

(19)



(11)

EP 4 570 990 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

18.06.2025 Bulletin 2025/25

(51) International Patent Classification (IPC):

E02D 3/12 (2006.01)

E02D 5/46 (2006.01)

E02D 3/08 (2006.01)

(21) Application number: **23215652.1**

(52) Cooperative Patent Classification (CPC):

E02D 3/126; E02D 5/46; E02D 3/08

(22) Date of filing: **11.12.2023**

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA

Designated Validation States:

KH MA MD TN

(72) Inventors:

- **KANTY, Piotr**
41-800 ZABRZE (PL)
- **Joczyk- Szostek, Magorzata**
32-085 MODLNICA (PL)
- **Saloni, Jakub**
01-651 WARSAW (PL)

(74) Representative: **Plasseraud IP**

104 Rue de Richelieu

CS92104

75080 Paris Cedex 02 (FR)

(71) Applicant: **Soletanche Freyssinet**

92500 Rueil Malmaison (FR)

(54) GROUND IMPROVEMENT METHOD TO FORM GRANULAR INCLUSIONS

(57) Method (100) for installing a granular inclusion by a soil boring technique, the method comprising: preparing (102) a pumpable mixture comprising stones in a gel-like matrix of a biodegradable polymer; rotating and

pushing down (104) a tooling into the ground, up to a predetermined depth; and retracting the tooling and simultaneously pumping (106) the mixture into the ground so as to build the ground granular inclusion.

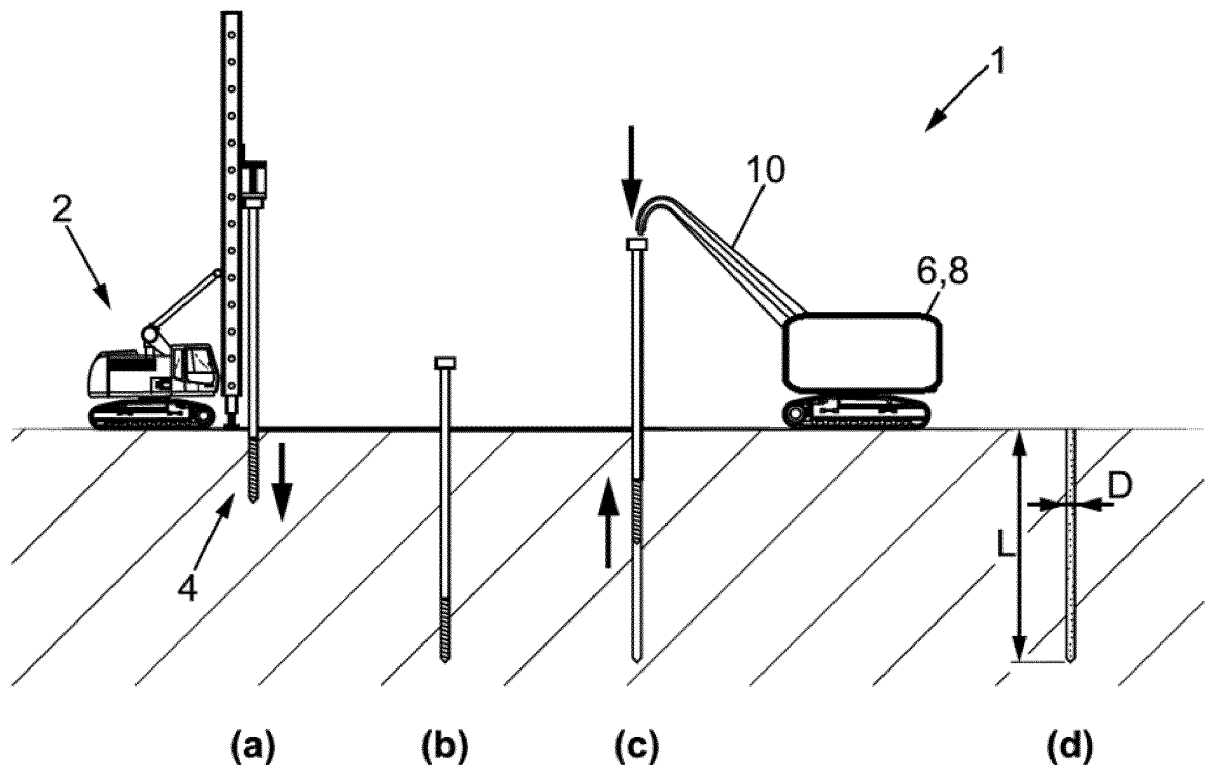


FIG. 1

EP 4 570 990 A1

Description**Technical Field**

- 5 **[0001]** This disclosure pertains to the field of ground improvement techniques and in particular to the construction of granular inclusions.

Background Art

- 10 **[0002]** For improving the ground before constructing a civil engineering structure such as a road or a building, two main groups of techniques are used for obtaining inclusions (columns). A first group of techniques is covering methods to form concrete/grout inclusions. Within this group there are two techniques which are mainly used worldwide where the hole is bored: full displacement drilling shown in the document WO 00/50358 A1 (also known as controlled modulus column, CMC) and continuous flight auger drilling (CFA). These techniques consist in drilling a well in the soil with a drilling tool and
15 subsequently filling the well with concrete as the drilling tool is retracted. The difference between the two techniques is mainly the shape of the auger (drilling tool) that is used. The use of concrete/cement is detrimental to the environment as the production of cement generates a substantial amount of greenhouse gases.

- 20 **[0003]** A second method, known as granular inclusions, contains stone columns (SC) and sand columns, and consists in filling a well with stones. To ensure that the stones occupy the entirety of the well, it is necessary to use a hammer or a vibratory tool. This method requires therefore the use of specific equipment (e.g., top or bottom vibrators attached to a lead, an excavator arm or a crane winch, etc.) and this technique involves vibrations and noise nuisance which can be inconvenient for the buildings, infrastructures, or inhabitants in the vicinity of the construction site. This method is also time consuming due to the need to vibrate/hammer the stones. In some cases, this method requires to perform a pre-drilling operation with a powerful tool (mainly of smaller diameter and length) to facilitate the penetration of the vibratory tool.

- 25 **[0004]** There is therefore a need to provide an improved granular inclusions construction method which does not present the above-mentioned drawbacks, i.e., a rapid and environmentally-friendly column construction method which does not influence the vicinity.

Summary

- 30 **[0005]** To that end, it is proposed a method for installing a granular inclusion by a soil boring technique, the method comprising: preparing a pumpable mixture comprising stones in a gel-like matrix of a biodegradable polymer; rotating and pushing down a tooling into the ground, up to a predetermined depth; and retracting the tooling and simultaneously pumping the mixture into the ground so as to build the granular inclusion.

- 35 **[0006]** This method is more environmentally friendly as it does not require the use of cement and it employs a biodegradable element. Also, this method uses a concrete/grout inclusions equipment which does not disturb the vicinity. The biodegradable gel-like matrix holds water and renders the stones pumpable: the stones are suspended in the matrix and the mixture has rheologic properties comparable to a pumpable fluid. In comparison, the stones alone do not hold water and are not pumpable.

- 40 **[0007]** In some examples, the tooling comprises an auger, tubes and a drilling head, and the step of pumping the mixture comprises pouring the mixture through the tooling. The pumpable stones are indeed suitable for being poured down through the tooling.

- 45 **[0008]** In some examples, preparing a pumpable mixture comprises adding water to the stones and adding the biodegradable polymer into the mix of water and stones, according to a ratio of 50 to 200 liters of water per kilogram of biodegradable polymer. Depending on the level of moisture of the stones, more or less water may be used. Below 50 liters, there may not be enough water for the polymer to distribute properly. This leads to portions of the mixture containing a greater amount of polymer than other portions. The mixture is thus too heterogeneous and this may prevent the pumping operation from being smooth and continuous. Above 200 liters, the effect of the polymer is reduced and a gel-like matrix may not form: the water is not held in the mixture which is therefore not pumpable. A too high amount of water may also
50 negatively impact the mechanical strength of the column, as pockets of air may appear once the water has drained out of the column. Alternatively, the biodegradable polymer may be diluted into water before adding the mix to the stones.

- 55 **[0009]** In some examples, preparing a pumpable mixture comprises dosing an amount of the biodegradable polymer comprised between 1 kg and 4 kg per cubic meter of stones. This range has been found to meet the properties of a pumpable mixture. A too high amount of polymer may result in the polymer sticking to the pipes, the pump or the tank which is used to prepare the mixture (e.g., concrete truck).

- [0010]** In some examples, the pumpable mixture is a mixture of class S2, S3, S4 or S5 in the slump test of point 4.2.1 of the standard EN-206-1. This standard, which is normally used to quantify the properties of concrete can also be used in the context of the present disclosure to assess the consistency and pumpability of the mixture.

[0011] In some examples, the pumpable mixture has a water permeability comprised between 1×10^{-3} m/s and 1×10^{-7} m/s. The value will depend on the stones used. Indeed, there should be enough water held in the mixture for allowing the pumpability of the mixture but too much water may be detrimental to the homogeneity of the mixture or to the mechanical strength of the resulting column. Once the column is poured down, the water (including rainwater) must be able to drain out of the column. The water permeability is sometimes referred to as the "k" coefficient.

[0012] In some examples, the biodegradable polymer comprises a natural or a synthetic polysaccharide. In some examples, the natural or synthetic polysaccharide comprises guar gum or xanthan gum. Other biodegradable additive suitable to form a matrix enveloping stones to form a fluid mixture may be used, such as dextrane, rhamosan, gellan, welan, carrageenan, agar, polyose or succinoglycan gum. Without wishing to be bound by theory, the molecular geometry of the polysaccharides seems to favor an adhesion to the stones, when provided in an appropriate amount, thereby helping the stones to become pumpable.

[0013] In some examples, the stones of the pumpable mixture comprise at least 5% in mass of stones having a size of less than 2 mm. In some preferred examples, this amount is of at least 25%. Without wishing to be bound by theory, it appears that in some cases, a sufficient amount of small-size stones may help improve the pumpability. It appears also that the biodegradable polymer is less prone to stick to stones of bigger size. In some examples, at least 5% of stones of less than 0,25 mm may be preferred.

[0014] The size of a stone is to be understood as the biggest dimension of the stone, i.e., a stone of a size less than 2 mm would pass through a sieve where the space between the meshes is 2 mm.

[0015] In some examples, the stones of the pumpable mixture comprise between 30% and 95% in mass of stones having a size comprised between 2 mm and 16 mm. In some preferred examples, this amount is comprised between 30% and 65%. In some examples, the stones of the pumpable mixture comprise between 15% and 70% in mass of stones having a size comprised between 16 mm and 64 mm. In some preferred examples, this amount is comprised between 40% and 70%.

[0016] In some examples, the method further comprises a step of degrading of the biodegradable polymer in a period of time comprised between 1 and 90 days. Depending on the temperature, oxygen availability and humidity in the soil, the biodegradable polymer may fully degrade more or less quickly. The resulting column (after biodegradation) has proven to have the same mechanical properties as a stone or sand column formed by vibrating or hammering.

[0017] In some examples, the column has a diameter that is comprised between 20 cm and 70 cm and the predetermined depth is comprised between 2 meters and 45 meters.

Brief Description of Drawings

[0018] Other features, details and advantages will be shown in the following detailed description and on the figures, on which:

Figure 1 represents a concrete/grout inclusions equipment and various steps of the method of the present disclosure.

Figure 2 illustrates the method of the present disclosure.

Description of Embodiments

[0019] Figure 1 shows schematically a concrete/grout inclusions equipment 1 used to form a CMC or CFA columns. The equipment comprises a vehicle 2 having tracks bearing a chassis and a structure that holds a tooling 4. The tooling 4 may comprise a drilling head, tubes and auger. The auger may have a maximal diameter D which may be comprised between 20 cm and 70 cm.

[0020] Figure 1 shows four different stages (a, b, c, d) depicting four steps of a method.

[0021] In stage a, the tooling 4 penetrates into the ground, forming a well. The tooling 4 simultaneously rotates around the vertical axis and translates downwards.

[0022] Stage b shows a tooling 4 having reached a desired depth L (the vehicle 2 is not shown in stage b). The depth L (or length of the column) may be designed so as to sufficiently reinforce the ground. The length L and diameter D may thus depend on the nature of the soil, the space between two adjacent columns and the structure (road, building) that is to be supported by the column.

[0023] In stage c, the tooling 4 is moved upwards (the vehicle 2 is not shown in stage c). Simultaneously to the upward movement of the tooling 4, a mixture is poured into the well. A pump 6 may be used to pump the mixture out of a tank 8 and into a hose 10 before pouring the mixture through the tooling 4. The pump 6 may be a concrete pump. The tank 8 may be a concrete truck.

[0024] After the total withdrawal of the tooling 4 and the complete filling of the well with mixture, the same operations may be repeated according to a predetermined pattern (or grid).

[0025] Stage d shows a resulting column. After the biodegradation of the biodegradable polymer, the column is essentially made of the stones which formed the mixture.

[0026] Figure 2 illustrates a diagram of a method 100.

[0027] The first step of the method 100 is the preparation 102 of the mixture. The mixture may be prepared in any appropriate container, including but not limited to, a tank, a cement mixer, a cement truck, etc. A predetermined amount of biodegradable polymer may be added into the container which already contains water and stones. The ingredients of the mixture may be mixed in a different order. The proportions of polymer, water and stones may be in accordance with the above-mentioned ranges. Additional elements may be added to the mixture in so far as they do not render the mixture improper for being pumped.

[0028] The biodegradable polymer may be a natural or a synthetic polysaccharide. For example, it may be guar gum or xanthan gum.

[0029] In the present disclosure, "stones" may refer to at least one of: coarse soil, sand (very fine sand, fine sand, medium sand, coarse sand, very coarse sand), gravel (very fine gravel, fine gravel, medium gravel, coarse gravel, very coarse gravel), naturally round-shaped stones, silt, clay, granule, pebble, marble chips, crushed stones, crushed rock, slate, sandstone, limestone, marble, granite basalt, dolomite, etc.

[0030] After, or during the preparation of the mixture 102, the tooling 4 is rotated and introduced 104 into the ground, until the tooling reaches a predetermined depth.

[0031] Once the tooling has reached the predetermined depth, it is retracted upwards while simultaneously pumping 106 and pouring the mixture into the well.

[0032] The biodegradable polymer will then degrade 108 for a duration that is dependent on many factors including the temperature, oxygen availability and humidity. This duration may be comprised between 1 and 90 days.

Examples

[0033] The following table presents some quantitative experimentations results.

	Example A	Example B	Example C	Example D	Example E	Example F	Example G	Example H	Example I
Amount of stones 0/2 mm	25%	25%	25%	35%	5,7%	7,7%	35%	42%	32%
Including an amount of stones <0.25 mm of:		2.5 %	10%		0.5%	4.8%	5%	9%	
Amount of stones 2/8 mm	15%	15%	15%	32.5%	78,3%	24,9%	37%	29%	15%
Amount of stones 8/16 mm	60%	60%	60%	32.5%	16%	64%	28%	29%	14%
Amount of stones 16/32 mm	0	0	0	0			0	0	39%
Amount of stones 32/64 mm	0	0	0	0	0	3,4	0	0	0
Amount of water (liter per m ³ of stones)	150	150	150	100	125	125	100	150	115
Biodegradable polymer	None	Xantan gum 3kg			Xantan gum 4kg		Guar gum 2kg		
Pumpability of the mixture	No	+	++	++	No	+	++	+++	++

Table 1

[0034] Example A relates to a mixture without biodegradable polymer. The water was not held by the stones and would drain out of the stones. This mixture was found to not be pumpable and would not behave as a fluid which could properly fill the well. It is thus not possible to use a CMC / CFA method to build a column with this mixture.

[0035] Examples B and C were made with a substantially similar content of stones than A but a polymer was used in those cases. Example B contained less small-sized stones than example C. Example B was found to be more difficult to pump than example C.

[0036] Example D compared to B and C shows that it makes no difference if the stones are in the range of 2-8mm or 8-16mm.

[0037] Examples E and F show that it is possible to pump the material with quite high amount of polymer (4kg) only when having few percent of fraction $< 0,25\text{mm}$ in the mix.

[0038] Examples G, H and I use guar gum as biodegradable polymer. It shows that with a certain amount of fraction 0-2 mm the polymer content could be quite small (2kg).

[0039] Other experimentations have been carried out to investigate the amount of biodegradable polymer or the amount of water which should be used.

[0040] For each mixture that was investigated, a slump test was performed in accordance with the standard EN 12350-1, (Testing fresh concrete, part 2 - Slump test). A sample is prepared and properly mixed. A cone and a plate are cleaned and dried, the cone is clamped to the plate. The cone is filled in three successively compacted layers, each approximately one-third of the height of the cone when compacted. Each layer is successively compacted with 25 strokes of a compacting rod. The strokes are to be uniformly distributed over the cross-section of each layer. The cone is then raised carefully in a vertical direction in two to five seconds, by a steady upward lift, with no lateral or torsional motion being imparted to the mixture. The overall operation must be completed within 150 seconds. Immediately after removal of the cone, the difference between the height of the cone and that of the highest point of the slumped test specimen is measured and recorded.

[0041] The various classes of slumps are presented in the table below:

Table 2

Class	Slump in mm
S1	10 to 40 mm
S2	50 to 90 mm
S3	100 to 150 mm
S4	160 to 210 mm
S5	≥ 220

[0042] The various examples that were tested with the slump test revealed that the mixture according to the present disclosure is situated in classes S2 to S5. The combination of stones with a matrix of biodegradable polymer is therefore comparable, in terms of rheologic properties to a pumpable concrete.

[0043] The compaction of stones in the granular inclusion has been tested by cone penetrometer test (CPT). In particular, experiments showed that after the degradation of the biodegradable matrix (which may take up to 90 days), the reinforcement of the soil which is obtained with the method disclosed in the present disclosure is substantially similar to a granular inclusions like stone columns or sand columns formed with the use of vibration or by hammering. Hence, the resulting column satisfies the mechanical requirements while setting aside the drawbacks of both most used techniques.

Claims

1. Method (100) for installing a granular inclusion by a soil boring technique, the method comprising:

- preparing (102) a pumpable mixture comprising stones in a gel-like matrix of a biodegradable polymer;
- rotating and pushing down (104) a tooling (4) into the ground, up to a predetermined depth; and
- retracting the tooling and simultaneously pumping (106) the mixture into the ground so as to build the granular inclusion.

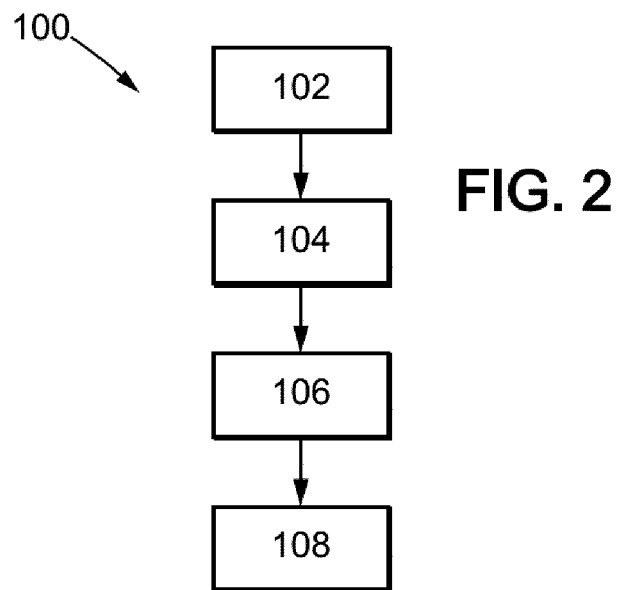
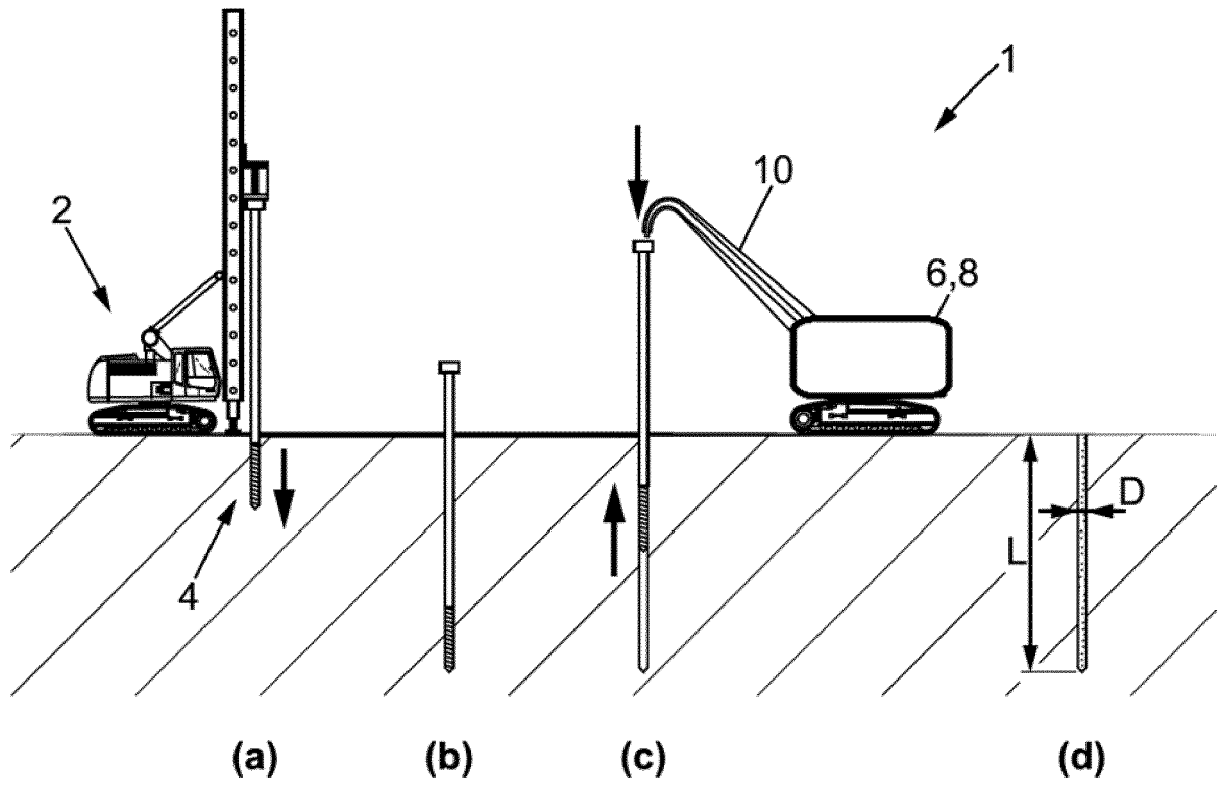
2. The method (100) of claim 1, wherein the tooling (4) comprises an auger, tubes and a drilling head, and the step of pumping the mixture comprises pouring the mixture through tooling.

3. The method (100) of any of the preceding claims, wherein preparing a pumpable mixture (102) comprises adding water to the stones and adding the biodegradable polymer into the mix of water and stones, according to a ratio of 50 to 200 liters of water per kilogram of biodegradable polymer.

4. The method (100) of any of the preceding claims, wherein preparing a pumpable mixture comprises dosing an amount of the biodegradable polymer comprised between 1 kg and 4 kg per cubic meter of stones.

5. The method (100) of any of the preceding claims, wherein the pumpable mixture is a mixture of class S2, S3, S4 or S5 in the slump test of point 4.2.1 of the standard EN-206-1.

6. The method (100) of any of the preceding claims, wherein the pumpable mixture has a water permeability comprised between 1×10^{-3} m/s and 1×10^{-7} m/s.
7. The method (100) of any of the preceding claims, wherein the biodegradable polymer comprises a natural or a synthetic polysaccharide.
8. The method (100) of the preceding claim, wherein the natural or synthetic polysaccharide comprises guar gum or xanthan gum.
9. The method (100) of any of the preceding claims, wherein the stones of the pumpable mixture comprise at least 5% in mass of stones having a size of less than 2 mm.
10. The method (100) of any of the preceding claims, wherein the stones of the pumpable mixture comprise between 50% and 95% in mass of stones having a size comprised between 2 mm and 64 mm.
11. The method (100) of any of the preceding claims, further comprising a step of degrading (108) of the biodegradable polymer in a period of time comprised between 1 and 90 days.
12. The method (100) of any of the preceding claims, wherein the column has a diameter that is comprised between 20 cm and 70 cm and the predetermined depth is comprised between 2 meters and 45 meters.





EUROPEAN SEARCH REPORT

Application Number

EP 23 21 5652

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	WO 00/50358 A1 (MENARD SOLTRAITEMENT [FR]; COGNON JEAN MARIE [FR]) 31 August 2000 (2000-08-31) * page 1, lines 24-27 * * page 4, lines 1-23 * * page 5, line 27 - page 7, line 10; claims 1,2; figures 1-3 * -----	1-12	INV. E02D3/12 E02D5/46 E02D3/08
Y	JP 2012 162919 A (TAKENAKA KOMUTEN CO) 30 August 2012 (2012-08-30) * abstract * * paragraphs [0009], [0010], [0022] - [0028], [0057], [0059]; figures 1-6,8,12 * -----	1-12	
A	JP H07 76821 A (KAJIMA CORP; CHEMICAL GROUT CO; SANSHO CO) 20 March 1995 (1995-03-20) * the whole document * -----	1	
A	WO 2018/130913 A2 (BUTLER MICHAEL GEORGE [US]) 19 July 2018 (2018-07-19) * paragraph [0027]; figure 1 * -----	8	TECHNICAL FIELDS SEARCHED (IPC) E02D C04B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 4 June 2024	Examiner Koulo, Anicet
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 21 5652

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

04-06-2024

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0050358 A1	31-08-2000	AU 2805000 A	14-09-2000
		EP 1077907 A1	28-02-2001
		JP 2002537216 A	05-11-2002
		KR 20010043016 A	25-05-2001
		WO 0050358 A1	31-08-2000

JP 2012162919 A	30-08-2012	NONE	

JP H0776821 A	20-03-1995	JP 2673872 B2	05-11-1997
		JP H0776821 A	20-03-1995

WO 2018130913 A2	19-07-2018	CN 110267928 A	20-09-2019
		EP 3568381 A2	20-11-2019
		US 2019308342 A1	10-10-2019
		WO 2018130913 A2	19-07-2018

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 0050358 A1 [0002]