - 1500
Own weight (kN)	0.0057 - 0.049
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Setting out ground anchors 2.Driving or screwing the anchors
Machinery required	An auto driving hammer, a hammer or a ground screw driver
Advantages	Fast. Lightweight installation equipment. Suitable for cramped and limited-access conditions. Sustain load immediately after installation. Ideal for temporary structures
Disadvantages	Limitated loads and grounds
More information	There are different types and sizes of ground anchors available to suit different soil conditions. When there is presence of water in the ground, the ground anchor must be proctected against corrosion by means of a protection system or treatment

Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / **Electricity**
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Devitation of the anchor

Reusable No / Partly / Depends on the case / **Yes**

Images

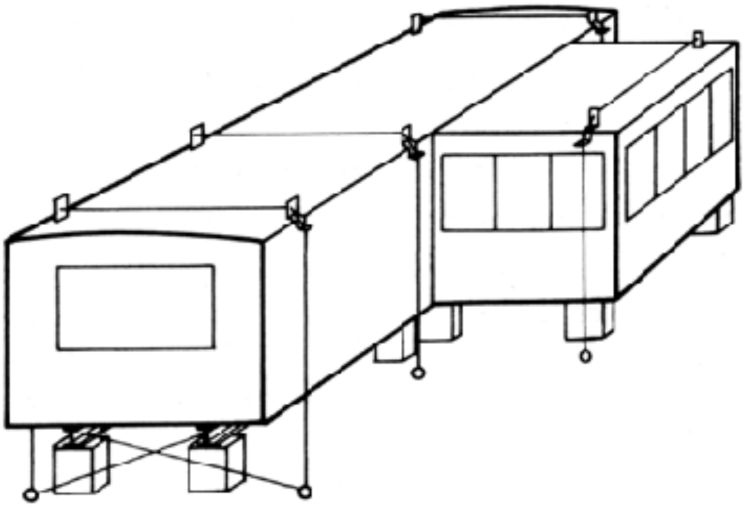


Figure 1. Over-the-top ties connected to same anchors as frame ties.[2]

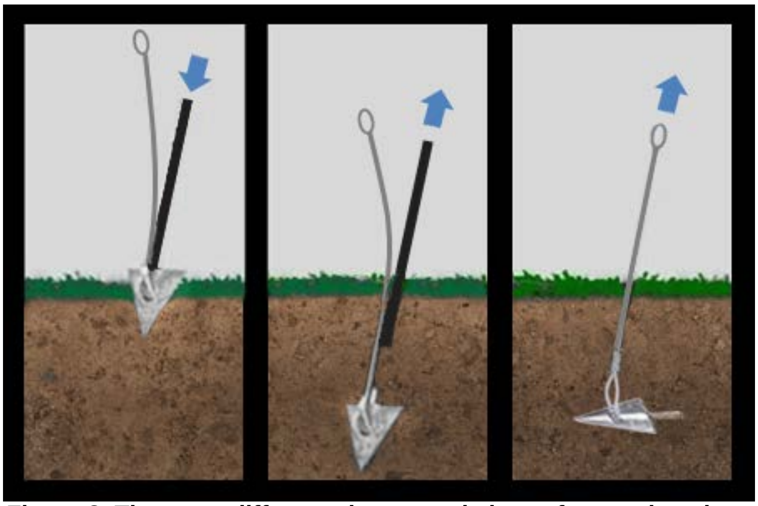


Figure 2. There are different shapes and sizes of ground anchors. Installation of a arrowhead ground anchor.[3]

[1] http://www.rapidanchor.com/The_Wombat.htm Accessed: 20/10/2015

[2] http://archive.nrc-cnrc.gc.ca/eng/ibp/irc/cbd/building-digest-188.html Accessed: 20/10/2015

[3] http://www.americanea.com/Cabled_into_the_ground.html Accessed: 20/10/2015

Screw pile (1) A2 - 1. 1. 3

Description

It is a giant galvanized steel screw that is screwed into the ground until the desired bearing capacity is achieved. It has not helix.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Galvanized steel
Allowable load (kN)	Fc = 2.5 - 175 / Ft = 1.70 - 115
Type of load	Point load
Type of soil	Soft, medium and hard

Common dimensions (mm)	Ø = 66 - 220 L = 550 - 3500
Own weight (kN)	0.02 - 0.24
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out screw piles (Pre-drilling holes in a rocky soil) 3.Screwing screws into the ground
Machinery required	A screw pile driver. (It has a compressor to drill rocky grounds)
Advantages	Fast. Lightweight installation equipment. Suitable for cramped and limited-access conditions. Sustain load immediately after installation. Ideal for temporary structures. Resistant to frost heave. They can be self-testing when they are installed. Sustainable and environmentally friendly. Foundations are suitable for retrofitting or repositioning. They can be spliced to achieve greater lengths
Disadvantages	High initial cost. Lack of acceptance in the engineering community. When there is presence of water in the ground, the screw pile must be proctected against corrosion by means of a protection system or treatment
More information	They can be spliced to achieve greater lengths
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / **1** / >1
Resources on the site	**None** / Water / **Electricity**[1]
Noise	No / Without ear protection / **With ear protection**
Vibrations	**No** / No problems near buildings / Problems near buildings

Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Damage or deviation of the screw pile
Reusable	No / Partly / **Yes**

Images

Figure 1. Driving the screw pile into the ground.

[1] The screw pile driver can be run on both diesel and electricity.

Screw pile (2) A2 - 1. 1. 4

Description

It is a steel pile that has one or more helixes and it is screwed into the ground until the desired bearing capacity is achieved.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Galvanized steel
Allowable load (kN)	Fc = Ft = 30.2 - 295.3
Type of load	Point load
Type of soil	Soft and medium

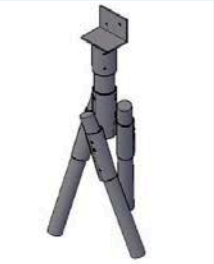
Common dimensions (mm)	Ø = 48 - 168 L = 2130 - 3200
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out screw piles 3.(Pre-drilling holes in a rocky soil) 4.Screwing piles into the ground
Machinery required	A ground screw driver
Advantages	Fast. Lightweight installation equipment. Suitable for cramped and limited-access conditions. Sustain load immediately after installation. Ideal for temporary structures. Resistant to frost heave. They can be self-testing when they are installed. Sustainable and environmentally friendly. Foundations are suitable for retrofitting or repositioning.
Disadvantages	High initial cost. Lack of acceptance in the engineering community. When there is presence of water in the ground, the pile must be proctected against corrosion by means of a protection system or treatment
More information	They can be used as a geothermal piles to recover the geothermal energy stored in the soil. A sleeve of heavy-duty polyethylene can be installed around the pier while the pile is screwed into te soil in order to remain stable despite movement caused by periods of freeze, thaw or dought. They can be spliced to achieve greater lengths
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**

Skilled workers required	0 / **1** / >1
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Damage or deviation of the screw pile. Screw pile plates can be substantially damaged
Reusable	No / Partly / **Yes**

Images

Figure 1. Screw pile foundation for a timber panel house.

Group of micropiles (1) — A2 - 1. 1. 5



Description

It consists of a steel footing and steel micropiles which are jobsite-installed through holes and driven into the soil.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Galvanized steel
Allowable load (kN)	Fc =Ft = 5 - 50
Type of load	Point loads
Type of soil	Soft and medium

Common dimensions (mm)	L = 350 - 1500
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out the anchor 3.Aligning the anchor 3.Driving the micropiles 4.Fixing the micropiles and riser. 7. Attaching the top
Machinery required	An auto driving hammer and screw driver
Advantages	Fast. Lightweight installation equipment. Suitable for cramped and limited-access conditions. Sustain load immediately after installation. Ideal for temporary structures. Resistant to frost heave. Sustainable and environmentally friendly
Disadvantages	Information not provided
More information	It is important to check for underground utilities. If there are an electrical lines in the area, de-energize the power source prior to installing micropiles. It is important to respect the horizontal micropile distance. Bolts and pipes can be stainless for certain projects. They are normally used in light buildings. Depending on the elevation of the structure bracing may be required
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	**0** / 1 / >1
Resources on the site	None / Water / **Electricity**
Noise	No / **Without ear protection** / With ear protection
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes

Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Information not provided
Reusable	No / Partly / Depends on the case / **Yes**

Images

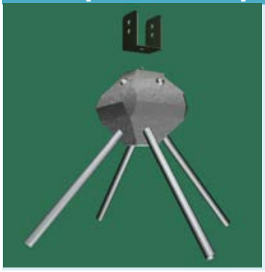
Figure 1. Micropiles house foundation.[1]

Videos

http://www.mega-anchor.com/#!mega-anchor-videos/cdvr Accessed: 20/10/15

[1] http://static.wixstatic.com/media/719799_4b7e5e1bbe9255d0da406be4a5b0cd81.jpg Accessed: 20/10/2015

Group of micropiles (2) A2 - 1. 1. 6



1

Description

It consists of a factory-fabricated, diamond-shaped concrete pier that has a steel anchor bolt precast into the center of the top of the pier; and steel micropiles which are jobsite-installed through holes precast in each pier, and driven into the soil.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Reinforced air-entrained concrete and galvanized steel
Allowable load (kN)	Fc = 12 - 53 kN
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	Concrete piers: X = 254 Y = 254 Z = 279 Steel micropiles: Ø = 33.4 - 60.32 L = 889 - 2667 Precast steel anchor bolt: Ø = 15.88 - 19.05
Own weight (kN)	0.22 - 0.93
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out piers 3.Digging out holes with a conical shape 4.Placing concrete piers by hand into position 5.The bearing micropiles must be slid through the holes in the pier, and driven into the soil 6.The exposed end of the bearing micropiles must then be capped and sealed by bolts
Machinery required	An auto driving hammer
Advantages	Fast. Lightweight installation equipment. Suitable for cramped and limited-access conditions. Sustain load immediately after installation. Ideal for temporary structures. Resistant to frost heave. Sustainable and environmentally friendly
Disadvantages	Limitated loads and soils
More information	It is important to check for underground utilities. If there are an electrical lines in the area, de-energize the power source prior to installing the footing. it is important to respect the horizontal micropile distance. Bolts and micropiles can be stainless for certain projects
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	None / Water **/ Electricity**

Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Information not provided
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. The bearing micropiles must be slid through the holes in the pier, and driven into the soil with an auto driving hammer.[2]

[1] http://www.pinfoundations.com/images/res/carl-bracket.jpg Accessed: 20/10/2015

[2] http://www.transmaterial.net/diamond-pier/ Accessed: 20/10/2015

H-pile — A2 - 1. 1. 7

1

Description

It consist of a pile with a H-shaped. Ideal solution when foundations are required for complex structures or where the ground conditions are difficult.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Steel
Allowable load (kN)	Fc max = 3000
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	X = Y = 200 - 360
Own weight (kN/m)	0.42 - 1.77
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site, leveling the ground and creating a platform to place the equipment 2.Setting out piles 3.Driving piles 4.(Cutting or splice them)
Machinery required	A free-fall equipment, using a hammer raised either by a simple cable system or an hydraulic pile driver
Advantages	Fast. Clean. They can be spliced to achieve greater lengths. High load capacity. Since H-piles do not cause large soil displacements, they are useful in urban areas or adjacent to structures where heave of the surrounding ground may cause problems. H-piles can be driving in large groups without the need of predrilling. They can be used to resist tensile as well as compressive loads and they can be designed for bending. Reduce the risk of excessive vibrations.
Disadvantages	H-section pile tend to bend on the weak axis during driving. Thus if piles are driven to a large depths, a considerable curvature may result. They may not achieve satisfactory resistance in loose sandy soils and may need to be driven to a dense sand stratum or other resistant layers.

More information	A wide range of pile sizes is available, with different grades of steel. H-piles may be strengthened by welding stiffening plates on to the pile toe, which facilitates punching through thin layers of rock or boulders. Special types of H-section piles can be manufactured, which are welded or coupled together to increase their end bearing area or resistance to lateral loads. They are also used in conjunction with sheet piles to add lateral stiffness and bending resistance where loads exceed the capacity of sheet piles alone.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / 1 / **>1**
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	**No** / No problems with precautions / Yes
Possible other problems	Damage or deviation of the pile
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figures 1. The pile allows H-piles to nest together making site storage easy.[2]

[1] http://www.14thstviaductreplacement.com/data/images2/steel_h-piles_for_new_foundations.jpg Accessed: 20/10/2015

[2] http://img.diytrade.com/cdimg/1495285/22791754/0/1312536891/steel_H-pile.jpg Accessed: 20/10/2015

Timber pile A2 - 1. 1. 8

1

Description

It is probably the oldest pile foundation method and it has been used for many centuries.Its section is normally round. It can be pointed to facilitate its driving into the ground.

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Timber (Normally from douglas fir, pitch pine, oak, larch and western red cedar)
Allowable load (kN)	Fc = 75 - 350
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	Tip Ø = 120 - 230 Head Ø = 300 - 550 L = 5000 - 20000
Own weight (kN)	4 - 100
Dimensional tolerances	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out timber piles 3.Driving piles 4.(Pile heads can be sawed and removed)
Machinery required	Pile driver
Advantages	Easy to handle. Relatively inexpensive where timber is plentiful. Renewable resource. Easy to drive. Used as friction or end bearing pile. Bellow ground-water level they are resistant to fungal decay and have an almost indefinite life. It resists attack from acidic soils. Can be easily installed at close spacing. Unaffected by stray electrical currents. Ease of delivery to jobsite
Disadvantages	Piles will rot above the groundwater level. Have a limited bearing capacity. Can easily be damaged during driving by stones and boulders. Piles are difficult to splice and are attacked by marine borers in salt water. Low axial capacity.
More information	The timber should be straight-grained and free from defects which could impair its strength and durability. Heads of timber piles can be protected against splitting and brooming during driving by means of a mild steel hoop or a cast steel helmet.The life of timber piles can be considerably increased by treating it with creosote, oil-borne preservatives, or salts. At the building place they are cut at the accurate length.
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the	0 / 0-50mm / **> 50mm**

Skilled workers required	0 / **1** / >1
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	**No** / No problems with precautions / Yes
Possible other problems	Damage or deviation of the pile.
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. Timber pile driving.[2]

[1] http://www.maritimejournal.com/__data/assets/image/0007/148687/01_PHMC_Rodney.jpg Accessed: 20/10/2015

[2] http://www.sawrey.co.nz/assets/foundation/driven%20timber%20piles.jpg Accessed: 20/10/2015

Composite pile A2 - 1. 1. 9

[1]

Description

A pile consisting of more than one member or material, but designed to act as one unit. They normally consists of a timber or H-steel pile and a precast concrete pile at the top

Characteristics

Type of foundation	Deep foundation
Foundation	Prefabricated
Material	Concrete, steel, and/or timber
Allowable load (kN)	Information not provided
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	Information not provided
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site, leveling the ground and creating a platform to place the equipment 2.Setting out piles 3.Driving piles 4.Cutting down the heads of piles and remove them
Machinery required	A free-fall equipment, using a hammer raised either by a simple cable system or an hydraulic pile driver
Advantages	They can be used as end-bearing piles or friction piles. They can be spliced to achieve greater lengths. High load capacity. These prove economical as they permit the utilization of the great corrosion resistance property of one material with the cheapness or strength of the other
Disadvantages	There can be problems with noise and vibration
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / 1 / **>1**
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / No problems near buildings / **Problems near buildings**
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	**No** / No problems with precautions / Yes
Possible other problems	Damage or deviation of the pile
Reusable	**No** / Partly / Depends on the case / Yes

[1] http://slideplayer.us/slide/1566591/ Accessed: 20/10/2015

Precast isolated footing — A2 - 1. 2. 1

Description

It is a prismatic concrete piece that normally has a hole to place the pillar. The joint between the pillar and the isolated footing is normally concreted. Precast isolated footings are normally braced by concrete tie beams.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN)	Fc = 500 - 1100 kN
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	X = 1600 - 2400 Y = 1600 - 2400 Z = 1000
Own weight (kN)	30 - 65
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out footings 3.Digging out holes 4.Land-levelling ditches with gravel and cleaning concrete 5.Placing isolated footings by crane into position 6.Placing precast tie beams or building them 7.Concreting joints and backfilling works.
Machinery required	A backhoe excavator, a crane and a concrete mixer truck.
Advantages	Reduction of time. It is possible to reposition the footing before concreting works. There is a minimum interference between working groups.
Disadvantages	Limitated loads and soils.
More information	Tie beams can also be precast but the union with isolated footing is built on-site.They are normally used in industrial buildings.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	0 / 1 / **>1**
Resources on the site	Information not provided
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes

Reusable No / Partly / Depends on the case / **Yes**

Images

Figure 1. Precast isolated footing with a precast tie beam.

Concrete block — A2 - 1. 2. 2

1

Description

It is a concrete brick that can have different strenghts, sizes and shapes. Hollow or solid. Installed variably on-site. A concrete or steel pier may be placed above the block.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Non-reinforced concrete
Allowable load (kN)	50 - 300
Type of load	Point load
Type of soil	Medium and hard

Common dimensions (mm)	X = 440 Y = 215 Z = 75 - 190
Own weight (kN)	0.142 - 0.358
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out blocks 3.Digging out holes 4.Land-levelling holes with a bed of gravel or unreinforced concrete 5.Placing blocks. Backfilling
Machinery required	None
Advantages	No speciallist skills required. Lightweight. Easy and quick to install. Re-position and re-useable. 100 % recycleable.
Disadvantages	Limitated loads and soils
More information	There are different shapes and sizes.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	**No** / No problems with precautions / Yes
Reusable	No / Partly / **Depends on the case** / Yes

Images

Figures 1 and 2. Concrete block foundation for a studio.[2]

[1] http://www.wdlconcrete.co.uk/images/blockmain-medium.jpg Accessed: 20/10/2015

[2] http://www.settstudio.com/ Accessed: 20/10/2015

Precast concrete pad **A2 - 1. 2. 3**


1

Description
It consists of a load bearing grid filled with pea gravel, a base stone (optional), a top stone, one or more geotextiles and an adjustable bracket.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Recycled polyestyrene, fiber-reinforced concrete, steel and geotextile
Allowable load (kN)	Fc = 24.9 - 74.73
Type of load	Point load
Type of soil	Medium

Common dimensions (mm)	Load bearing grid: X = 500 Y = 1000 Z = 30 - 400 Base stone (optional): X = 450 Y = 450 Z = 50 Top stone: X = 330 Y = 330 Z = 90 - 120 Adjustable bracket: Z = 50
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out pads 3.Digging out holes 4. Fit the sub base membrane into each hole 5.Position the load bearing grid onto the membrane 6.Pour the pea gravel into the grid and level it out across the top surface 7.Fit the base stone over the grid 8.Temporarily fit the top stones and bracket assemblies and check the final alignment of the building base 9.Remove the top stones and bracket assemblies 10.Backfill (Lay a single layer of permeable membrane over the entire area of the building ground plan) 11.Place the top stones and brackets
Machinery required	None
Advantages	No speciallist skills required. Lightweight. Easy and quick to install. Re-position and re-useable. 100 % recycleable
Disadvantages	Limitated loads and soils

More information	In UK excavations are ususally 500 mm deep to get to stable ground and also get below the frost zone. With light loads an excavation of 200 mm is enough. They are normally used in garden offices and studios, log cabins, cricket pavilions, static caravans, timber frame buildings, decking and raised platforms.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. Concrete pad foundation.[2]

[1] http://www.swiftfoundations.co.uk/images/home/swift_plinth_image.jpg Accessed: 20/10/2015

[2] http://www.swiftfoundations.co.uk/swift_plinth.php Accessed: 20/10/2015

Plastic pad — A2 - 1. 2. 4

1

Description

It is made of recycled plastic and steel. It consists on a pad block one or more support blocks and a adjustable bracket. For modular housing and portable buildings.

Characteristics

Foundation	Shallow foundation Prefabricated
Material	Plastic and steel
Allowable load (kN)	Fc = 48 - 295
Type of load	Point load
Type of soil	Medium and hard

Common dimensions (mm)	Pad block: X = 450 Y = 450 Z = 50 Support block: X = 360 Y = 360 Z = 80 Adjustable bracket
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Compacting ground. 3.Setting out pads. 4. Fit pad blocks. 5. Fit support blocks and bracket. 6. Level the bracket.
Machinery required	None
Advantages	No speciallist skills required. Lightweight. Easy and quick to install. Re-position and re-useable. Manufactured from 100% recycled materials. It is possible to hire too. Zero landfills.
Disadvantages	Limitated loads and soils
More information	It is possible to combine some pads
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / **0-50mm** / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	Information not provided
Reusable	No / Partly / Depends on the case / **Yes**

Images

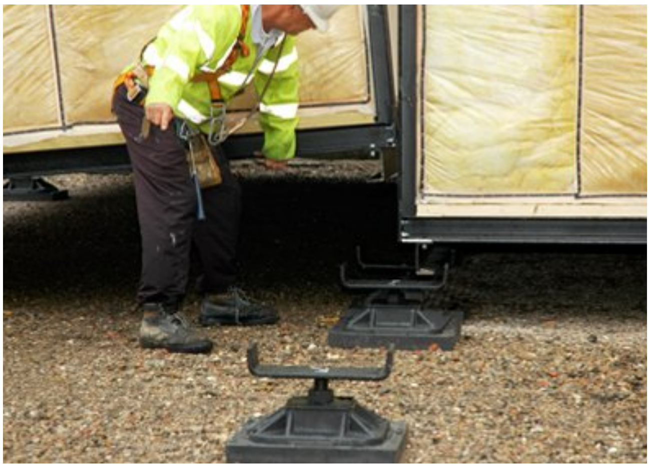


Figure 1. Plastic pads in a modular building.[2] Figure 2. Four pads combined.[3]

Videos

https://www.youtube.com/watch?v=8ZWDXDvuJk4 Accessed: 20/10/2015

[123] http://www.jackpad.co.uk/about/what-is-jackpad/ Accessed: 20/10/2015

Precast concrete pier (1) A2 - 1. 2. 5

1

Description

It consists of three reinforced concrete stackable components: base, risers and cap. It's necessary a stable base.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN)	Information not provided
Type of load	Point load
Type of soil	Medium

Common dimensions (mm)	Components: Z = 140 - 160 Pier: Z_{max} = 1150
Own weight (kN)	22 - 110
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out piers 3.Digging out holes 4.Land-levelling holes with a bed of granular stone or unreinforced concrete layer 5.Placing bases by hand into position 6.Stacking risers and cap components over the base 7.Backfilling
Machinery required	A backhoe excavator
Advantages	Easy and quick to install. Re-position and re-useable. No hazardous / toxic chemicals. Made with some recycled content. Uses regional materials.
Disadvantages	Limitated loads and soils.
More information	Spherical polyurethane pins can be used to connect caps with beams. They are normally used in precast board concrete boardwalks and elevated greenways.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	Information not provided
Resources on the site	Information not provided
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	Information not provided
Obstacles problems	Information not provided
Frost line problems	Information not provided
Possible other problems	Information not provided

Reusable No / Partly / Depends on the case / **Yes**

Images

Figure 1. Each base can be maneuvered by hand into position. Lifting inserts allow contractors to easily move these pieces around by hand.[2]

[1]http://www.permatrak.com/Portals/94143/images/precast%20concrete%20foundation%20pier%20components.jpg

Accessed: 20/10/2015

[2]http://permatrak.web9.hubspot.com/Portals/94143/images/hpim1713-resized-315.jpg Accessed: 20/10/2015

Precast concrete pier (2) — A2 - 1. 2. 6

[1]

Description

It consists on a precast reinforced concrete column with a large square base.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN)	70 - 205
Type of load	Point load
Type of soil	Medium

Common dimensions (mm)	X = Y = 570 - 635 Z = 1550 - 2140
Own weight (kN)	4 - 5.5
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out piers 3.Digging out holes 4.Land-levelling holes with a bed of granular stone or unreinforced concrete layer 5.Placing piers by crane into position 6. Backfilling holes
Machinery required	A backhoe excavator and a crane.
Advantages	No speciallist skills required. Re-position and re-useable.
Disadvantages	Limitated loads and soils. It is necessary a crane and a excavator.
More information	They are normally used in porches and decks.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	Information not provided
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	No / Partly / Depends on the case / **Yes**

[1] http://www.whitesprecast.com/products.html Accessed: 20/10/2015

Metal pier A2 - 1. 2. 7

Description
It is a metallic light foundation. It normally has an adjustable bracket and it is used in mobile homes and caravans.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Steel
Allowable load (kN)	Fc = 40 - 50
Type of load	Point load
Type of soil	Hard

Common dimensions (mm)	X - Y = 200 - 300 Z = 150 - 400
Own weight (kN)	0.098 - 0.0196
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site (Compact the ground) 2.Setting out piers 3.Placing piers. 4. Adjusting brackets in high
Machinery required	None
Advantages	No speciallist skills required. Lightweight. Easy and quick to install. Re-position and re-useable. Cheap.
Disadvantages	Limitated loads and soils
More information	It is possible to compensate horizontal forces by means of a bracing system. The base must be stable and flat. Steel must be protected

Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. Metal pier over a concrete ground slab.

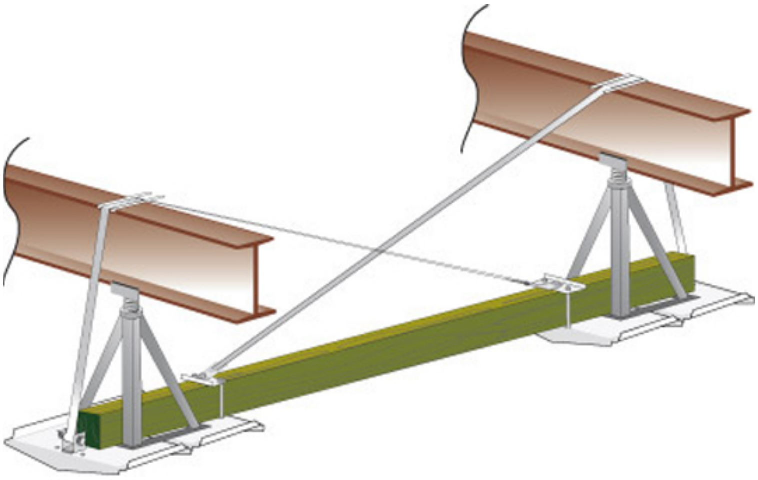


Figure 2. It is possible to compensate horizontal forces by means of a bracing system.[1]

[1] http://www.cusa-dds.net/seed/?tag=foundation Accessed: 20/10/2015

Precast strip footing / ground beam (1) A2 - 1. 2. 8

Description

It is a monolitic piece of reinforced concrete of square or T section. They are normally braced by precast tie beams.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN/m)	Fc = 25 - 250
Type of load	Distributed load
Type of soil	Soft and medium

Common dimensions (mm)	X = 500 - 2000 Y = 1000 - 12000 Z = 500 - 750
Own weight (kN)	6.5 - 101.21
Dimensional tolerances (mm)	V = 20 / H = 10
Phases of construction	1.Cleaning the site 2.Compact the ground 3.Setting out footings (Digging out ditches) 4.Placing footings/beams 4.Sealing joints with mortar (Backfilling)
Machinery required	A crane and a mortar mixer
Advantages	Fast. The quality of concrete can be checked. Less dependent on weather conditions. They can be used in contaminated soil. Better working conditions for workers.They have set out facilities. No specialist skills required
Disadvantages	Low-rise buildings. Not suitable for all types of soils, only for good bearing capacity soils
More information	Unions are sealed with mortar. If it is necessary, the soil can be improved by compacting it with a vibrating machine. Soil resistance is controlled (> 5 N/mm^2). Can be installed with or without piles
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	0 / 1 / **>1**
Resources on the site	None / **Water /** Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes

Reusable No / Partly / Depends on the case / **Yes**

Images

Figure 1. Joints are sealed with mortar. Tie beams have already holes for pipes.

[1] Calculated for a strip footing of 1 and 12 meters

Precast strip footing / ground beam (2) A2 - 1. 2. 9

1

Description

It is a monolitic piece of reinforced concrete of square section that it is post-tensionated on the site.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete and steel cable
Allowable load (kN/m)	$Fc_{max} = 50$
Type of load	Distributed load
Type of soil	Soft, medium and hard

Common dimensions (mm)	X = 330 - 450 Y = 400 Z = 1000 - 12000
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning and leveling the ground 2. Setting out footings/beams 3.Placing precast strip footings/beams 4.A bitumen impregnated foam-board is placed between footings/beams. 5.A steel cable is threaded through the ducting cast into the strip footings/beams. 6.Cables are tensioned using a hydraulic jack. 7.The excess cable is cut and the recess grouted.
Machinery required	A crane and a hydraulic jack
Advantages	Fast. The quality of concrete can be checked. Less dependent on weather conditions. Better working conditions for workers. They can be used in contaminated soil. Excavations and offsite landfill taxes are significantly reduced.
Disadvantages	Information not provided
More information	The foundation once tensioned, it acts as a single unit. Can be installed with or without piles. Used in housing. It can be de-stressed and re-tensioned in new locations for temporary buildings
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	0 / 1 / **>1**
Resources on the site	None / **Water / Electricity**
Noise	No / Without ear protection / **With ear protection**
Vibrations	**No** / No problems near buildings / Problems near

Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. The foundation once tensioned, it acts as a single unit.[2]

Videos

http://vimeo.com/32151225 Accessed: 20/10/2015

[12] http://www.van-elle.co.uk/services/Smartfoot/ Accessed: 20/10/2015

Precast strip footing (3) A2 - 1. 2. 10

1

Description

It consists of a serie of precast concrete pieces placed at the perimeter of a building. They are joined together with polyurethane. This type of foundation has not tie beams.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced concrete
Allowable load (kN/m)	Fc = 95 - 300
Type of load	Distributed load
Type of soil	Medium

Common dimensions (mm)	X = 700 Y = 500 - 5500 Z = 1100
Own weight (kN/m)	10.25
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out footings 3.Digging out ditches 4.Land-levelling ditches with a bed of gravel 5. Placing wooden battens 6.Filling the bottom with leveling concrete 7.Placing precast strip footings 8.Sealing joints 9.Backfilling
Machinery required	A crane, a mortar mixer and a backhoe excavator
Advantages	Fast. The quality of concrete can be checked. Less dependent on weather conditions. Better working conditions for workers. Pieces can have set out facilities. No speciallist skills required
Disadvantages	Not suitable for all types of soils or loads. The foundation is perimetrical. No possibility to build tie beams.
More information	Pieces can be 5000 mm maximum of length but they can be joined with polyurethane. This foundation is normally used for industrial buildings or electrical substations.
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes

Reusable	No / Partly / Depends on the case / **Yes**

Images

Figure 1. Precast strip footing foundation.[2]

[1] http://www.invertaresa.com/aplihorsa/espanol/quehacemos/submenu-04/detalle-006.htm Accessed: 20/10/2015

[2] http://www.invertaresa.com/aplihorsa/espanol/obras/submenu-07/detalle-005.htm Accessed: 20/10/2015

Precast strip footing (prototype) A2 - 1. 2. 11

[1]

Description

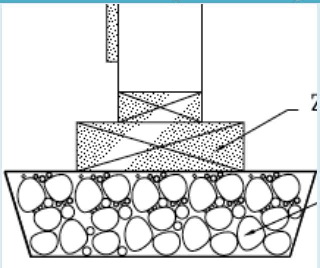
It consists of a precast concrete strip footing that has steel micropiles which are jobsite-installed through holes precast in each footing and driven into the soil.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Reinforced air-entrained concrete and galvanized steel
Allowable load (kN/m)	Information not provided
Type of load	Distributed load
Type of soil	Information not provided
Common dimensions (mm)	Information not provided
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out footings 3.Digging out holes 4.Placing concrete strip footings 5.The micropiles must be slid through the holes in the footing, and driven into the soil 6.The exposed end of the micropiles must then be capped and sealed by bolts
Machinery required	An auto driving hammer and a truck crane
Advantages	Sustain load immediately after installation. Sustainable and environmentally friendly
Disadvantages	Information not provided
More information	It is currently being developed. It is important to check for underground utilities. If there are an electrical lines in the area, de-energize the power source prior to installing the strip footing
Custom manufactured	Information not provided
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	None / Water **/ Electricity**
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Information not provided
Reusable	No / Partly / Depends on the case / **Yes**

[1] http://mashupstudio.pbworks.com/f/pin%20foundation.jpg Accessed: 21/10/15

Timber strip footing — A2 - 1. 2. 12



Description

It consist of timber framework and a plywood board. Timber strip footing is placed over a gravel layer. This foundation is normally used in extremely cold countries.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Timber
Allowable load (kN/m)	Information not provided
Type of load	Distributed load
Type of soil	Medium and hard

Common dimensions (mm)	Information not provided
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out footings 3.Digging out trenches 4.Land-levelling trenches with a layer of gravel 5.Placing timber strip footings over the gravel layer 6.Backfilling excavations
Machinery required	Information not provided
Advantages	Relatively inexpensive where timber is plentiful. Renewable resource. Lightweight.
Disadvantages	Limitated loads and soils.
More information	Timber strip footings have to lay bellow the frost zone. Timber must be protected with a treatement. Foundation depth will depend on the bearing capacity of the soil.
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	Information not provided
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	No / Partly / Depends on the case / **Yes**

Images

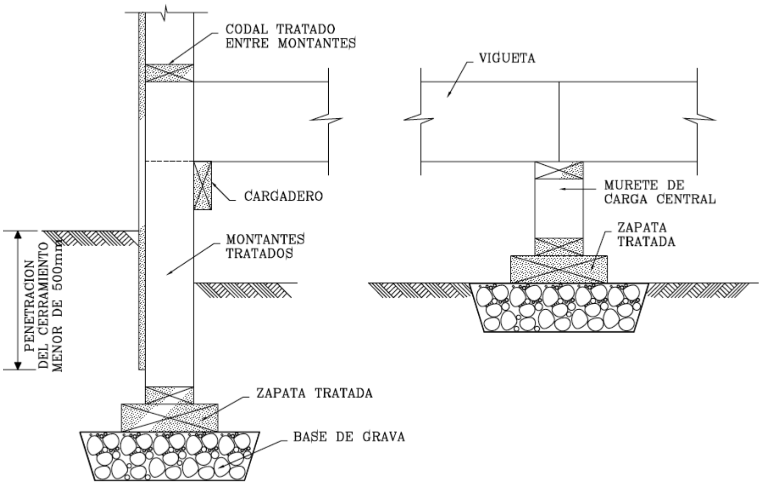
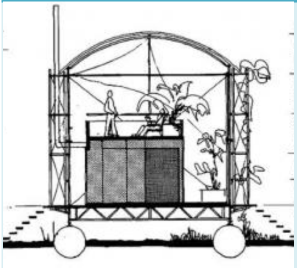


Figure 1. Timber strip footing foundation. [Peraza et al., 1995]

Steel strip footing (prototype)	A2 - 1. 2. 13
	**Description** It consists of floating drums.

Characteristics

Type of foundation	Shallow foundation
Foundation	Prefabricated
Material	Steel
Allowable load (kN/m)	Information not provided
Type of load	Distributed load
Type of soil	Information not provided

Images

Figure 1. Experimental house in Almere by Holvast & Van Woerden.

Semi-prefabricated concrete micropile A2 - 2. 1. 1

Description

It consists of a cylinder of high-strength concrete reinforced with rebars and an iron spiral, that has pipes and valves along its entire lenght to inject grout into the ground.

Characteristics

Type of foundation	Deep foundation
Prefabricated	Semi-prefabricated
Material	Reinforced concrete (and grout)
Allowable load (kN)	Information not provided
Type of load	Point load
Type of soil	Soft, medium and hard

Common dimensions (mm)	Ø = 110 - 260 L = 8000 - 12000
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	H ≤ 50[1]
Phases of construction	1. Cleaning and leveling the ground 2.Setting out micropiles 3.Drilling holes 4.Hold the micropile inside the hole 5.Injecting the first grout injection (6 atm). (After 8-24 hours, injecting the second grout injection (20-40 atm)) 6.Removing grout from the ground
Machinery required	Boring machine and tooling, grouting equipment and backhoe excavator
Advantages	Compatible with all soils. Reduction of the total execution time and costs comparing to conventional ones. Good connection with surrounding soil due to drilling and grouting. Reduction of the axial deformation and foundation subsidence. Assurance of the micropile continuity. This precast micropiles do not require specialized pile driving equipment or workers.
Disadvantages	Residues are generated from drilling soil with grout.
More information	Easy to splice by means a high-strength screw. They can be spliced to achieve greater lengths.
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	Information not provided
Skilled workers required	**0** / 1 / >1
Resources on the site	None / **Water** / **Electricity**
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near
Water table problems	No / **No problems with precautions** / Yes

Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	**No** / No problems with precautions / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figure 1. Precast concrete micropiles.

[1] *1. Asociación Española de Normalización y Certificación. Ejecución de trabajo geotécnicos especiales. Micropilotes. UNE-EN 14199. Madrid: AENOR, 2006*, p. 46.

Injection micropile | A2 - 2. 1. 2

Description

It is a continuously threaded, hollow reinforcing tendon which is encapsulated within a grout body of furnace cement, which allows the transfer of both tensile and compressive forces, by the friction of the threaded tendon, the grout body and the soil.

Characteristics

Type of foundation	Deep foundation
Foundation	Semi-prefabricated
Material	Steel (and grout)
Allowable load (kN)	Tendon: Fc = Ft = 176 - 2697
Type of load	Point load
Type of soil	Soft, medium and hard

Common dimensions (mm)	Tendon: Ø = 30 - 127 L = 1500 - 6000
Own weight (kN)	Tendon: 0.05 - 1.31
Dimensional tolerances (mm)	H ≤ 50[1]
Phases of construction	1.Cleaning and leveling the ground 2.Setting out micropiles 3.Direct perforation: perforation and grouting injection W/C=0,7-1 4.Dinamic injection: grouting injection W/C=0,45-0,7 5.Removing grout from the ground
Machinery required	Hydraulic drilling rig, grouting equipment and backhoe excavator
Advantages	Compatible with all soils. It works well both in tension and compression. Suitable for cramped and limited-access conditions. Good connection with surrounding soil due to drilling and grouting. Soil improvement thanks to rotary impact driving and flushing. Rapid, effective ground and structural stabilization (ground improvement). Single step casing free operation significantly improves productivity. Lightweight installation equipment. Wide variety of drill bits to suit different ground conditions
Disadvantages	High initial cost; specially in rocky soils. Residues are generated from drilling soil with grout
More information	Optional use of stainless steel. Suitable for use in zones with a high risk of corrosion. Spacer elements could be used to assure the minimum distance of 20 mm. Different drill bits depending on the soil
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**

Skilled workers required	0 / **1** / >1
Resources on the site	None / **Water / Electricity**
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	**No** / It is necessary to pre-drill / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figure 1. Drilling and injecting grout through the hollow reinforcing tendon.

[1] Asociación Española de Normalización y Certificación. Ejecución de trabajo geotécnicos especiales. Micropilotes. UNE-EN 14199. Madrid: AENOR, 2006, p. 46.

Semi-prefabricated steel micropile — A2 - 2. 1. 3

Description

It consists of a tubular or bar-shaped reinforcement, covered by grout or mortar which is in contact with the ground. The transmission of forces is in most cases obtained by the shaft's friction, ignoring the point resistance.

Characteristics

Type of foundation	Deep foundation
Foundation	Semi-prefabricated
Material	Steel (and grout or mortar)
Allowable load (kN)	Fc = 670 - 1250
Type of load	Point load
Type of soil	Soft, medium and hard

Common dimensions (mm)	Tubular reinforc.: Ø = 90 - 140 L = 8000 - 15000
Own weight (kN)	Tubular reinforc.: 1.11 - 4.56
Dimensional tolerances (mm)	H ≤ 50[1]
Phases of construction	1.Cleaning and leveling the ground 2.Setting out micropiles 3.Drilling holes (Placing a waste tubing) 4.Placing the reinforcement 5.Injecting mortar. (Remove the waste tubing). 6.Removing grout or mortar from the ground
Machinery required	Boring machine and tooling, grouting equipment and backhoe excavator
Advantages	They are able to transmit loads of compression, bending, shear and traction. Compatible with all soils. Suitable for cramped and limited-access conditions. Good connection with surrounding soil due to drilling and grouting. Rapid, effective ground and structural stabilization (ground improvement). Lightweight installation equipment
Disadvantages	High initial cost. Residues are generated from drilling soil with grout
More information	If the land is not stable for boring, it may be necessary to use waste tubing, which can substitute or complement the reinforcing required. There are several grouting systems. They can be spliced to achieve greater lengths
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / 1 / **>1**
Resources on the site	None / **Water** / Electricity
Noise	No / Without ear protection / **With ear protection**

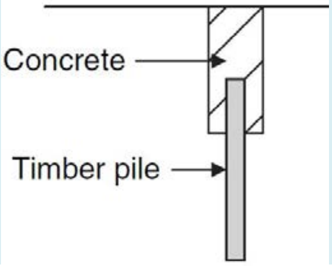
Vibrations	No / **No problems near buildings** / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Possible other problems	Mortar discontinuity
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figure 1.Placing the tubular reinforcement.

[1] Asociación Española de Normalización y Certificación. Ejecución de trabajo geotécnicos especiales. Micropilotes. UNE-EN 14199. Madrid: AENOR, 2006, p. 46.

Semi-prefabricated composite pile — A2 - 2. 1. 4



Description

A pile consisting of more than one member or material, but designed to act as one unit. Most common are made of a timber pile, steel pile or H-pile at the bottom and built on-site concrete pile at the top.

Characteristics

Type of foundation	Deep foundation
Foundation	Semi-prefabricated
Material	Concrete, steel, plastic and/or timber
Allowable load (kN)	Information not provided
Type of load	Point load
Type of soil	Soft and medium

Common dimensions (mm)	Information not provided
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site, leveling the ground and creating a platform to place the equipment 2.Setting out piles 3.Driving piles 4.Completing piles with concrete 5.Cutting down the heads of piles and remove them
Machinery required	A free-fall equipment, using a hammer raised either by a simple cable system or an hydraulic pile driver
Advantages	They can be used as end-bearing piles or friction piles. They can be spliced to achieve greater lengths. High load capacity. These prove economical as they permit the utilization of the great corrosion resistance property of one material with the cheapness or strength of the other
Disadvantages	There can be problems with noise and vibration.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	0 / 0-50mm / **> 50mm**
Skilled workers required	0 / 1 / **>1**
Resources on the site	**None** / Water / Electricity
Noise	No / Without ear protection / **With ear protection**
Vibrations	No / No problems near buildings / **Problems near buildings**
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / It is necessary to pre-drill / **Yes**
Frost line problems	**No** / No problems with precautions / Yes
Possible other problems	Damage or deviation of the pile
Reusable	**No** / Partly / Depends on the case / Yes

[1] http://civilengineersforum.com/pile-foundation-steel-piles-concrete-piles-timber-piles-composite-piles/ Accessed: 20/10/2015

Semi-prefabricated strip footing (1) A2 - 2. 2. 1

Description

It consists of a serie of precast concrete parts placed in line. They are joined together filled with reinforced concrete.

Characteristics

Type of foundation	Shallow foundation
Foundation	Semi-prefabricated
Material	Reinforced concrete
Allowable load (kN/m)	Fc = 19.61 - 41.16
Type of load (kN/m)	Distributed load
Type of soil	Medium and hard

Common dimensions (mm)	X = 400 - 600 Y = 300 - 330 Z = 330
Own weight (kN)	0.44 - 1.08
Dimensional tolerances (mm)	V = 2 / H = 2
Phases of construction	1.Cleaning the site 2.Setting out footings (Digging out ditches) Land-levelling ditches with a layer of gravel of 5 cm.) 3.Compact the ground 4.Placing precast strip footings 5.Placing rebars into strip footing holes 6.Concreting strip footings holes. (Backfilling)
Machinery required	A concrete mixer and a backhoe excavator
Advantages	Uses regional materials. Cheap. Easy. No speciallist skills required. Fast. The quality of concrete can be checked. Less dependent on weather conditions
Disadvantages	Limitated loads and soils
More information	Minimum reinforcement is 4 rebars of 6 mm. This type of foundation is normally used in housing
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	None / **Water / Electricity**
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figure 1. Precast strip footing foundation.

Figure 2. Precast strip footing foundation with rebars.

Completed on-site strip footing (2) A2 - 2. 2. 2

Description

It consists of a precast concrete beam with supports legs and reinforcement. Once it is in position, the bellow part is concreted on-site.

Characteristics

Type of foundation	Shallow foundation
Foundation	Completed on-site
Material	Reinforced concrete
Allowable load (kN/m)	Information not provided
Type of load	Distributed load
Type of soil	Medium and hard

Common dimensions (mm)	X = 500 - 2000 Y = 1000 - 12000 Z = 500 - 750
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out footings 3.Digging out ditches 4.Land-levelling ditches with gravel and cleaning concrete 5.Placing strip footings by crane into position 5.Levelling strip footings by metal plates. 6.Concreting bellow strip footings 7.Backfilling
Machinery required	A backhoe excavator, a concrete mixer truck and a crane.
Advantages	Fast. The quality of concrete can be checked. Less dependent on weather conditions. Better working conditions for workers.Good contact with the ground is guaranteed
Disadvantages	Limitated loads and soils.

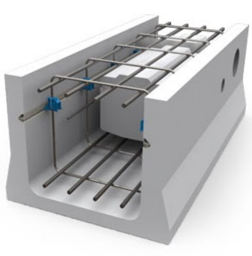
More information

Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	0 / 1 / **>1**
Resources on the site	None / **Water /** Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images

Figure 1. Placing a strip footing by crane into position.

Semi-prefabricated strip footing / ground beam (3) — A2 - 2. 2. 3



1

Description

It consists of a permament EPS formwork into which concrete is poured. It have rebars. It is possible to leave anchors on top.

Characteristics

Type of foundation	Shallow foundation
Foundation	Semi-prefabricated
Material	Expanded Polystyrene, steel and concrete
Allowable load (kN/m)	Information not provided
Type of load	Distributed load
Type of soil	Soft, medium and hard

Common dimensions (mm)	X = 500 Y = 500
Own weight (kN)	Information not provided
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Compacting the ground 3.Setting out footings/beams (Digging out ditches) 4.Placing EPS strip footings/beams 4.Sealing joints with PUR-foam 5.Concreting 6.Flattering surface. (Backfilling)
Machinery required	A backhoe excavator and a concrete mixer truck.
Advantages	Fast. Less dependent on weather conditions. No specialist skills required. Shorter producing time and 75% less construction time on the site comparing to traditional systems. It is not necessary to vibrate concrete. Saving of concrete compared to traditional ones.
Disadvantages	Not suitable for all types of soils.
More information	Can be installed with or without piles. For housing and small buildings.
Custom manufactured	No / **Customized** / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	**None** / Water / Electricity
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near
Water table problems	**No** / No problems with precautions / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images



Figure 1. Ground beams before concreting. Figures 2 and 3. Concreting the foundation.

Figure 4. It is possible to leave anchors on top of the foundation.

Videos

https://www.youtube.com/watch?v=kJzzhF0Dskk Accessed: 20/10/15

[1] https://plus.google.com/106948571911731171611/posts Accessed: 20/10/2015

Formwork A2 - 2. 2. 4

1

Description

It consists of a permament mold into which concrete or similar materials are poured. It can have rebars. It can have rebar holders for both horizontal and vertical rebar. A connector can be placed on the top.

Characteristics

Type of foundation	Shallow foundation
Foundation	
Material	Plastic and steel (and concrete or similar)
Load bearing (kN)	Shallow foundation
Type of load (kN)	Point load
Type of soil	Medium and hard

Common dimensions (mm)	Ø = 457 - 635 Z = 914 - 1829
Own weight (kN)	Fc = 2.28 - 5
Dimensional tolerances (mm)	Information not provided
Phases of construction	1.Cleaning the site 2.Setting out formworks (Digging out holes). Land-levelling holes with a layer of gravel of 5 cm. 3. Assemble the framework. 4. Level the framework inside the hole. 5. Backfill the hole and compress it by feet. 6. Concrete the framework and flatten its surface by a board. 7. Embed the connector.
Machinery required	A concrete mixer and a backhoe excavator.
Advantages	Easy. No speciallist skills required. Fast. Rebars space is assured when there are rebar holders.
Disadvantages	Limitated loads.
More information	Depending on formwork type it can provides lateral, horizontal and seismic load resistance.
Custom manufactured	**No** / Customized / Yes
Adjustable height (on the site)	**0** / 0-50mm / > 50mm
Skilled workers required	**0** / 1 / >1
Resources on the site	None / **Water / Electricity**
Noise	**No** / Without ear protection / With ear protection
Vibrations	**No** / No problems near buildings / Problems near buildings
Water table problems	No / **No problems with precautions** / Yes
Obstacles problems	No / **It is necessary to pre-drill** / Yes
Frost line problems	No / **No problems with precautions** / Yes
Reusable	**No** / Partly / Depends on the case / Yes

Images


Figure 1. Digging out holes. Figure 2. Land-levelling holes with a layer of gravel of 5 cm. The framework is assembled, placed and leveled in the hole.


Figure 3. Rebars are hold in the plastic framework. Figure 4. The hole is filled with backfill.


Figure 5. The ground is compressed by feet. Figure 6. The framework is ready to concrete.


Figure 7. The framework is filled with concrete and pressed. Figure 8. And it is flattened with a board.[2]

Videos

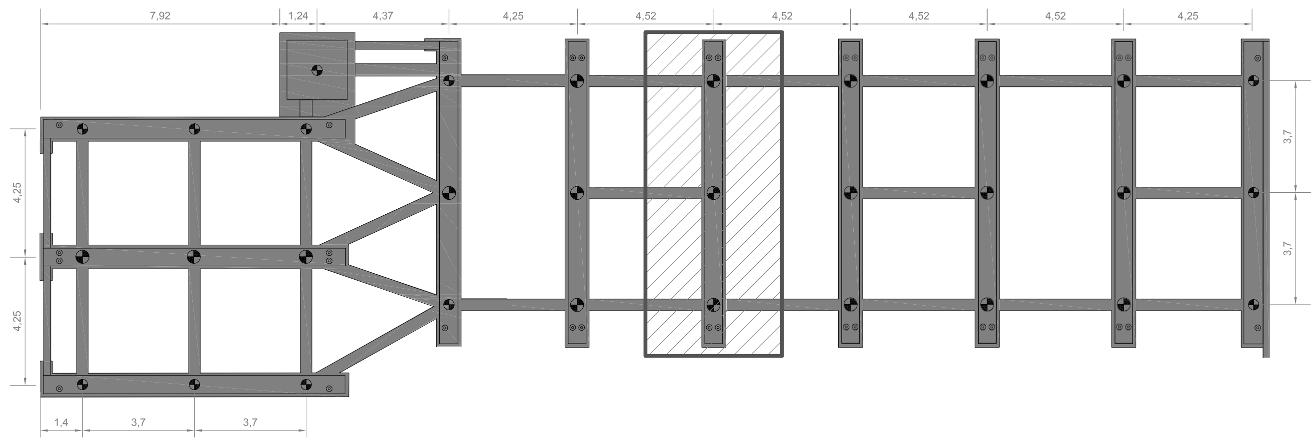
https://www.youtube.com/watch?v=CDke0Vj1mGU Accessed: 20/10/2015

[1] https://www.youtube.com/watch?v=CDke0Vj1mGU Accessed: 20/10/2015

[2] https://www.youtube.com/watch?v=_kS11DnB2Bs&feature=youtu.be Accessed: 20/10/2015

3. Data

A3 - 1.1. Foundations (A1-10)



Foundation plan E:1/250

Geotechnical study summary

0

LAYER R: Topsoil. This layer is not resistant.

0.90 - 1.50

LAYER A: Brown clay with a fraction of sand, from fine to medium size. Cohesive materials. They are not much consolidated. They are saturated with water under 4.80 meters. qu = 1.69 Kg/cm².

11.90 - 12.50

LAYER B: Consolidated clay with layers of sand. 22 - 40 SPT. Resistance increase in depth.

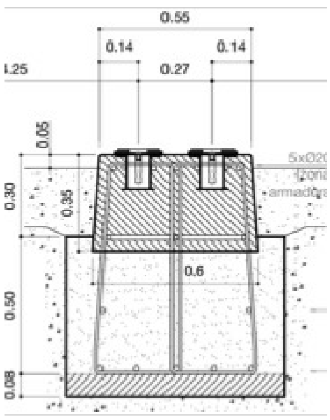
23.90 - 25.00

Water table: 4.80 m from surface / Chemical aggressiveness: cement has to be resistant to sulphates (Qb)
Expansiveness: Not detected.

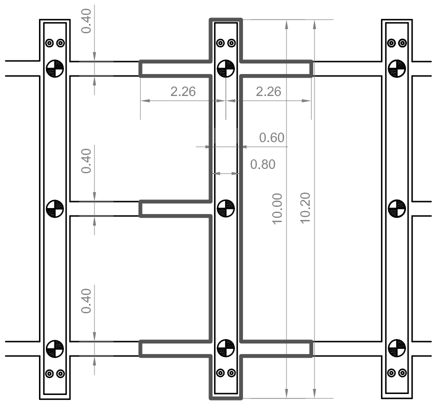
It is recommended to build a foundation composed of piles. They should be embbeded into layer B.
Working stresses: Layer A: 0.20 (shaft) / Layer B: 0.60 kg/cm² (shaft) and 30.00 kg/cm² (toe).

Loads to the ground beam: 1970 kN

SEMI-PREFABRICATED FOUNDATION
PILES (3u): Ø 45 cm, Z = 14.10 m
GROUND BEAM
Cast-in-place part: 10.20 x 0.80 x 0.50 m
Precast part: 10.00 x 0.60 x 0.35 m
TIE BEAMS: 11.30 x 0.40 x 0.50 m

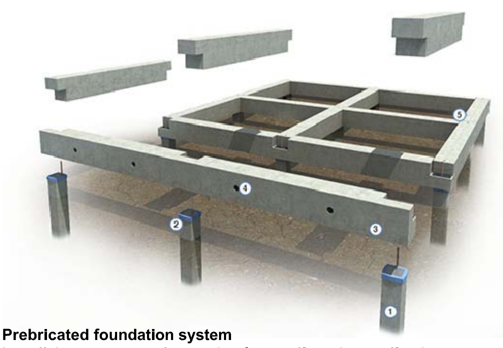


Semi-precast ground beam detail

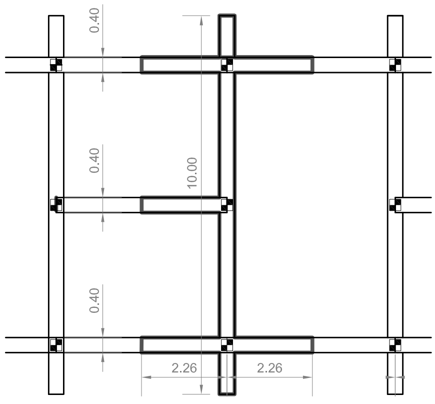


Semi-prefabricated foundation plan E:1/200

PREFABRICATED FOUNDATION
PILES (3u): 30 x 30 cm, Z = 15.00 m
GROUND BEAM: 10.00 x 0.40 x 0.50 m
TIE BEAMS: 11.30 x 0.40 x 0.50 m



Prebricated foundation system
http://charconcs.com/ground-solutions/foundations/fastbeam
Accessed: 01/11/15



Prefabricated foundation plan E:1/200

A3 - 1.2. Semi-prefabricated foundation (A1-10)

PILES (3 u) Ø 45 cm, Z = 14.10 m - GROUND BEAM (cast-in-place part): 10.20 x 0.80 x 0.50 m - GROUND BEAM (precast part): 10.00 x 0.60 x 0.35 m - TIE BEAMS: 11.30 x 0.40 x 0.50 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ $_{total}$**	**MJ**	**MJ $_{total}$**	**kg**	**kg $_{total}$**
1 PILES					**3238.90**		**64140.23**		**7282.95**
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	6.73	45.49	173.53	1167.86	10.71	72.08
E2RA7LP0	m^3	Controlled deposition to an authorised diposit of inert soil waste with a density of 1.6 t/m3, from excavation, with code 170504 according to the European Waste List (ORDER MAM/304/2002)	4.70	6.73	31.63	0.00	0.00	0.00	0.00
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	12.09	0.48	5.80	197.96	95.02	12.21	5.86
K2RA71H0	m^3	Controlled deposition to an authorised diposit of inert concrete waste with a density of 1.45 t/m3, from construction or demolition, with code 170101 according to the European Waste List (ORDEN MAM/304/2002)	8.73	0.48	4.19	0.00	0.00	0.00	0.00
E3E5847E	m	Drilling and concreting of continuous fight auger piles on soft soil, in 45 cm diameter with HA-30/ L/10/IIa+Qb concrete with a superplasticizer additive, of liquid consistency and maximum size of granules of 10 mm, with > = 375 kg/m^3 cement	47.55	42.30	2011.50	1182.29	50010.98	112.63	4764.01
E3EB3000	kg	AP500 S steel reinforcement for piles, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.07	538.14	575.81	23.14	12452.56	4.49	2416.25
E3EZ1800	u	Displacement, assembly and dismantling of pile driver for fight auger piles	4600.00	0.10	445.16	2773.83	268.44	156.30	15.13
E3EZA040	m	Pile head breaking, in 45 cm diameter	39.77	3.00	119.31	48.46	145.38	3.21	9.63
2 GROUND BEAM					**1838.19**		**29780.60**		**4203.29**
E222142B	m^3	Digging a trench and a shaft of a maximum 2 meters depth, in a compact ground (SPT 20-50), made with a backhoe and soil left to the side	5.30	5.30	28.09	63.30	335.49	4.20	22.26
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	5.30	35.83	173.53	919.71	10.71	56.76
E3F515H1	m^3	Concrete for caps, HA-25/B/20/IIa, of soft consistency and maximum size of granulate of 20 mm, dumped from truck	84.21	4.08	343.58	2342.22	9556.26	317.17	1294.05
E3FB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.13	268.52	303.42	23.14	6213.46	4.49	1205.64
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	8.16	86.33	141.54	1154.97	18.33	149.57
7	m^3	Precast linear foundation	368.00	2.01	740.60	2770.12	5546.59	424.14	849.25
E3FB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		80.12		23.14	1853.98	4.49	359.74
4	t	Precast foundation transport	23.66	5.03	119.04	420.80	2117.15	25.88	130.21
5	m	Assembly of heavy precast concrete foundation	18.13	10.00	181.30	208.30	2083.00	13.58	135.80

3 TIE BEAMS					**452.93**		**10299.73**		**1548.83**
E222142B	m^3	Digging a trench and a shaft of a maximum 2 meters depth, in a compact ground (SPT 20-50), made with a backhoe and soil left to the side	5.30	3.16	16.75	63.30	200.03	4.20	13.27
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	3.16	21.36	173.53	548.35	10.71	33.84
E3F515H1	m^3	Concrete for caps, HA-25/B/20/IIa, of soft consistency and maximum size of granulate of 20 mm, dumped from truck	84.21	2.26	190.31	2342.22	5293.42	317.17	716.80
E3FB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.13	156.36	176.69	23.14	3618.17	4.49	702.06
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	4.52	47.82	141.54	639.76	18.33	82.85
TOTAL					**5530.02**		**104220.57**		**13035.07**

A3 - 1.3. Prefabricated foundation (A1-10)

PILES (3u) 30 x 30 cm, Z = 15.00 m - GROUND BEAM: 10.00 x 0.40 x 0.50 m - TIE BEAM: 11.30 x 0.40 x 0.50 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	U.	Definition	€	U	€ total	MJ	MJ total	kg	kg total
1 PILES					**4167.84**		**24455.77**		**4172.72**
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	12.09	0.27	3.26	197.96	53.45	12.21	3.30
K2RA71H0	m^3	Controlled deposition to an authorised diposit of inert concrete waste with a density of 1.45 t/m^3, from construction or demolition, with code 170101 according to the European Waste List (ORDEN MAM/304/2002)	8.73	0.27	2.36	0.00	0.00	0.00	0.00
9	m	Driving a concrete pile (30 x 30 cm) with an ABB joint	75.40	45.00	3393.00	533.89	24025.05	92.10	4144.50
E3EZ3A00	u	Displacement, assembly and dismantling of pile driver for precast concrete piles	7053.64	0.10	682.61	2773.83	268.44	156.30	15.13
3	m	Pile head breaking, 30 x 30 cm	28.87	3.00	86.61	36.28	108.84	3.27	9.80
2 GROUND BEAM					**1047.66**		**17180.52**		**2533.22**
E222142B	m^3	Digging a trench and a shaft of a maximum 2 meters depth, in a compact ground (SPT 20-50), made with a backhoe and soil left to the side	5.30	1.00	5.30	63.30	63.30	4.20	4.20
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	1.00	6.76	173.53	173.53	10.71	10.71
7	m^3	Precast linear foundation	368.00	2.00	736.00	2770.12	5428.49	424.14	831.17
E3EB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		316.69		23.14	7328.21	4.49	1421.94
4	t	Precast foundation transport	23.66	5.00	118.30	420.80	2104.00	25.88	129.40
5	m	Assembly of heavy precast concrete foundation	18.13	10.00	181.30	208.30	2083.00	13.58	135.80
3 TIE BEAMS					**1183.86**		**14822.39**		**1968.69**
E222142B	m^3	Digging a trench and a shaft of a maximum 2 meters depth, in a compact ground (SPT 20-50), made with a backhoe and soil left to the side	5.30	1.13	5.99	63.30	71.53	4.20	4.75
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	1.13	7.64	173.53	196.09	10.71	12.10
7	m^3	Precast linear foundation	368.00	2.26	831.68	2770.12	6205.29	424.14	950.11
E3EB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		156.36		23.14	3618.17	4.49	702.06
4	t	Precast foundation transport	23.66	5.65	133.68	420.80	2377.52	25.88	146.22
5	m	Assembly of heavy precast concrete foundation	18.13	11.30	204.87	208.30	2353.79	13.58	153.45
TOTAL					**6399.36**		**56458.69**		**8674.62**

A3 - 1.4. Cast-in-place pile (A1-10)

PILE: Ø 45 cm, Z = 14.10 m

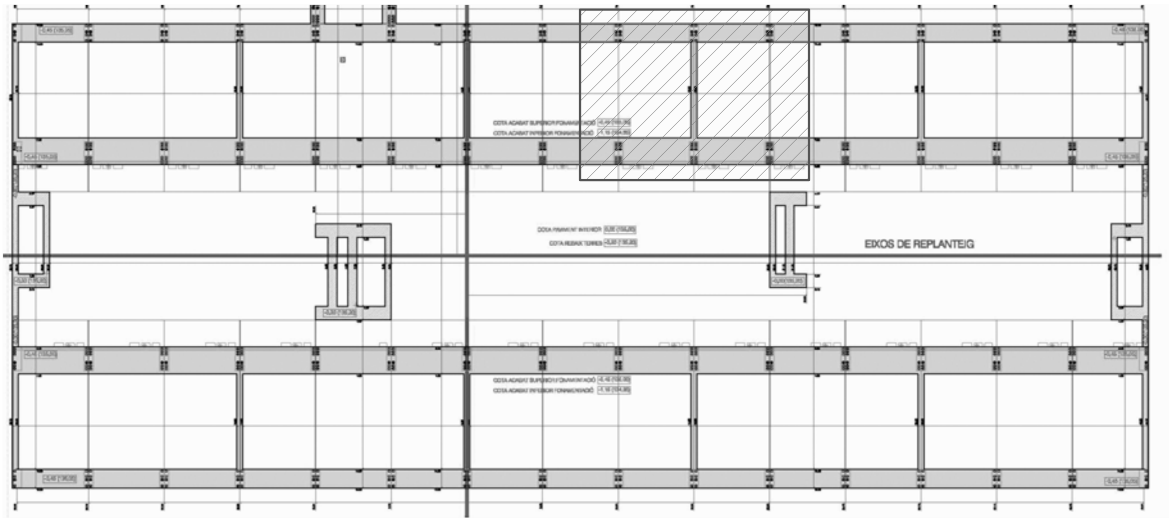
Economic costs						**Energetic costs**		**CO_2 eq emissions**	
Code	**U.**	**Definition**	**€**	**U**	**€ $_{total}$**	**MJ**	**MJ $_{total}$**	**kg**	**kg $_{total}$**
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	2.24	15.16	173.53	389.29	10.71	24.03
E2RA7LP0	m^3	Controlled deposition to an authorised diposit of inert soil waste with a density of 1.6 t/m^3, from excavation, with code 170504 according to the European Waste List (ORDER MAM/304/2002)	4.70	2.24	10.54	0.00	0.00	0.00	0.00
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	12.09	0.16	1.93	197.96	31.67	12.21	1.95
K2RA71H0	m^3	Controlled deposition to an authorised diposit of inert concrete waste with a density of 1.45 t/m^3, from construction or demolition, with code 170101 according to the European Waste List (ORDEN MAM/304/2002)	8.73	0.16	1.40	0.00	0.00	0.00	0.00
C3E58400	m	Drilling and materials placement, labour and machinery for continuous fight auger piles, in 45 cm diameter	28.20	14.10	397.62	667.73	9414.95	43.55	614.02
B3EE1410	m^3	HA-30/L/10/IIa+Qb concrete with a liquid consistency, maximum granulate size of 10 mm, with >= 375 kg/m^3 cement, superplasticizer additive, suitable for exposure IIa + Qb	97.35	2.80	272.88	2588.36	7255.38	347.47	973.99
E3EB3000	kg	AP500 S steel reinforcement for piles, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.07	179.38	191.94	23.14	4150.85	4.49	805.42
E3EZ1800	u	Displacement, assembly and dismantling of pile driver for fight auger piles	4600.00	0.03	148.39	2773.83	89.48	156.30	5.04
E3EZA040	m	Pile head breaking, in 45 cm diameter	39.77	1.00	39.77	48.46	48.46	3.21	3.21
TOTAL					**1079.63**		**21380.08**		**2427.65**

A3 - 1.5. Precast pile (A1-10)

PILE: 30 x 30 cm, Z = 15.00 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ total**	**MJ**	**MJ total**	**kg**	**kg total**
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	12.09	0.09	1.09	197.96	17.82	12.21	1.10
K2RA71H0	m^3	Controlled deposition to an authorised diposit of inert concrete waste with a density of 1.45 t/m^3, from construction or demolition, with code 170101 according to the European Waste List (ORDEN MAM/304/2002)	8.73	0.09	0.79	0.00	0.00	0.00	0.00
C3E61000	m	Pile driver	4.73	15.00	70.97	11.36	170.40	0.74	11.10
10	m^3	Precast concrete pile (30 x 30 cm) with an ABB joint	785.22	1.35	1060.05	2770.12	3676.20	424.14	562.87
E3EB3000	kg	AP500 S steel reinforcement for piles, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		179.85		23.14	4161.73	4.49	807.53
E3EZ3A00	u	Displacement, assembly and dismantling of pile driver for precast concrete piles	7053.64	0.03	227.54	2773.83	89.48	156.30	5.04
3	m	Pile head breaking, 30 x 30 cm	28.87	1.00	28.87	36.28	36.28	3.27	3.27
TOTAL					**1389.29**		**8151.90**		**1390.90**

A3 - 2.1. Foundations (A1-16)



Foundation plan E: 1/500.

Geotechnical study summary

0 – 0.20: LAYER R: Topsoil layer. This layer is not resistant.

0.20 – 4.50 - 5.00: LAYER A: Silts. qu = 2.57 kg/cm².

4.50 - 5.00 – 8.70-11.00: LAYER B: Clays and silts. qu = 3.62 kg/cm².

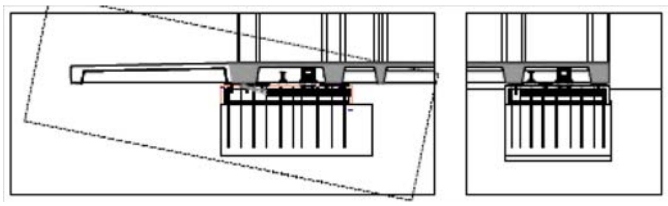
Water table: Not detected / Chemical aggressiveness: Not detected / Expansiveness: Not detected.

It is recommended to build continuous footings embedded in layer A. Qa = 1.20 kg/cm².

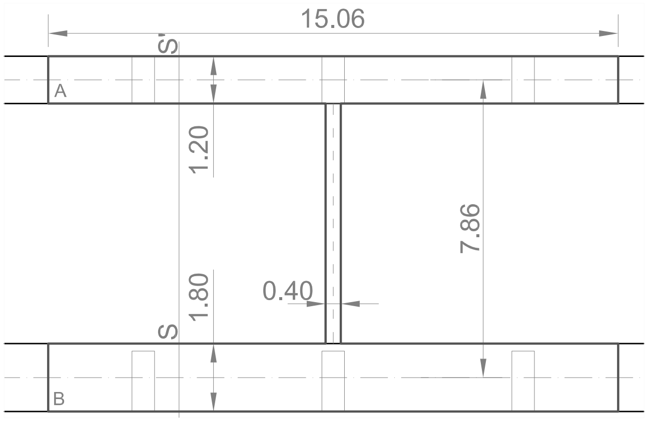
Loads to the continuous footing A: 123.56 kN/m. Loads to the continuous footing B: 185.34 kN/m

CAST-IN-PLACE FOUNDATION
CONTINUOUS FOOTING A: 15.06 x 1.20 x 0.60 m
CONTINUOUS FOOTING B: 15.06 x 1.80 x 0.60 m
TIE BEAM: 7.86 x 0.40 x 0.60 m

PRECAST PADS A (3u): 1.24 x 0.60 x 0.24 m
PRECAST PADS B (3u): 1.50 x 0.60 x 0.24 m

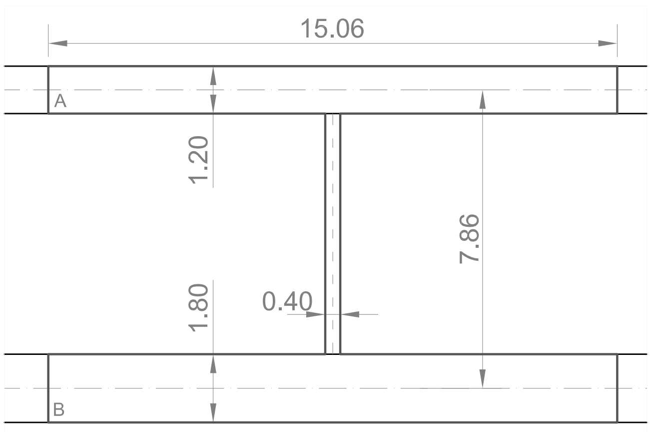


Cast-in-place foundation section (S-S')



Cast-in-place foundation E:1/200

PREFABRICATED FOUNDATION
CONTINUOUS FOOTING A: 15.06 x 1.20 x 0.60 m
CONTINUOUS FOOTING B: 15.06 x 1.80 x 0.60 m
TIE BEAM: 7.89 x 0.40 x 0.60 m



Prefabricated foundation E:1/200

A3 - 2.2. Cast-in-place foundation (A1-16)

CONTINUOUS FOOTING A: 15.06 x 1.20 x 0.60 m - CONTINUOUS FOOTING B: 15.06 x 1.80 x 0.60 m - TIE BEAM: 7.86 x 0.40 x 0.60 m - PRECAST PAD A (3 u) : 1.24 x 0.60 x 0.24 m - PRECAST PAD B (3 u): 1.50 x 0.60 x 0.24 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ $_{total}$**	**MJ**	**MJ $_{total}$**	**kg**	**kg $_{total}$**
1 CONTINUOUS FOOTING A					**2362.83**		**50929.64**		**7565.45**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	16.08	72.36	53.75	864.30	3.56	57.24
E2241100	m^2	Revision of floors and walls of trenches and shafts up to 1.5 meters depth	1.90	44.88	85.27	0.00	0.00	0.00	0.00
E225277F	m^3	Landfill and compression of trenches and shafts with suitable ground, in successive layers up to 25 cm, with a compaction of 95%	14.27	3.01	42.95	48.66	146.47	3.23	9.72
1	m^3	Transport of soil over a distance of 30 km to an authorized waste management facility, in a 24-tonne lorry, with a waiting time for loading by mechanical means	6.76	13.07	88.35	173.53	2268.04	10.71	139.98
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	18.07	191.20	141.54	2557.91	18.33	331.26
E31522H1	m^3	Concrete for trenches and shafts, HA-25/B/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12	10.84	836.23	2342.22	25397.16	317.17	3439.14
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.15	653.15	751.12	23.14	15113.89	4.49	2932.64
7	m^3	Precast linear foundation	368.00	0.53	196.34	2770.12	1450.54	424.14	222.10
E3EB3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		77.58		23.14	1795.20	4.49	348.33
4	t	Precast foundation transport	23.66	1.33	31.56	420.80	561.26	25.88	34.52
5	m	Assembly of heavy precast concrete foundation	18.13	3.72	67.44	208.30	774.88	13.58	50.52
2 CONTINUOUS FOOTING B					**3624.33**		**72016.70**		**10544.38**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	24.13	108.59	53.75	1296.99	3.56	85.90
E2241100	m^2	Revision of floors and walls of trenches and shafts up to 1.5 meters depth	1.90	53.91	102.43	0.00	0.00	0.00	0.00
E225277F	m^3	Landfill and compression of trenches and shafts with suitable ground, in successive layers up to 25 cm, with a compaction of 95%	14.27	4.64	66.21	48.66	225.78	3.23	14.99
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	23.66	19.49	461.13	173.53	3382.10	10.71	208.74
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	27.11	286.80	141.54	3836.87	18.33	496.89
E31522H1	m^3	Concrete for trenches and shafts, HA-25/B/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12	16.26	1254.34	2342.22	38095.74	317.17	5158.71
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.15	843.59	970.13	23.14	19520.67	4.49	3787.72
7	m^3	Precast linear foundation	368.00	0.65	238.46	2770.12	1763.18	424.14	269.97

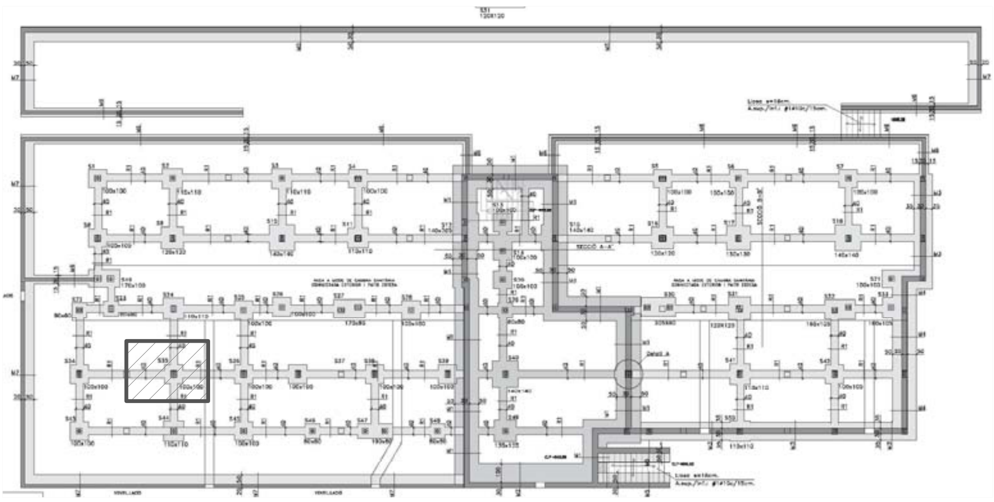
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		90.27		23.14	2088.85	4.50	406.22
4	t	Precast foundation transport	23.66	1.62	38.33	420.80	681.70	25.88	41.93
5	m	Assembly of heavy precast concrete foundation	18.13	5.40	97.90	208.30	1124.82	13.58	73.33
3 TIE BEAM					**426.62**		**9032.58**		**1391.44**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	2.80	12.60	53.75	150.50	3.56	9.97
E2241100	m^2	Revision of floors and walls of trenches and shafts up to 1.5 meters depth	1.90	17.13	32.55	0.00	0.00	0.00	0.00
E225277F	m^3	Landfill and compression of trenches and shafts with suitable ground, in successive layers up to 25 cm, with a compaction of 95%	14.27	0.60	8.56	48.66	29.20	3.23	1.94
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	2.20	14.87	173.53	381.77	10.71	23.56
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	3.14	33.26	141.54	445.00	18.33	57.63
E31522H1	m^3	Concrete for trenches and shafts, HA-25/B/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12	1.89	145.48	2342.22	4418.36	317.17	598.31
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.15	155.91	179.30	23.14	3607.76	4.49	700.04
TOTAL					**6413.77**		**131978.92**		**19501.28**

A3 - 2.3. Prefabricated foundation (A1-16)

CONTINUOUS FOOTING A: 15.06 x 1.20 x 0.60 m - CONTINUOUS FOOTING B: 15.06 x 1.80 x 0.60 m - TIE BEAM: 7.86 x 0.40 x 0.60 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ total**	**MJ**	**MJ total**	**kg**	**kg total**
1 CONTINUOUS FOOTING A					**5016.63**		**61723.49**		**8550.83**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	9.94	44.73	53.75	534.25	3.56	35.38
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	9.94	67.19	173.53	1724.82	10.71	106.45
7	m^3	Precast linear foundation	368.00	10.84	3990.30	2770.12	29806.48	424.14	4563.74
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		653.15		23.14	15113.89	4.50	2939.18
4	t	Precast foundation transport	23.66	27.11	641.38	420.80	11407.05	25.88	701.56
5	m	Assembly of heavy precast concrete foundation	18.13	15.06	273.04	208.30	3137.00	13.58	204.51
2 CONTINUOUS FOOTING B					**7388.43**		**87914.61**		**12110.30**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	14.91	67.09	53.75	801.38	3.56	53.08
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	14.91	100.79	173.53	2587.23	10.71	159.68
7	m^3	Precast linear foundation	368.00	16.26	5985.45	2770.12	44757.76	424.14	6852.97
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		843.59		23.14	19520.67	4.49	3787.72
4	t	Precast foundation transport	23.66	40.66	962.06	420.80	17110.57	25.88	1052.33
5	m	Assembly of heavy precast concrete foundation	18.13	15.06	273.04	208.30	3137.00	13.58	204.51
3 TIE BEAM					**967.75**		**12793.04**		**1745.17**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	4.50	1.73	7.78	53.75	92.94	3.56	6.16
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	1.73	11.69	173.53	300.07	10.71	18.52
7	m^3	Precast linear foundation	368.00	1.89	694.20	2770.12	5170.54	424.14	791.67
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		155.91		23.14	3607.76	4.49	700.04
4	t	Precast foundation transport	23.66	4.72	111.58	420.80	1984.49	25.88	122.05
5	m	Assembly of heavy precast concrete foundation	18.13	7.86	142.50	208.30	1637.24	13.58	106.74
TOTAL					**13372.81**		**162431.13**		**22406.30**

A3 - 3.1. Foundations (A1-14)



Foundation plan E:1/400

Geotechnical study summary

0

0 - 0.70 — LAYER R: Topsoil layer. This layer is not resistant.

LAYER A: Sandy loamy clays and grey loams. Rocky consistency.
Loamy clays: qu = 2.71 kg/cm². Grey loams: qu = 77.63 - 143.78 kg/cm².

+ 12.00 m

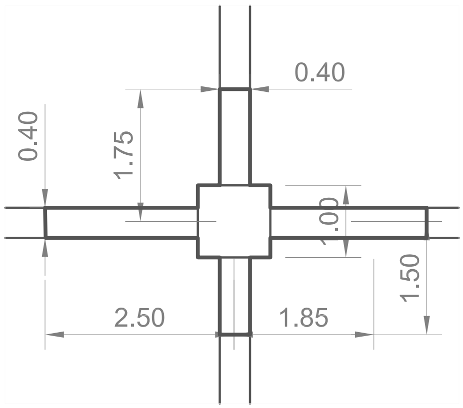
Water table: Not detected / Chemical aggressiveness: Not detected / Expansiveness: Not detected.

The geotechnical study recommends to build isolated footings. Qa = 5.00 kg/cm².
But the thesis considers Qa = 31.56 kg/cm² (94.67/3) as it is explained in section 6.3.1.

Loads to the isolated footing: 478.07 kN

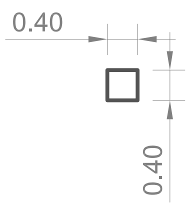
CAST-IN-PLACE FOUNDATION
ISOLATED FOOTING: 1.00 x 1.00 x 0.50 m
TIE BEAMS: 7.6 x 0.40 x 0.50 m

Cast-in-place foundation



Cast-in-place foundation plan E:1/100

PREFABRICATED FOUNDATION
ISOLATED FOOTING: 0.40 x 0.40 x 0.40 m



Prefabricated foundation plan E:1/100

A3 - 3.2. Cast-in-place foundation (A1-14)

ISOLATED FOOTING: 1.00 x 1.00 x 0.50 m - TIE BEAMS: 7.60 x 0.40 x 0.50 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ total**	**MJ**	**MJ total**	**kg**	**kg total**
1 ISOLATED FOOTING					**125.41**		**2169.45**		**284.07**
E222172B	m^3	Excavation of trench and shaft of a maximum 2 meters depth, in low compression resistant rock (<25 MPa), made with a hammer breaker and soil left to the side	15.88	0.55	8.73	141.54	77.85	9.38	5.16
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	0.55	3.72	173.53	95.44	10.71	5.89
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	1.00	10.58	141.54	141.54	18.33	18.33
11	m^3	Concrete for trenches and shafts, HA-25/P/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12	0.50	38.56	2041.74	1020.87	302.20	151.10
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.15	22.38	25.74	23.14	517.87	4.49	100.49
E31DC100	m^2	Formwork with timber planks for trenches and shaft foundations	19.04	2.00	38.08	157.94	315.88	1.55	3.10
2 TIE BEAMS					**489.31**		**8427.35**		**1174.85**
E222172B	m^3	Excavation of trench and shaft of a maximum 2 meters depth, in low compression resistant rock (<25 MPa), made with a hammer breaker and soil left to the side	15.88	1.67	26.55	141.54	236.65	9.38	15.68
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	1.67	11.30	173.53	290.14	10.71	17.91
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm, dumped from truck	10.58	3.04	32.16	141.54	430.28	18.33	55.72
11	m^3	Concrete for trenches and shafts, HA-25/P/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12	1.52	117.22	2041.74	3103.44	302.20	459.34
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	1.15	136.84	157.37	23.14	3166.48	4.49	614.41
E31DC100	m^2	Formwork with timber planks for trenches and shaft foundations	19.04	7.60	144.70	157.94	1200.34	1.55	11.78
TOTAL					**614.72**		**10596.80**		**1458.91**

A3 - 3.3. Prefabricated foundation (A1-14)

ISOLATED FOOTING: 0.40 x 0.40 x 0.40 m

Economic costs						Energetic costs		CO_2 eq emissions	
Code	**U.**	**Definition**	**€**	**U**	**€ $_{total}$**	**MJ**	**MJ $_{total}$**	**kg**	**kg $_{total}$**
1 ISOLATED FOOTING					**90.35**		**743.21**		**77.93**
E222172B	m^3	Excavation of trench and shaft of a maximum 2 meters depth, in low compression resistant rock (<25 MPa), made with a hammer breaker and soil left to the side	15.88	0.06	0.89	141.54	7.93	9.38	0.53
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	6.76	0.06	0.38	173.53	9.72	10.71	0.60
8	u	Precast isolated footing	63.59	1.00	63.59	175.59	175.59	26.89	26.89
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2		4.80		23.14	111.07	4.49	21.55
4	t	Precast foundation transport	23.66	0.16	3.90	420.80	69.35	25.88	4.27
6	u	Assembly of light precast concrete foundation	21.59	1.00	21.59	369.55	369.55	24.10	24.10
TOTAL					**90.35**		**743.21**		**77.93**

A3–4. Readjustment of BEDEC database items

1. The BEDEC database includes items on the transport of soil over some distances to an authorized waste management facility, in a 24-tonne lorry, with a waiting time for loading by mechanical means. However, there is no option for a distance of 30 km. Therefore, transport items were scaled to create an item for a 30 km distance.

Code	U.A.	Definition	€
1	m^3	Transport of soil over a distance of 30 km to an authorized waste management facility, in a 24-tonne lorry, with a waiting time for loading by mechanical means	6.76

2. The BEDEC database includes items on loading with mechanical means and transport of inert or ordinary waste over some distances to an authorized waste management facility, in a 20-tonne lorry. However, there is no option for a distance of 30 km. Therefore, items were scaled to create an item for a 30 km distance.

Code	U.A.	Definition	€
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	12.09

3. The BEDEC database includes precast piles of circular section, but not precast piles of square section. Therefore, it was considered that breaking a precast pile of circular section is similar to breaking a precast pile of square section. However, there is no precast concrete pile with a diameter of 30 cm in the database. Therefore, precast concrete pile items from the database were scaled to create an item of a precast pile of 30 cm diameter.

Code	U.A.	Definition	€
3	m	Pile head breaking, 30 x 30 cm	28.87

4. The BEDEC database does not include items on the transport of precast foundations. Transport was considered from the item "*Transport for precast concrete beams for distances from 100 to 150 km, in a 24-tonne lorry"* (G4LM1430).

Code	U.A.	Definition	€
4	t	Precast foundation transport	23.66

5. The BEDEC database does not include items on assembling precast foundations. Therefore, it was assumed that the assembly of precast heavy foundations (≥ 5 tonnes) was similar to that of a precast concrete beam: "Precast concrete beam with pre-stressed reinforcement, double T section, up to 20 m, inertia of 5,000,000 and 10,000,000 cm^4 and section of 3,000 and 4,000 cm^2, assembled by crane (G4L11197).

Code	U.A.	Definition	€
5	m	Assembly of heavy precast concrete foundation	18.13

6. It was assumed that the assembly of precast light foundations (< 5 tonnes) was similar to that of a precast inspection chamber: "Precast inspection chamber, 40x40x45 internal measurements and 4 cm thick, intended for wastewater disposal, precast concrete cover included, installed" (ED351430).

Code	U.A.	Definition	€
6	u	Assembly of light precast concrete foundation	21.59

7. Spanish and international companies were asked how much it would cost to build a precast linear foundation. (For more information, please see the next section). As shown in the table below, the steel reinforcement price is included in the price of the precast concrete linear foundation.

Code	U.A.	Definition	€
7	m^3	Precast linear foundation	368
E3EB3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	

8. The price of the precast isolated footing was provided by a Spanish precast company. It was considered that the isolated footing was made from pillar molds, and that the design has 78 precast isolated footings. Note that the steel reinforcement price is included in the footing price.

Code	U.A.	Definition	€
8	u	Precast isolated footing	63.59
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	

9. The BEDEC database does not include precast concrete piles of square section. Therefore, this item was considered: "Driving precast concrete piles, with a diameter of 30 cm, in sandy ground". The price of the precast pile (Ø 30 cm) has been changed for the price of a precast pile (30 x 30 cm). An ABB joint was also included. Data on the precast pile (30 x 30 cm) was provided by a Spanish precast pile company.

Code	U.A.	Definition	€
9	m	Driving a concrete pile (30 x 30 cm) with an ABB joint	75.40

These are the sub-items for this item:

Code	U.A.	Definition	Price	Quantity	€
A0140000	h	First officer	18.69	0.106	1.98
[1]	m	Precast concrete pile (30 x 30 cm)	60.00	1.00	60.00
[1]	u	ABB pile joint	0.07	160.00	10.67
C3E61000	h	Pile driver	50.95	0.053	2.70
A%AUX001	%	Labour-associated auxiliary expenses	1.98114	0.025	0.05
B3EE1410	m	Precast concrete pile (Ø 30 cm)	60.00	1.00	60.00

[1] Data on the precast pile (30 x 30 cm) was provided by a leading Spanish precast company that manufactures piles.

10. According to Item 9, a precast concrete pile (30 x 30 cm) of 15 m of length with an ABB joint costs 70.67 €/m. Therefore, the price for one cubic metre of pile is 785.22 m^3.

Code	U.A.	Definition	€
10	m^3	Precast concrete pile (30 x 30 cm) with an ABB joint	785.22
E3EB3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	

11. The BEDEC database includes an item on concrete trenches and shafts with HA-25/B/20/IIa concrete (E31522H1). However, there is no item on concrete trenches and shafts with HA-25/P/20/IIa. According to the BEDEC database, one cubic meter of HA-25/B/20/IIa concrete costs the same as one cubic meter of HA-25/P/20/IIa concrete. Therefore, the E31522H1 item was adapted.

Code	U.A.	Definition	€
11	m^3	Concrete for trenches and shafts, HA-25/P/20/IIa, soft consistency and maximum size of granulate of 20 mm, dumped from truck	77.12

A3 – 5. Precast linear foundation price

Spanish and international companies were asked how much it would cost to make a 10-m beam that could support a load of 110.89 kN/m. Companies provided the following information. The average of the figures given for a rectangular section beam by two Spanish companies was used (€350.00 + €386.08 = €368.04 ➞ **€368.00**).

Companies not specialized in linear foundations									
Image system	**Information**				**Precast Company (country)**			**Components**	
Project A1-10	**Rectangular beam**				**Precast Company 1 (ES)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	x
	169.60	10.04	1702.78	0.58	10.00	0.35	2.01	Transport	x
								Installation	x
	€	**m^3**	**€/m^3**					Total	1696.00
	1702.78	2.01	846.10					**Mat. €/m^3**	**x**
	The price include metallic connectors / 10 units							Mat. €/m	x
	T inverted beam (b = 1.00 m)				**Precast Company 2 (ES)**				
	€/m	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	981.75
	140.25	10.00	1402.50		10.00		2.55	Transport	102.00
								Installation	318.75
	€	**m^3**	**€/m^3**					Total	1402.50
	1402.50	2.55	550.00					**Mat. €/m^3**	**385.00**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units							Mat. €/m	98.18
	Rectangular beam (b = 1.00 m)				**Precast Company 2 (ES)**				
	€/m	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	875.00
	125.00	10.00	1250.00	1.00	10.00	0.25	2.50	Transport	100.00
								Installation	275.00
	€	**m^3**	**€/m^3**					Total	1250.00
	1250.00	2.50	500.00					**Mat. €/m^3**	**350.00**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units							Mat. €/m	87.50
	Rectangular beam (b = 1.00 m)				**Precast Company 3 (ES)**				
	€/m	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	965.21
	96.52	10.00	965.21	1.00	10.00	0.25	2.50	Transport	62.37
								Installation	143.27
	€	**m^3**	**€/m^3**					Total	1170.85
	965.21	2.50	386.08					**Mat. €/m^3**	**386.08**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units							Mat. €/m	96.52
	T inverted beam (b = 1.00				**Precast Company 3 (ES)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	1750.00
	195.56	10.00	1955.63		10.00		2.55	Transport	62.37
								Installation	143.26
	€	**m^3**	**€/m^3**					Total	1955.63
	1955.63	2.55	766.91					**Mat. €/m^3**	**686.27**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units / carpenter work							Mat. €/m	175.00
	T inverted beam (b = 0.66 m)				**Precast Company 4 (ES)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	x
	300.00	10.00	3000.00		10.00		3.98	Transport	x
								Installation	x
	€	**m^3**	**€/m^3**					Total	3000.00
	3000.00	3.98	753.77					**Mat. €/m^3**	**x**
								Mat. €/m	x
VAT excluded									

Table 1. Companies not specialized in linear foundations.

Companies specialized in linear foundations									
Image system	**Information**				**Precast Company (country)**			**Components**	
	T inverted beam (b = 1.50 m)				**Company 5 (NL)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	950.00
	125.50		1255.00				3.30	Transport	165.00
								Installation	140.00
	€	**m^3**	**€/m^3**					Total	1255.00
	1255.00	3.30	380.30					**Mat. €/m^3**	**287.88**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units							Mat. €/m	95.00
	T inverted beam (b = 1.00 m)				**Company 5 (NL)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	712.50
	98.00		980.00		10.00		2.55	Transport	127.50
								Installation	140.00
	€	**m^3**	**€/m^3**					Total	980.00
	980.00	2.55	384.31					**Mat. €/m^3**	**279.41**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 30 units							Mat. €/m	71.25
	Rectangular beam				**Company 6 (NL)**				
	**€/m**	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	703.13
	85.94	10.00	859.38	x	10.00	x	x	Transport	46.88
								Installation	109.38
	€	**m^3**	**€/m^3**					Total	859.38
	859.38	x	x					**Mat. €/m^3**	**x**
	Qa=1.2 kg/cm2 / 81 km / 110.09 kN/m / 32 units							Mat. €/m	70.31
	Rectangular beam (b = 0.40 m)				**Company 7 (UK)**				
	€/m	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	968.36
	**108.55**	10.00	1085.50	0.50	10.00	0.40	2.00	Transport	156.19
								Installation	249.90
	€	**m^3**	**€/m^3**					Total	1374.45
	1085.50	2.00	542.75					**Mat. €/m^3**	**484.18**
								Mat. €/m	96.84
	**Rectangular beam / post-tensioned**				**Company 8 (UK)**				
	€/m	**m**	**€**	**Width**	**Length**	**Height**	**m^3**	Material	x
	112.46	10.00	1124.55	x	x	x	x	Transport	x
								Installation	x
	€	**m^3**	**€/m^3**					Total	1124.55
	1124.55	x	x					**Mat. €/m^3**	**x**
	This price is based on a piled solution and includes breaking the pile.							Mat. €/m	x
VAT excluded									

Table 2. Companies specialized in linear foundations.

A3 – 6. Environmental impact of precast concrete

Environmental impact of precast concrete (isolated footing) – 1.60 x 1.60 m

Items	MJ	Kg CO_2 eq
Concrete HA-40/F/20/IIa	2529.44	412.10
Mold	56.02	2.82
Factory machinery and coffering removal agent	131.90	6.57
Skid loader	0.14	0.01
TOTAL	**2717.50**	**421.49**

Table 3. Environmental impact of precast concrete (isolated footing).

Environmental impact of precast concrete (beam) - 0.40 x 0.55 x 10.00 m

Items	MJ	Kg CO_2 eq
Concrete HA-40/F/20/IIa	2529.44	412.10
Mold	86.12	4.33
Factory machinery and coffering removal agent	154.68	7.70
Skid loader	0.11	0.01
TOTAL	**2770.12**	**424.14**

Table 4. Environmental impact of precast concrete (beam).

Materials: We considered a HA-40/F/20/IIa concrete with: 160 l of water, 400 kg of cement I 52,5R, 875 kg of aggregate from 0 to 5 mm, 200 kg of aggregate from 5 to 12 mm, 750 kg of aggregate from 12 to 20 mm, 5 l of admixtures. We took into account the extraction, production and transport of materials from the production-site to the construction site [Kellenberger, 2009] as production-site to factory. **Factory machinery and coffering removal agent:** Concrete mixer, admixture dispenser, concrete skip and bridge cranes. And coffering removal agent: 40 m^2/l. **Molds:** They were made of Fe 470 and Fe 360. We established a depreciation of 250 uses. Transport of the precast foundation to the construction-site is not considered in these items.

Figure 1. Precast isolated footing mold. Figure 2. Precast beam mold.

A3 – 7. Environmental impact of construction items

In this section, it is shown how environmental data of construction items has been calculated. Two indicators are studied: the embodied energy (MJ) and greenhouse gas emissions (CO_2 equivalent). Information of construction items is organized in colours:

Construction item
Construction items and sub-items from BEDEC database
Data entered into SIMAPRO software

The study considers the extraction, production and transport of materials from the production site to the construction site or factory. The following distances for materials were considered [Kellenberger, 2009]: cement (75 km), admixtures (100 km), gravel and sand (45 km) and reinforcing steel (131 km), construction steel (188 km) and sawn timber (48 km).

The foundation construction processes and the associated machinery were also considered, as well as the depreciation of mold or formwork. In the case of precast foundations, the transport of the foundation from the factory to the construction site [QPA, 2008] and its assembly was also taken into account.

The diesel consumption of construction work machinery (MJ) was calculated from BEDEC database [ITeC, 2015]. The lorry consumption was taken from the Ecoinvent v3 database [Ecoinvent, 2015]. The proportioning of concrete was provided by two Spanish concrete companies, and verified with the regulations [EHE-08, 2011]. The impact of admixtures was taken from http://efca.info/publications.html (Accessed: 25/10/2015). The impact of materials and processes was looked up in the Ecoinvent v3 database. All of this data was calculated with SIMAPRO software [SIMAPRO, 2015].

The Ecoinvent database only includes one precast concrete that is reinforced and not specifically designed for foundations. Therefore, the environmental impact of precast concrete for foundations was calculated. To do this calculation, the materials, processes, machinery and time needed to construct a precast beam of 0.4 x 0.55 x 10.00 metres were taken into account. The beam was not designed for foundations, but was constructed in the same way. The impact of the mold was considered, and a depreciation rate of 250 uses was established. In addition, the distances of the materials were used, drawn from Kellenberger [Kellenberger, 2009]. The rebar was not considered, as it is calculated separately for each foundation. All precast foundations in the three cases would have been produced in molds similar to those of precast beams. Therefore, the environmental impact of prefabricated beams (MJ and kilogrammes of CO_2 equivalent) was considered for all precast foundations.

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
1	m^3	Transport of soil to an authorized waste management facility, with a 24-tonne lorry and waiting time for loading by mechanical means, for a distance of 30 km	173.53	10.71
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
C1501A00	h	24-tonne lorry	~~123.15~~	~~32.17~~

Ecoinvent database items	**t**	**km**	**tkm**
Transport, freight, lorry 16-32T, EURO5/RER6	2.00	30.00	60.00
	MJ		
Energy, from diesel burned in machinery/RER Economic (skid loader)	7.71		
Comments			
Excavation items leave the soil on the edge of the plot. Therefore, a skid loader is added to load the soil onto the lorry			

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
2	m^3	Loading with mechanical means and transport of inert or ordinary waste over a distance of 30 km to an authorized waste management facility, in a 20-tonne lorry	197.96	12.21
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
C1501900	h	20-tonne lorry	~~193.39~~	~~50.51~~
C1311440	h	Skid loader	7.71	~~2.01~~

Ecoinvent database items			
Definition	**t**	**km**	**tkm**
Transport, freight, lorry 16-32T, EURO5/RER6	2.30	30.00	69.00
	MJ		
Energy, from diesel burned in machinery/RER Economic (skid loader)	7.71		

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E222142B	m^3	Digging a trench and a shaft of a maximum 2 meters depth, in a compact ground (SPT 20-50), made with a backhoe and soil left to the side	63.30	4.20
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
C1313330	h	Backhoe (8 -10 t)	45.80	~~11.96~~

Ecoinvent database items	
Definition	**MJ**
Energy, from diesel burned in machinery/RER Economic	45.80

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E222122B	m^3	Excavation of a trench and a shaft of a maximum 2 meters depth, in a soft ground (SPT <20), made with a backhoe and soil left to the side	53.75	3.56
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
C1313330	h	Backhoe (8 -10 t)	38.89	~~10.16~~
Ecoinvent database item				
Definition				**MJ**
Energy, from diesel burned in machinery/RER Economic				38.89

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E222172B	m^3	Excavation of trench and shaft of a maximum 2 meters depth, in low compression resistant rock (<25 MPa), made with a hammer breaker and soil left to the side	141.54	9.38
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
C1103331	h	Backhoe (8 -10 t), with a hammer breaker	89.88	~~23.48~~
C1313330	h	Backhoe (8 -10 t)	12.53	~~3.27~~
Ecoinvent database item				
Definition				**MJ**
Energy, from diesel burned in machinery/RER Economic				102.41

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E225277F	m^3	Landfill and compression of trenches and shafts with suitable ground, in successive layers up to 25 cm, with a compaction of 95%	48.66	3.23
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
C1316100	h	Skid steer (2 - 5.9 t)	4.87	~~1.27~~
C133A0J0	h	Rammer (30 x 30 cm)	30.43	~~7.95~~
Ecoinvent database item				
Definition				**MJ**
Energy, from diesel burned in machinery/RER Economic (machinery)				35.30

<table>
<tr><td colspan="6">Construction item</td></tr>
<tr><td>Code</td><td>Units</td><td colspan="2">Definition</td><td>MJ</td><td>kg</td></tr>
<tr><td>E3EZ1800</td><td>u</td><td colspan="2">Displacement, assembly and dismantling of pile driver for fight auger piles</td><td>2773.83</td><td>156.30</td></tr>
<tr><td colspan="6">Construction sub-item</td></tr>
<tr><td>Code</td><td>Units</td><td colspan="2">Definition</td><td>MJ</td><td>kg</td></tr>
<tr><td>C3EZ1800</td><td>u</td><td colspan="2">Displacement, assembly and dismantling of pile driver for fight auger piles</td><td><s>1720.33</s></td><td><s>449.35</s></td></tr>
<tr><td colspan="6">Ecoinvent database item</td></tr>
<tr><td colspan="3"></td><td>t/m^3</td><td>km</td><td>tkm/m^3</td></tr>
<tr><td colspan="3">Transport, freight lorry >32 metric ton, EURO6 RER</td><td>100.00</td><td>600.00</td><td>60000.00</td></tr>
<tr><td colspan="6">Comments</td></tr>
<tr><td colspan="6">Transport, assembly and dismantling of pile driver was calculated as a lorry. It has been calculated on the basis of 600 km distance (average provided by a Spanish pile company) and 31 piles.</td></tr>
</table>

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E3E5847E	m	Drilling and concreting of continuous fight auger piles on soft soil, in 45 cm diameter with HA-30/ L/10/IIa+Qb concrete with a superplasticizer additive, of liquid consistency and maximum size of granules of 10 mm.	1182.29	112.63
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
B065CA2E	m^3	HA-30/L/10/IIa+Qb concrete, liquid consistency, maximum size of granulate of 10 mm, with a superplasticizer additive and dumped from truck	~~440.40~~	~~80.35~~
C3E58400	m	Drilling and installation of materials, equipment and machinery for continuous fight auger piles with a diameter of 45 cm	483.86	~~126.38~~
Ecoinvent database items				
Definition	**kg/m^3**	**m^3**	**kg/m^3**	**kg/m^3 (x 0.20)**
Water	160.00	1.05	168.00	33.60
Gravel	950.00	1.05	997.50	199.50
Sand	900.00	1.05	945.00	189.00
	325.00	1.05	341.25	68.25
	l/m^3	**kg/m^3**	**MJ/m^3**	**MJ**
Electricity. medium voltage. production ES, at grid/ES U (admixture)	2.10	2.52	11.59	2.32
Electricity. medium voltage. production ES, at grid/ES U (admixture)	3.15	3.28	59.95	11.99
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)	1.94	45.00	87.41	17.48
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (cement)	0.34	75.00	25.59	5.12
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (concrete)	2.46	30.00	73.73	14.75
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)	0.01	100.00	0.58	0.12
	MJ			
Diesel, burned in building machine/GLO U (machinery)	483.86			
Comments				
It has been considered a reduction in volume of 5% during the curing To build one linear meter of a continuous fight auger pile, 0.1988 m^3 of concrete is needed (BEDEC database)				

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E3F515H1	m^3	Concrete for caps, HA-25/B/20/IIa, of soft consistency and maximum size of granulate of 20 mm and dumped from truck	2342.22	317.17
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
B065960B	m3	HA-25/B/20/IIa concrete, soft consistency and maximum size of granulate of 20 mm.	~~1470.25~~	~~269.44~~

Ecoinvent database items			
Definition	**kg/m^3**	**m^3**	**kg/m^3**
Water	165.00	1.05	173.25
Gravel	950.00	1.05	997.50
Sand	950.00	1.05	997.50
Cement	275.00	1.05	288.75
	l/m^3	**l/m^3**	**kg/m^3**
Electricity. medium voltage. production ES, at grid/ES U (admixture)	2.10	2.52	11.59
Electricity. medium voltage. production ES, at grid/ES U (admixture)	1.05	1.09	19.98
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)	2.00	45.00	89.78
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (cement)	0.29	75.00	21.66
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)	0.00	100.00	0.36
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (concrete)	2.46	30.00	73.82

Comments
It has been considered a reduction in volume of 5% during the curing

Construction item					
Code	**Units**	**Definition**		**MJ**	**kg**
E3Z112P1	m^2	Levelling base course of 10 cm and HL-150/P/20 concrete with plastic consistency and maxim granulate of 20 mm and dumped from truck		141.54	18.33
Construction sub-item					
Code	**Units**	**Definition**		**MJ**	**kg**
B06NLA2C	m3	HL-150/P/20 concrete, plastic consistency, cement 150 kg/m^3, and maxim granulate of 20 mm and dumped from truck		95.21	15.02

Ecoinvent database items				
Definition	**kg/m^3**	**m^3**	**kg/m^3**	**kg/m^3 (x 0.10)**
Water	100.00	1.05	105.00	10.50
Gravel	950.00	1.05	997.50	99.75
Sand	950.00	1.05	997.50	99.75
Cement	155.00	1.05	162.75	16.28
	l/m^3	**kg/m^3**	**MJ/m^3**	**MJ**
Electricity. medium voltage. production ES, at grid/ES U (admixture)	2.10	2.52	11.59	1.16
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)	2.00	45.00	89.78	8.98
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (cement)	0.16	75.00	12.21	1.22
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)	0.00	100.00	0.25	0.03
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (concrete)	2.27	30.00	67.96	6.80
Comments				
It has been considered a reduction in volume of 5% during the curing It is considered a base course of 10 cm high				

<table>
<tr><td colspan="5">Construction item</td></tr>
<tr><td>Code</td><td>Units</td><td>Definition</td><td>MJ</td><td>kg</td></tr>
<tr><td>11</td><td>m^3</td><td>Concrete for trenches and shafts, HA-25/P/20/IIa, soft consistency and maximum size of granulate of 20 mm and dumped from truck</td><td>2041.74</td><td>302.20</td></tr>
<tr><td colspan="5">Construction sub-item</td></tr>
<tr><td>Code</td><td>Units</td><td>Definition</td><td>MJ</td><td>kg</td></tr>
<tr><td>B065960C</td><td>m^3</td><td>HA-25/B/20/IIa concrete, soft consistency and maximum size of granulate of 20 mm.</td><td>~~1470.25~~</td><td>~~269.44~~</td></tr>
<tr><td colspan="5">Ecoinvent database items</td></tr>
<tr><td colspan="2">Definition</td><td>kg/m³</td><td>m³</td><td>kg/m³</td></tr>
<tr><td colspan="2">Water</td><td>160.00</td><td>1.05</td><td>168.00</td></tr>
<tr><td colspan="2">Gravel</td><td>950.00</td><td>1.05</td><td>997.50</td></tr>
<tr><td colspan="2">Sand</td><td>950.00</td><td>1.05</td><td>997.50</td></tr>
<tr><td colspan="2">Cement</td><td>275.00</td><td>1.05</td><td>288.75</td></tr>
<tr><td colspan="2"></td><td>l/m³</td><td>l/m³</td><td>kg/m³</td></tr>
<tr><td colspan="2">Electricity. medium voltage. production ES, at grid/ES U (admixture)</td><td>2.10</td><td>2.52</td><td>11.59</td></tr>
<tr><td colspan="2"></td><td>t/m³</td><td>km</td><td>tkm/m³</td></tr>
<tr><td colspan="2">Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)</td><td>2.00</td><td>45.00</td><td>89.78</td></tr>
<tr><td colspan="2"></td><td>t/m³</td><td>km</td><td>tkm/m³</td></tr>
<tr><td colspan="2">Transport, freight, lorry 16-32T, EURO5/RER6 (cement)</td><td>0.29</td><td>75.00</td><td>21.66</td></tr>
<tr><td colspan="2"></td><td>t/m³</td><td>km</td><td>tkm/m³</td></tr>
<tr><td colspan="2">Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)</td><td>0.00</td><td>100.00</td><td>0.25</td></tr>
<tr><td colspan="2"></td><td>t/m³</td><td>km</td><td>tkm/m³</td></tr>
<tr><td colspan="2">Transport, freight, lorry 16-32T, EURO5/RER6 (concrete)</td><td>2.45</td><td>30.00</td><td>73.63</td></tr>
<tr><td colspan="5">Comments</td></tr>
<tr><td colspan="5">It has been considered a reduction in volume of 5% during the curing</td></tr>
</table>

Construction item					
Code	**Units**	**Definition**		**MJ**	**kg**
E31DC100	m^2	Formwork with timber planks for trenches and shaft foundations		157.94	1.55
Construction sub-items					
Code	**Units**	**Definition**		**MJ**	**kg**
B0A14300	kg	Steel wire Ø 3 mm		~~4.34~~	~~0.35~~
B0A31000	kg	Steel nail		~~5.25~~	~~0.42~~
B0D21030	m	Pine wooden plank (10 uses)		~~11.64~~	~~0.33~~
B0D31000	m^3	Pine batten		~~5.51~~	~~0.16~~
B0DZA000	l	Coffering removal agent		~~2.55~~	~~0.38~~
Ecoinvent database items					
Definition				**kg**	**m^3**
Three layered laminated board RER				4.7188	0.01
				kg	
Metal working, average for steel product manufacturing [RER]				0.25	
				kg	
Steel				0.25	
			t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (wood)			0.00	48.00	0.23
			t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (steel)			0.00	188.00	0.05
				MJ	
Electricity, medium voltage, production ES, at grid/ES U (coffering removal agent)				2.55	
Comments					
Steel wire and steel nail were considered steel					

Construction item

Code	Units	Definition	MJ	kg
x	m^3	HA-40/F/20/IIa concrete, fluid consistency and maximum size of granulate of 20 mm	2529.44	412.10

Ecoinvent database items

Definition	kg/m^3	m^3	kg/m^3
Water	160.00	1.05	168.00
Gravel	950.00	1.05	997.50
Sand	875.00	1.05	918.75
Cement	400.00	1.05	420.00
	l/m^3	**l/m^3**	**kg/m^3**
Electricity. medium voltage. production ES, at grid/ES U (admixture)	3.15	3.78	17.39
Electricity. medium voltage. production ES, at grid/ES U (admixture)	2.10	2.18	39.97
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)	1.92	45.00	86.23
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (cement)	0.42	75.00	31.50
	t/m^3	**km**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)	0.01	100.00	0.60

Comments

It has been considered a reduction in volume of 5% during the curing
The transport of precast foundations is considered in item 4
There is no concrete with this characteristics in BEDEC database

Construction item

Code	Units	Definition	MJ	kg
5	m	Assembly of heavy precast concrete foundation	208.30	13.58

Construction sub-item

Code	Units	Definition	MJ	kg
C150G800	h	Self-propelled crane (12 t)	267.79	~~69.31~~

Ecoinvent database item

Definition	MJ
Energy, from diesel burned in machinery/RER Economic	267.79

Comments

The installation was taken from the item G4L113EA (BEDEC/ITeC)

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
6	u	Assembly of light precast concrete foundation	369.55	24.10
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
C1503500	h	Self-propelled crane (5 t)	150.94	~~39.42~~
Ecoinvent database item				
Definition				**MJ**
Energy, from diesel burned in machinery/RER Economic				150.94
Comments				
The installation was taken from the item ED351430 (BEDEC/ITeC)				

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
4	t	Precast foundation transport	420.80	25.88
Construction sub-item				
Definition		**t**	**km**	**tkm**
Transport, lorry 16-32T, EURO5/RER6 (155 km)		1	155	**155**

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E3EZA040	m	Pile head breaking, in 45 cm diameter	48.46	3.21
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
C1101200	h	Two jackhammers and a compressor	35.06	~~9.16~~
Ecoinvent database item				
				MJ
Diesel, burned in building machine/GLO U				35.06

Construction items				
Code	**Units**	**Definition**	**MJ**	**kg**
3	m	Pile head breaking, 30 x 30 cm	36.28	2.37
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
C1101200	h	Two jackhammers and a compressor	26.29	~~6.87~~
Ecoinvent database items				
				MJ
Diesel, burned in building machine/GLO U				26.29

Construction items				
Code	**Units**	**Definition**	**MJ**	**kg**
E31B3000	kg	AP500 S steel reinforcement for trenches and shafts, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	23.14	4.49
E3FB3000	kg	AP500 S steel reinforcement for caps, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	23.14	4.49
E3EB3000	kg	AP500 S steel reinforcement for piles, formed by B500S corrugated steel bars with yield >= 500 N/mm^2	23.14	4.49
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
B0A14200	kg	Steel wire Ø1.3 mm	~~4.87~~	~~1.27~~
D0B2A100	kg	B500S corrugated steel bars with yield >= 500 N/mm^2	~~30.43~~	~~7.95~~

Ecoinvent database items			
Definition	**kg**		
Metal working, average for steel product manufacturing [RER]	1.00		
	t	**km**	**tkm**
Transport, freight, lorry 16-32T, EURO5/RER6	0.0010	131.0000	0.1310
Comments			
It has been considered same data for these three construction items Steel wire has been counted as steel rebar due to its little impact			

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
E3EZ3A00	u	Displacement, assembly and dismantling of pile driver for fight auger piles	2773.83	156.30
Construction sub-item				
Code	**Units**	**Definition**	**MJ**	**kg**
E3EZ1800	u	Displacement, assembly and dismantling of pile driver for fight auger piles	~~1720.33~~	~~449.35~~

Ecoinvent database item			
	t/m^3	**km**	**tkm/m^3**
Transport, freight lorry >32 metric ton, EURO6 RER	100.00	600.00	60000.00
Comments			
Transport, assembly and dismantling of pile driver was calculated as a lorry. It has been calculated on the basis of 600 km distance (average provided by a Spanish pile company) and 31 piles.			

Construction item				
Code	**Units**	**Definition**	**MJ**	**kg**
9	m	Driving a concrete pile (30 x 30 cm) with an ABB joint	533.89	92.10
Construction sub-items				
Code	**Units**	**Definition**	**MJ**	**kg**
~~B3EE1410~~	~~m~~	~~Precast concrete pile with a diameter of 30 cm~~	~~709.31~~	~~62.64~~
C3E61000	h	Pile driver	8.23	2.15

Ecoinvent database items				
Definition	**kg/m^3**	**m^3**	**kg/m^3**	**kg/m^3 (x 0.09)**
Water	160.00	1.05	168.00	15.12
Gravel	950.00	1.05	997.50	89.78
Sand	875.00	1.05	918.75	82.69
Cement	400.00	1.05	420.00	37.80
	l/m^3	**kg/m^3**	**MJ/m^3**	**MJ**
Electricity. medium voltage. production ES, at grid/ES U (admixture)	3.15	3.78	17.39	1.56
Electricity. medium voltage. production ES, at grid/ES U (admixture)	2.10	2.18	39.97	3.60
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (gravel+sand)	1.92	45.00	86.23	7.76
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (cement)	0.42	75.00	31.50	2.84
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (concrete)	2.51	155.00	389.08	35.02
	t/m^3	**km**	**tkm/m^3**	**tkm/m^3**
Transport, freight, lorry 16-32T, EURO5/RER6 (admixtures)	0.01	100.00	0.60	0.05
			kg	
Reinforcing steel [RER] production alloc def u			11.99	
			kg	
Metal working, average for steel product manufacturing [RER]			11.99	
	t	**km**	**tkm**	
Transport, freight, lorry 16-32T, EURO5/RER6 (steel)	0.0010	131.0000	0.1310	
	MJ			
Diesel, burned in building machine/GLO U (pile driver)	8.23			

Comments
It has been considered a reduction in volume of 5% during the curing The section of the pile is square (0.09 m^3) It is considered the impact of the precast pile reinforcement