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European Technical Assessment

ETA 17/0660 of 19.02.2018

General part

Technical Assessment Body issuing the ETA: ITeC	
ITeC has been designated according to Article 29 of Regulation (EU) No 305/2011 and is member of EOTA (European Organisation for Technical Assessment)	
Trade name of the construction product	**Piloedre®**
Product family to which the construction product belongs	1 – Precast normal / lightweight / autoclaved aerated concrete products
Manufacturer	**2PE Pilotes SL** Av. Maresme 9 ES-08396 Sant Cebrià de Vallalta (Barcelona) Spain
Manufacturing plant(s)	Av. Maresme 9 ES-08396 Sant Cebrià de Vallalta (Barcelona) Spain
This European Technical Assessment contains	20 pages including 3 annexes which form an integral part of this assessment.
This European Technical Assessment is issued in accordance with Regulation (EU) 305/2011, on the basis of	European Assessment Document 010028-00-0103 *Shallow and reusable foundation kit for lightweight structures.*

General comments

Translations of this European Technical Assessment in other languages shall fully correspond to the original issued document and should be identified as such.

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Specific parts of the European Technical Assessment

1 Technical description of the product

Piloedre® is a shallow foundation kit made of a precast reinforced concrete block passed through by four steel tubes hammered diagonally into the ground.

The precast concrete block is partially or completely buried into the ground and it includes the connection elements to support a lightweight structure.

There are three types of concrete block in accordance with the connection system to the structure. The dimensions of the concrete blocks are shown in the table below.

Type	Connection system to the structure	Length x width (mm)	Height (mm)
PM1	1 hexagon nut at the centre of the top surface	260 x 260	280 to 320
PM5	1 hexagon nut at the centre of the top surface and 4 perimeter hexagon nuts.	260 x 260	280 to 320
PP4 (*)	Central hole through the block	260 x 260	280 to 320

(*) Combinations between model PP4 and other models are possible. For example, model PP4 with 4 perimeter hexagon nuts.

Table 1.1: Concrete block types.

The steel tubes pass through the block and penetrate the ground with an inclination of approximately 40º referred to the vertical and up to an approximate depth of 70 cm or 90 cm depending on the tube length, constituting a shallow foundation.

The type of tube to be used in each case will be specified case by case.

The system has the following accessories: plastic plugs for the top of the tubes and sealant for the joint between plastic plug and precast concrete block.

The foundation kit and its components are described in Annex A.

The foundation kit is reusable.

The lightweight structure is supported by the required number of foundation units.

In the manufacturing of the precast concrete block, the required embedment depth in the ground and soil quality must be taken into account to ensure a sufficient freeze-thaw resistance.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer’s instructions or (in absence of such instructions) according to the usual practice of the building professionals.

2 Specification of the intended use(s) in accordance with the applicable European Assessment Document (hereinafter EAD)

Piloedre® is intended for use as shallow foundation of permanent or temporal lightweight structures.

The provisions made in this ETA are based on an assumed working life of at least 50 years for Piloedre®. These provisions are based upon the current state of the art and the available knowledge and experience.

The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

3 Performance of the product and reference to the methods used for its assessment

Performance of Piloedre® related to the basic requirements for construction works (hereinafter BWR) 1 and 2 of Regulation (EU) Nº 305/2011 were determined according to European Assessment Document 010028-00-0103 *Shallow and reusable foundation kit for lightweight structures*. Essential characteristics of Piloedre® are indicated in table 3.1.

Basic Works Requirement	**Essential characteristic**	**Performance**
BWR 1 Mechanical resistance and stability	Compression resistance of the concrete block to point loads	200,0 kN
	Compression resistance of the concrete block to surface loads	200,0 kN
	Compression resistance (failure by cave-in of the foundation unit)	See annex B
	Tensile resistance of the concrete block	≤ 49,5 kN
	Tensile resistance (failure by pulling the foundation unit out)	See annex B
	Bending resistance	See annex B
	Resistance to horizontal efforts	See annex B
	Maximum compression load for a given foundation displacement	See annex B
	Maximum compression load allowing the steel tubes to be reused	See annex B
	Maximum tensile load allowing the steel tubes to be reused	See annex B
	Protection against corrosion	See annex B
	Prevention of the cracking of the concrete blocks	See annex B
BWR 2 Safety in case of fire	Reaction to fire	A1

Table 3.1: Performance of Piloedre®.

The methods used to determine the performance regarding protection against corrosion of the kit are based on available and well-known standard methods for concrete and steel products.

4 Assessment and verification of constancy of performance (hereinafter AVCP) system applied, with reference to its legal base

According to the Decision 1999/94/EC amended by Decision 2012/202/EU, as amended of the European Commission[1], the systems of AVCP (see EC delegated regulation (EU) No 568/2014 amending Annex V to Regulation (EU) 305/2011) given in the following table applies.

Product	Intended use(s)	System
Piloedre®	Shallow and reusable foundation kit for lightweight structures	2+

Table 4.1: Applicable AVPC system.

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

All the necessary technical details for the implementation of the AVCP system are laid down in the *Control Plan* deposited with the ITeC[2], with which the factory production control shall be in accordance.

Any change in the manufacturing procedure which may affect the properties of the product shall be notified and the necessary type-testing revised according to the *Control Plan*.

Issued in Barcelona on 19 February 2018

by the Catalonia Institute of Construction Technology.

ITeC
Institut de Tecnologia de la Construcció de Catalunya

Ferran Bermejo Nualart

Technical Director, ITeC

[1] Official Journal of the European Union (OJEU) L29/55 of 03/02/1999.
Official Journal of the European Union (OJEU) L109/22 of 21/04/2012.

[2] The *Control Plan* is a confidential part of the ETA and is only handed over to the notified certification body involved in the assessment and verification of constancy of performance.

ANNEX A: DESCRIPTION OF PILOEDRE®

A.1 Material properties and dimensions

The figures of the shallow foundation kit and of its incorporation into the ground can be seen below.

Figure A.1: Shallow foundation kit.

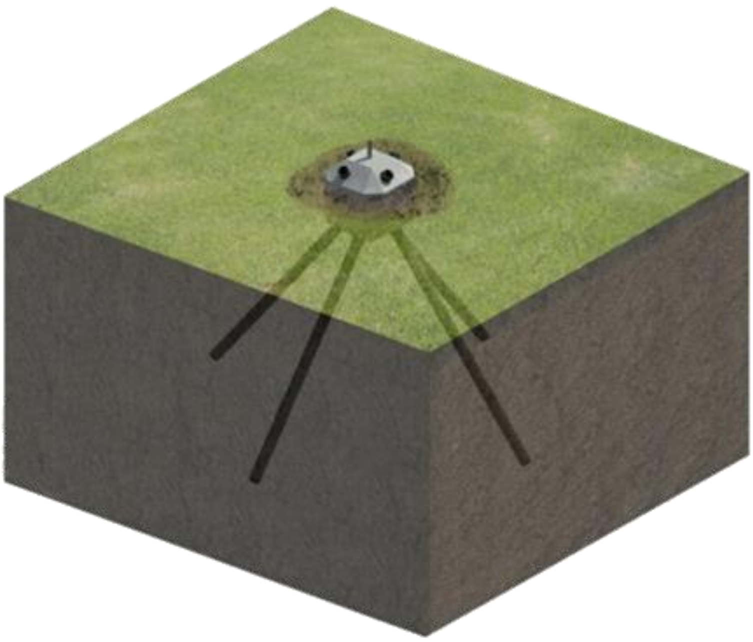

Figure A.2: Shallow foundation kit into the ground.

A.1.1 Concrete block

The compressive strength of the concrete used in the block is ≥ 30 N/mm^2.

The main characteristics of the components used in the manufacturing of the concrete are:

- Type of cement, bearing the CE marking in accordance with EN 197-1.
- Size of aggregates, bearing the CE marking in accordance with EN 12620.
- Water.
- Type of additives used, bearing the CE marking in accordance with EN 934-2.
- Fibres for concrete for structural purposes, bearing the CE marking in accordance with EN 14889-2.
- Fibres for concrete for cracking control.

Steel rebars are used for the perimetral reinforcement of the block.

Different types of concrete blocks are possible depending on the number of connections to the structure above and on the block height.

The connections to the structure supported on the concrete block are made by means of hexagon nuts embedded in the concrete block, whose dimensions are typically M16 but can be modified. These nuts are connected to threaded rods inside the concrete block. The number of nuts in the concrete block can be 1, 4 or 5 according to the type of block. Nuts and threaded rods can be of galvanised or stainless steel.

The nominal dimensions of the concrete block are the following:

- Length x width: (260 mm ± 10 %) x (260 mm ± 10 %).
- Height: between 280 mm and 320 mm.

The concrete block is passed through by 4 diagonal holes in order to allow the use of steel tubes through it.

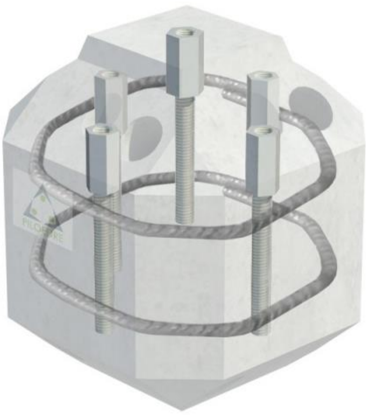

Figure A.3: Typical distribution of steel reinforcements and connections (5) in the concrete block.

A.1.2 Steel tubes

The steel tubes to be used when anchoring the concrete block to the ground are made of galvanised steel quality N80 in accordance with API 5CT, with a minimum yield strength of 500 N/mm^2.

The following types of steel tubes are possible:

<table>
<tr><th>Type of steel tube</th><th>Outer diameter (mm)</th><th>Thickness (mm)</th><th>Length (mm) (*)</th></tr>
<tr><td>1</td><td rowspan="4">42,9</td><td rowspan="4">Between 2,9 and 7,0</td><td>900</td></tr>
<tr><td>2</td><td>1.200</td></tr>
<tr><td>1 special</td><td>900</td></tr>
<tr><td>2 special</td><td>1.200</td></tr>
<tr><td colspan="4">(*) Steel tubes up to 1.500 mm are possible depending on the type of soil.</td></tr>
</table>

Table A.1: Dimensions of the steel tubes.

ANNEX B: MECHANICAL PERFORMANCE OF THE FOUNDATION KIT IN SERVICE CONDITIONS

This annex deals with the following mechanical performance of the foundation kit, in accordance with table 3.1:

1. Compression resistance (failure by cave-in of the foundation unit)
2. Tensile resistance (failure by pulling the foundation unit out)
3. Bending resistance
4. Resistance to horizontal efforts
5. Maximum compression load for a given foundation displacement
6. Maximum compression load allowing the steel tubes to be reused
7. Maximum tensile load allowing the steel tubes to be reused
8. Protection against corrosion
9. Prevention of the cracking of the concrete blocks

The mechanical performance #1 to #5 are indicated in tables B.1 to B.5. They have been obtained from the application of the calculation methods of Annex C.

The mechanical performance #6 to #9 must be obtained from the application of the calculation methods of clauses C.6 to C.9 of Annex C, respectively. This performance need to be determined case by case from the mechanical properties of the soil, the foundation depth (distance from the top of the soil to the bottom of the concrete block) and the dimensions (thickness, diameter and length) of the steel tubes.

The mechanical performance #1 to #5 depend on the dimensions of the steel tubes, the foundation depth and the mechanical properties of the soil in which the foundation kit is to be installed. The mechanical properties of the soil are defined by the combination of the following characteristics:

- Internal friction angle (ϕ)
- Cohesion (c)
- Winkler modulus (K)
- Soil density (γ)

Interpolation between values within the same table is possible. Extrapolation is not allowed.

The Ultimate Limit States approach is considered and the resistance values in the tables are characteristic values (R_k) (the safety factors are not applied). Safety factors are established at National level.

The upper values of the performance of Piloedre® in tables B.1 to B.4 are limited by the holder. The designer of the kit should consider the maximum performance values of the concrete block in table 3.1 (the compression resistance of the concrete block to point loads, to surface loads, and the tensile resistance of the concrete block) during the design procedure.

The contribution of the passive earth pressure surrounding the concrete block is not considered in the resistance to horizontal efforts.

The performance of the installed kit shown in the tables have been determined considering that only the equivalent effort is applied, e.g.: the compression resistance (failure by cave-in of the foundation kit) is determined considering that only a compression effort is applied to the foundation kit.

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Performance of Piloedre® (R_{k1}, R_{k2}, R_{k3}, R_{k4})								
Cohesion (C) [kPa]	Essential characteristic	Soil density (γ) [kN/m³] = 15,0				Foundation depth [m] = 0,20		
		Internal friction angle (ϕ) [º]						
		0	15	20	25	30	35	40
0	R_{k1}	---	6,8	11,2	18,9	33,1	60,7	118,9
	R_{k2}	---	3,7	4,4	5,2	5,2	5,2	5,2
	R_{k3}	---	3,3	4,0	4,8	5,8	7,2	8,9
	R_{k4}	---	1,6	2,0	2,4	2,9	3,6	4,5
1	R_{k1}	2,6	8,1	12,7	20,8	35,6	64,4	124,6
	R_{k2}	2,7	4,4	5,2	6,2	7,5	7,7	7,4
	R_{k3}	2,7	4,1	4,7	5,6	6,6	7,9	9,7
	R_{k4}	1,4	2,0	2,4	2,8	3,3	4,0	4,9
5	R_{k1}	6,1	13,2	18,9	28,6	46,0	79,0	147,1
	R_{k2}	5,0	7,4	8,5	9,8	11,5	13,5	16,1
	R_{k3}	5,8	7,2	7,8	8,7	9,7	11,1	12,8
	R_{k4}	2,9	3,6	3,9	4,3	4,9	5,5	6,4
10	R_{k1}	10,6	19,6	26,6	38,3	58,8	98,3	175,2
	R_{k2}	7,9	11,2	12,6	14,4	16,4	19,0	22,3
	R_{k3}	9,7	11,1	11,7	12,6	13,6	14,9	16,7
	R_{k4}	4,9	5,5	5,9	6,0	6,8	7,5	8,4
25	R_{k1}	24,0	38,9	49,8	67,4	97,5	152,2	259,7
	R_{k2}	16,6	22,4	25,0	27,9	31,4	35,6	40,8
	R_{k3}	21,4	22,7	23,4	24,2	25,3	26,6	28,4
	R_{k4}	10,7	11,4	11,7	12,1	12,6	13,3	14,2
50	R_{k1}	46,2	70,9	88,4	116,0	162,0	243,6	> 300,0
	R_{k2}	31,0	41,2	45,5	50,5	56,4	63,3	71,7
	R_{k3}	40,8	42,2	42,8	43,7	44,7	46,0	47,8
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
75	R_{k1}	68,4	103,0	127,0	164,5	226,4	> 300,0	> 300,0
	R_{k2}	45,4	60,0	66,1	73,1	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
100	R_{k1}	90,7	135,1	165,5	213,2	290,9	> 300,0	> 300,0
	R_{k2}	59,9	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
200	R_{k1}	179,6	263,3	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
400	R_{k1}	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0

Legend:

- R_{k1}: compression resistance (failure by cave-in of the foundation unit) [kN]
- R_{k2}: tensile resistance (failure by pulling the foundation unit out) [kN]
- R_{k3}: resistance to horizontal efforts [kN]
- R_{k4}: bending resistance [kN·m]

Notes:

- The dimensions of steel tubes considered in the table are: outer diameter = 42,9 mm; thickness = 2,9 mm; length = 1.200 mm.

Table B.1: Performance of Piloedre®.

Performance of Piloedre® (R_{k1}, R_{k2}, R_{k3}, R_{k4})								
Cohesion (C) [kPa]	Essential characteristic	Soil density (γ) [kN/m³] = 15,0			Foundation depth [m] = 0,50			
		Internal friction angle (ϕ) [º]						
		0	15	20	25	30	35	40
0	R_{k1}	---	12,0	20,2	34	59,1	107,7	209,6
	R_{k2}	---	5,9	7,1	8,5	10,4	12,3	12,3
	R_{k3}	---	5,3	6,3	7,7	9,3	11,5	14,3
	R_{k4}	---	2,6	3,2	3,8	4,7	5,7	7,2
1	R_{k1}	4,1	13,8	21,9	36,0	61,7	111,5	215,3
	R_{k2}	4,0	6,6	7,9	9,4	11,3	13,9	15,8
	R_{k3}	3,9	6,1	7,1	8,4	10,1	12,2	15,1
	R_{k4}	1,9	3,0	3,6	4,2	5,0	6,1	7,5
5	R_{k1}	8,1	19,3	28,5	44,2	72,5	126,6	238,3
	R_{k2}	6,3	9,6	11,2	13,0	15,4	18,8	22,1
	R_{k3}	7,0	9,2	10,2	11,6	13,2	15,4	18,2
	R_{k4}	3,5	4,6	5,1	5,8	6,6	7,7	9,1
10	R_{k1}	13,1	26,3	36,7	54,5	85,9	145,4	267,0
	R_{k2}	9,2	13,4	15,3	17,6	20,3	23,8	28,2
	R_{k3}	10,9	13,1	14,1	15,4	17,1	19,2	22,1
	R_{k4}	5,4	6,5	7,1	7,7	8,6	9,6	11,0
25	R_{k1}	28,1	47,2	61,5	85,2	126,2	201,9	> 300,0
	R_{k2}	17,9	24,6	27,6	31,1	35,3	40,4	46,8
	R_{k3}	22,6	24,7	25,8	27,1	28,8	30,9	33,7
	R_{k4}	11,3	12,3	12,9	13,6	14,4	15,5	16,9
50	R_{k1}	53,0	81,9	102,8	136,4	193,4	296,1	> 300,0
	R_{k2}	32,3	43,4	48,2	53,7	60,2	68,1	> 75,0
	R_{k3}	42,0	44,2	45,2	46,5	48,2	50,3	53,2
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
75	R_{k1}	78,0	116,7	144,1	187,7	260,5	> 300,0	> 300,0
	R_{k2}	46,7	62,2	68,7	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
100	R_{k1}	102,9	151,4	185,4	238,9	> 300,0	> 300,0	> 300,0
	R_{k2}	61,2	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
200	R_{k1}	202,7	290,5	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
400	R_{k1}	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0

Legend:

- R_{k1}: compression resistance (failure by cave-in of the foundation unit) [kN]
- R_{k2}: tensile resistance (failure by pulling the foundation unit out) [kN]
- R_{k3}: resistance to horizontal efforts [kN]
- R_{k4}: bending resistance [kN·m]

Notes:

- The dimensions of steel tubes considered in the table are: outer diameter = 42,9 mm; thickness = 2,9 mm; length = 1.200 mm.

Table B.2: Performance of Piloedre®.

Performance of Piloedre® (R_{k1}, R_{k2}, R_{k3}, R_{k4})								
Cohesion (C) [kPa]	Essential characteristic	Soil density (γ) [kN/m³] = 17,5				Foundation depth [m] = 0,20		
		Internal friction angle (ϕ) [º]						
		0	15	20	25	30	35	40
0	R_{k1}	---	8,0	13,1	22,1	38,6	70,8	138,8
	R_{k2}	---	4,3	5,1	6,1	6,1	6,1	6,1
	R_{k3}	---	3,8	4,6	5,6	6,8	8,4	10,4
	R_{k4}	---	1,9	2,3	2,8	3,4	4,2	5,2
1	R_{k1}	2,9	9,2	14,6	24,0	41,2	74,5	144,0
	R_{k2}	3,1	5,0	5,9	7,1	8,6	8,6	8,3
	R_{k3}	3,0	4,6	5,4	6,4	7,6	9,2	11,2
	R_{k4}	1,5	2,3	2,7	3,2	3,8	4,6	5,6
5	R_{k1}	6,4	14,4	20,8	31,8	51,5	89,1	166,9
	R_{k2}	5,4	8,0	9,3	10,7	12,6	14,8	17,1
	R_{k3}	6,2	7,7	8,5	9,5	10,7	12,3	14,3
	R_{k4}	3,1	3,9	4,2	4,7	5,3	6,1	7,2
10	R_{k1}	10,9	20,8	28,5	41,5	64,0	107,4	195,1
	R_{k2}	8,3	11,8	13,4	15,3	17,5	20,4	23,9
	R_{k3}	10,1	11,6	12,4	13,4	14,6	16,1	18,2
	R_{k4}	5,0	5,8	6,2	6,7	7,3	8,1	9,1
25	R_{k1}	24,2	40,0	51,6	70,6	103,0	162,3	279,5
	R_{k2}	17,0	23,0	25,7	28,8	32,5	37,0	42,5
	R_{k3}	21,7	23,3	24,1	25,0	26,2	27,8	29,9
	R_{k4}	10,9	11,6	12,0	12,5	13,1	13,9	14,9
50	R_{k1}	46,5	72,1	90,2	119,1	167,5	253,8	> 300,0
	R_{k2}	31,4	41,8	46,3	51,4	57,4	64,6	73,3
	R_{k3}	41,2	42,7	43,5	44,5	45,7	47,2	49,3
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
75	R_{k1}	68,7	104,1	128,8	167,6	231,9	> 300,0	> 300,0
	R_{k2}	45,8	60,6	66,8	74,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
100	R_{k1}	91,0	136,2	167,4	216,2	296,4	> 300,0	> 300,0
	R_{k2}	60,2	> 75,0	> 75,0	> 75,0	>75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	>60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	>18,0	> 18,0	> 18,0
200	R_{k1}	179,9	264,5	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
400	R_{k1}	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0

Legend:

- R_{k1}: compression resistance (failure by cave-in of the foundation unit) [kN]
- R_{k2}: tensile resistance (failure by pulling the foundation unit out) [kN]
- R_{k3}: resistance to horizontal efforts [kN]
- R_{k4}: bending resistance [kN·m]

Notes:

- The dimensions of steel tubes considered in the table are: outer diameter = 42,9 mm; thickness = 2,9 mm; length = 1.200 mm.

Table B.3: Performance of Piloedre®.

Performance of Piloedre® (R_{k1}, R_{k2}, R_{k3}, R_{k4})								
Cohesion (C) [kPa]	Essential characteristic	Soil density (γ) [kN/m³] = 17,5				Foundation depth [m] = 0,50		
		Internal friction angle (ϕ) [º]						
		0	15	20	25	30	35	40
0	R_{k1}	---	14,4	23,6	39,6	68,9	125,7	244,5
	R_{k2}	---	6,8	8,2	9,9	12,1	14,4	14,4
	R_{k3}	---	6,2	7,4	8,9	10,9	13,4	16,7
	R_{k4}	---	3,1	3,7	4,5	5,4	6,7	8,3
1	R_{k1}	4,6	15,8	25,3	41,7	71,6	129,5	250,3
	R_{k2}	4,6	7,6	9,1	10,8	13,1	16,0	17,9
	R_{k3}	4,4	6,9	8,2	9,7	11,7	14,2	17,4
	R_{k4}	2,2	3,5	4,1	4,9	5,8	7,1	8,7
5	R_{k1}	8,6	21,4	31,9	49,9	82,3	144,5	273,2
	R_{k2}	6,9	10,6	12,3	14,4	17,7	20,4	24,7
	R_{k3}	7,5	10,0	11,3	12,8	14,8	17,3	20,6
	R_{k4}	3,7	5,0	5,6	6,4	7,4	8,6	10,3
10	R_{k1}	13,6	28,4	40,1	60,1	95,8	163,4	> 300,0
	R_{k2}	9,8	14,4	16,4	18,0	22,1	25,9	30,9
	R_{k3}	11,4	13,9	15,2	17,0	18,3	21,2	24,4
	R_{k4}	5,7	7,0	7,6	8,3	9,3	10,6	12,0
25	R_{k1}	28,6	49,2	64,9	90,8	136,1	219,9	> 300,0
	R_{k2}	18,5	25,6	28,8	32,5	37,0	42,5	49,4
	R_{k3}	23,1	25,6	26,8	28,4	30,3	32,8	36,1
	R_{k4}	11,5	12,8	13,4	14,2	15,2	16,4	18,0
50	R_{k1}	53,5	84,0	106,2	142,1	203,2	> 300,0	> 300,0
	R_{k2}	32,9	44,4	49,4	55,1	62,0	70,2	> 75,0
	R_{k3}	42,5	44,0	46,3	47,8	49,8	52,3	55,5
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
75	R_{k1}	78,5	118,7	147,5	193,3	270,4	> 300,0	> 300,0
	R_{k2}	47,3	63,1	69,9	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
100	R_{k1}	103,4	153,5	188,8	244,6	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
200	R_{k1}	203,2	292,6	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0
400	R_{k1}	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0	> 300,0
	R_{k2}	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0	> 75,0
	R_{k3}	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0	> 60,0
	R_{k4}	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0	> 18,0

Legend:

- R_{k1}: compression resistance (failure by cave-in of the foundation unit) [kN]
- R_{k2}: tensile resistance (failure by pulling the foundation unit out) [kN]
- R_{k3}: resistance to horizontal efforts [kN]
- R_{k4}: bending resistance [kN·m]

Notes:

- The dimensions of steel tubes considered in the table are: outer diameter = 42,9 mm; thickness = 2,9 mm; length = 1.200 mm.

Table B.4: Performance of Piloedre®.

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Compression load [kN]	Foundation displacement under compression load (δ) [cm] Winkler modulus (K) [kg/cm³]							
	0,5	1	2	3	4	5	10	20
2	0,67	0,33	0,17	0,11	0,08	0,07	0,03	0,02
5	1,67	0,83	0,42	0,28	0,21	0,17	0,08	0,04
10	3,33	1,67	0,83	0,56	0,42	0,33	0,17	0,08
15	5,00	2,50	1,25	0,83	0,63	0,50	0,25	0,13
20	6,67	3,33	1,67	1,11	0,83	0,67	0,33	0,17
25	8,33	4,17	2,08	1,39	1,04	0,83	0,42	0,21
30	10,00	5,00	2,50	1,67	1,25	1,00	0,50	0,25
40	13,33	6,67	3,33	2,22	1,67	1,33	0,67	0,33
50	16,67	8,33	4,17	2,78	2,08	1,67	0,83	0,42
75	25,00	12,50	6,25	4,17	3,13	2,50	1,25	0,63
100	33,33	16,67	8,33	5,56	4,17	3,33	1,67	0,83

Notes:

- Values greater than 2,50 cm are shown in red in the table.
- The compression load is a characteristic value (not affected by safety factors).

Table B.5: Maximum compression load for a given foundation displacement.

ANNEX C: CALCULATION METHODS

C.1 Compression resistance (failure by cave-in of the foundation unit)

The cave-in resistance of the foundation unit shall be calculated by the sum of the cave-in resistance of the concrete block (clause C.1.1) and the downward jacking resistance of the steel tubes (clause C.1.2).

C.1.1 Cave-in resistance of the concrete block

The cave-in resistance of the concrete block shall be determined by using a calculation method based on Terzaghi's bearing capacity theory and considering the properties of the soil.

The concrete block activates stresses and deformations only in the first 2 m below the kit. Therefore, the concrete block can be considered a shallow foundation with its particular shape, and its mechanism of resistance can be simulated using traditional failure mechanisms based on the Terzaghi's bearing capacity theory.

For calculation purposes, the concrete block is considered equivalent to a shallow foundation with its supporting plane in the base of the concrete block and whose dimensions are variable depending on the friction coefficient of the soil.

The bearing capacity factors N_c, N_q and N_γ are function of the soil internal friction angle ϕ.

$$N_q = \frac{1+\sin\phi}{1-\sin\phi} \cdot e^{\pi \cdot \tan\phi} \qquad \text{(equation 1)}$$

$$N_c = (N_q - 1) \cdot \cot\phi \qquad \text{(equation 2)}$$

$$N_\gamma = 1,5 \cdot (N_q - 1) \cdot \tan\phi \qquad \text{(equation 3)}$$

The ultimate soil bearing capacity (q_u) [kN/m^2] is obtained from the Terzaghi's bearing capacity equation.

$$q_u = p_0 \cdot N_q + c \cdot N_c + \frac{1}{2} \cdot \gamma \cdot B \cdot N_\gamma \qquad \text{(equation 4)}$$

$$q_a = \frac{q_u}{\gamma_R} \qquad \text{(equation 5)}$$

$$R_c = q_a \cdot B^2 \qquad \text{(equation 6)}$$

Where:

q_a: allowable bearing capacity of the soil [kN].

R_c: cave-in resistance of the concrete block [kN].

γ_R: safety factor.

Parameters of the soil and of the foundation kit needed for the design:

- Internal friction angle (ϕ).
- Cohesion (c).
- Soil density (γ).
- Overburden pressure (p_0).

- Width of footing (B).

C.1.2 Downward jacking resistance of the steel tubes

A similar mechanism to the point mechanism used for deep foundations is assumed. The tip resistance shall be determined.

The steel tubes shall be discretised in sections to obtain the variation of soil performance with depth.

A reduction coefficient of 0,7 shall be applied to R_p because of the longitudinal and not point jacking of the tubes.

$$R_s = 0{,}7 \cdot R_p \qquad \text{(equation 7)}$$

Where:

R_s: downward jacking resistance of the steel tubes.

R_p: resistance assumed by the tip.

$$R_p = \left(q_{pf} + q_{pc}\right) \cdot A_p \qquad \text{(equation 8)}$$

Where:

q_{pf}: frictional tip resistance per tube.

q_{pc}: cohesive tip resistance per tube.

A_p: area of the tip. The horizontal projection is considered for inclined tubes.

$$q_{pf} = f_p \cdot \sigma'_{vp} \cdot N_q \leq 20 \text{ MPa} \qquad \text{(equation 9)}$$

Where:

f_p (corrective factor) = 3.

σ'_{vp}: effective vertical pressure on tip level before the tube installation. The value of soil density (γ) is used.

N_q: bearing capacity factor.

$$q_{pc} = N_p \cdot c_u \qquad \text{(equation 10)}$$

Where:

N_p: it depends on the embedding of the tube. A value of 9 is assumed.

c_u: shear resistance of the soil without draining. It is equivalent to the cohesion.

This resistance shall be calculated for one steel tube and shall be multiplied by the 4 steel tubes of each foundation unit.

C.2 Tensile resistance (failure by pulling the foundation unit out)

The tensile resistance shall be obtained from the horizontal stress supported by the soil (σ_h) determined by equation 12 (clause C.2.1) and from the limitation due to the weight of the soil above the tubes (T) determined by equation 13 (clause C.2.2).

The tensile resistance is the minimum between $\sigma_h/3$ and T.

$$R_T=\min\left\{\frac{\sigma_h}{3};T\right\}$$ (equation 11)

Where:

R_T: tensile resistance (failure by pulling the foundation out).

σ_h: horizontal stress supported by the soil.

T: weight of the soil above the tubes.

C.2.1 Horizontal stress supported by the soil (σ_h)

A pseudo-elastic strain-deformation behaviour of the soil is assumed, so that every compression stress (N) causes a tensile stress (T) in the perpendicular plane which fulfils T = 0,3·N.

If a vertical crack appears it means that the lateral earth pressure of the soil is overcome. This will correspond with a passive situation since it is necessary that the soil opens to let the tubes go through it.

The Bell's relationship for soil with cohesion and passive situations is used to calculate the total lateral earth pressure.

$$\sigma_h= K_p\cdot\sigma_v + 2\cdot c\cdot\sqrt{K_p}$$ (equation 12)

Where:

σ_h: horizontal stress.

K_p : passive earth pressure coefficient $\left(K_p= \tan^2\left(45+\frac{\phi}{2}\right)\right)$; ϕ: Internal friction angle.

σ_v : vertical stress ($\sigma_v = h\cdot\gamma$); h: depth; γ: soil density.

c: cohesion.

When the vertical load (F) exceeds a third of the horizontal stress ($\sigma_h/3$) the soil opens and the tubes go through it.

C.2.2 Weight of the soil above the tubes (T)

Additionally, the maximum vertical load that the tubes can transmit to the soil is limited by the weight of the soil above the tubes. This volume of soil corresponds to a wedge with an inclination angle of 30º with respect to the vertical, whose edge is in contact with the tube. The adhesion of this wedge to the soil is based on the cohesion of the soil. Therefore, the maximum vertical load (T) is defined as follows:

$$T=2\cdot c\cdot\frac{\cos\phi}{1+\sin\phi}$$ (equation 13)

Where:

c: cohesion.

ϕ: internal friction angle.

This equation is obtained from the application of the Mohr-Coulomb theory for pure tensile efforts.

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C.3 Bending resistance

The bending resistance is based on the lateral jacking resistance of the steel tubes, which shall be calculated using the formulas for lateral jacking resistance of piles.

The steel tubes shall be discretised in sections to obtain the variation of soil performance with the depth.

The following formula is applied:

$$s(z)=\left(9\cdot c + 3\cdot \gamma\cdot z\cdot \frac{1+\sin\phi}{1-\sin\phi}\right)\cdot D \qquad \text{(equation 14)}$$

Where:

s(z): lateral jacking resistance as a function of depth (z).

c: cohesion.

γ: soil density.

z: depth.

ϕ: internal friction angle.

D: vertical projection of the cross section of the steel tubes.

C.4 Resistance to horizontal efforts

The resistance to horizontal efforts shall be calculated by the sum of the resistance to lateral displacement of the concrete block (clause C.4.1) and the lateral jacking resistance of the steel tubes (clause C.4.2).

C.4.1 Resistance to lateral displacement of the concrete block

The resistance to lateral displacement of the concrete block shall be determined by using the methodology from passive earth pressure.

The following formula is applied:

$$R_1=\left(9\cdot c+3\cdot \gamma\cdot z\cdot \left(\frac{1+\sin\phi}{1-\sin\phi}\right)\right)\cdot S \qquad \text{(equation 15)}$$

Where:

c: cohesion.

γ: soil density.

z: depth of the midpoint of the face of the concrete block pressing the soil.

ϕ: internal friction angle.

S: surface of the concrete block pressing the soil

C.4.2 Lateral jacking resistance of the steel tubes

The lateral jacking resistance of the steel shall be determined by the methodology indicated in clause C.3.

C.5 Maximum compression load for a given foundation displacement

The Winkler modulus measures the rigidity of a soil (K) and gives a relationship between the vertical load applied (F), the area in contact with the surface of the soil in which the load is applied (A) and the vertical displacement achieved (δ).

$$K = \frac{F}{\delta \cdot A} \qquad \text{(equation 16)}$$

The existing values for the Winkler modulus referred to a defined surface K_{30} (A = 30 cm x 30 cm) in the literature or National regulations for the different type of soils will be provided. The soil is defined by the internal friction angle (ϕ) and the cohesion (c).

The Winkler modulus for the equivalent dimensions (K) will be obtained by application of the equivalent dimensions to the Winkler modulus (K_{30}).

The maximum compression load (F_{max}) is obtained from equation (16), in which K is obtained from the soil properties, δ is the given foundation displacement and A is the equivalent area of the foundation.

C.6 Maximum compression load allowing the steel tubes to be reused

The maximum compression load allowing the steel tubes to be reused shall be determined from the calculation of the maximum resistant bending moment of the steel tubes, under the following hypothesis:

- The same resistant mechanism as for the compression resistance (failure by cave-in of the foundation unit) is developed.

The following procedure shall be applied:

- The maximum resistant bending moment of the steel tubes is calculated from the materials and geometry of the tubes, under the consideration of the embedment of the tubes in the concrete block. A reduction of 30 % of the bending moment from the calculation is applied.

The maximum resistant bending moment shall be compared with the bending moment due to the applied loads, calculated under the following hypothesis:

- The bending moment due to the applied loads is uniformly distributed along the steel tube, reaching the maximum value in the point between tube and concrete block.
- The steel tube is embedded in the concrete block.

C.7 Maximum tensile load allowing the steel tubes to be reused

The maximum tensile load allowing the steel tubes to be reused shall be determined from the calculation of the maximum resistant bending moment of the steel tubes, under the following hypothesis:

- The same resistant mechanism as for the tensile resistance (failure by pulling the foundation out) is developed.

The same procedure as for clause C.6 applies.

C.8 Protection against corrosion

- Concrete block

According to EN 1992-1-1, the concrete block is suitable for the following general and specific classes and subclasses of exposure: X0, XC1, XC2, XC3, XC4, XS1, XD1, XF1, XF3, XA1 and XA2.

- Steel tubes

The thickness of the hot dip galvanized, determined case by case for each type of soil in which the kit is to be installed for the expected working life, shall be proper for the loss of thickness due to corrosion in accordance with the table 4.1 of EN 1993-5.

The minimum value of the mean and the local thickness of the hot dip galvanized of the steel tubes according to UNE-EN ISO 1461 is 70 µm and 55 µm, respectively.

C.9 Prevention of the cracking of the concrete blocks

The cracking of the concrete blocks will be calculated case-by-case for each building work depending on the applied load, on the type of applied effort and on the characteristics of the concrete block.