US009957684B2

(12) **United States Patent**
Suver et al.

(10) **Patent No.: US 9,957,684 B2**
(45) **Date of Patent: May 1, 2018**

(54) **SYSTEMS AND METHODS FOR INSTALLING PILE STRUCTURES IN PERMAFROST**

(71) Applicant: **American Piledriving Equipment, Inc.**, Kent, WA (US)

(72) Inventors: **Paul Suver**, Kent, WA (US); **Matthew E. Fenwick**, Kent, WA (US)

(73) Assignee: **American Piledriving Equipment, Inc.**, Kent, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days. days.

(21) Appl. No.: **15/372,196**

(22) Filed: **Dec. 7, 2016**

(65) **Prior Publication Data**

US 2017/0167102 A1 Jun. 15, 2017

Related U.S. Application Data

(60) Provisional application No. 62/266,379, filed on Dec. 11, 2015.

(51) **Int. Cl.**
E02D 7/00 (2006.01)
E02D 5/52 (2006.01)
E02D 5/24 (2006.01)

(52) **U.S. Cl.**
CPC ***E02D 5/526*** (2013.01); ***E02D 5/24*** (2013.01); ***E02D 7/00*** (2013.01); *E02D 2250/0023* (2013.01); *E02D 2250/0038* (2013.01); *E02D 2300/0023* (2013.01)

(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

48,515	A	7/1865	Campbell et al.
500,780	A	7/1893	Simon
628,962	A	7/1899	Speer
910,421	A	1/1909	Schlueter
999,334	A	8/1911	Pearson
1,288,989	A	12/1918	Rees
1,294,154	A	2/1919	Payne
1,322,470	A	11/1919	Schenk
1,464,231	A	8/1923	Yezek
1,654,093	A	12/1927	Reid

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2394894 A1		8/2003
CA	2942801	*	10/2015

(Continued)

OTHER PUBLICATIONS

USPTO, "Non-Final Office Action, U.S. Appl. No. 15/285,326,", dated Apr. 25, 2017, 10 pages.

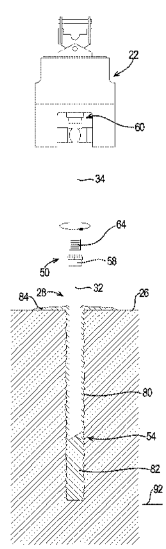
(Continued)

Primary Examiner — Sean Andrish
(74) *Attorney, Agent, or Firm* — Michael R. Schacht; Schacht Law Office, Inc.

(57) **ABSTRACT**

A pile system for permafrost comprising a pilot hole, at least one pile, and frozen slurry. The pilot hole is formed to a pilot hole depth. The at least one pile is arranged at least partly within the pilot hole and extends to a pile string depth. The frozen slurry is within the pilot hole and is at least partly around the at least one pile.

14 Claims, 6 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

1,684,816 A	9/1928	Arden	
1,787,000 A	12/1930	Hunt	
1,903,555 A	4/1933	Robertson	
2,101,285 A	12/1937	Stevens	
2,128,428 A	8/1938	Murray, Jr.	
2,232,845 A	2/1941	Fieroh	
2,239,024 A	4/1941	Vance	
2,350,921 A	6/1944	Pinazza	
2,436,251 A	2/1948	Dobie et al.	
2,439,219 A	4/1948	O'Connor	
2,577,252 A	12/1951	Kjellman	
2,760,747 A	8/1956	Mordarski	
2,952,132 A	9/1960	Urban	
2,975,846 A	3/1961	Bodine	
3,004,389 A	10/1961	Muller	
3,059,436 A	10/1962	Hermann, Jr.	
3,106,258 A	10/1963	Muller	
3,115,198 A	12/1963	Kuss	
3,172,485 A	3/1965	Spannhake et al.	
3,175,630 A	3/1965	Hein et al.	
3,278,235 A	10/1966	Bergstrom	
3,280,924 A	10/1966	Tatamikov	
3,287,983 A	11/1966	Austin et al.	
3,300,987 A	1/1967	Maeda	
3,313,376 A	4/1967	Holland	
3,371,727 A	3/1968	Belousov et al.	
3,381,422 A	5/1968	Olson	
3,391,435 A	7/1968	Lebelle	
3,394,766 A	7/1968	Lebelle	
3,396,805 A	8/1968	Muller	
3,411,305 A	11/1968	Cella	
3,412,813 A	11/1968	Johnson	
3,460,637 A	8/1969	Schulin	
3,513,587 A	5/1970	Artur	
3,528,302 A	9/1970	Kinnan	
3,530,947 A	9/1970	Gendron	
3,577,645 A	5/1971	Zurawski	
3,583,497 A	6/1971	Kossowski et al.	
3,684,037 A	8/1972	Bodine	
3,686,877 A	8/1972	Bodin	
3,711,161 A	1/1973	Proctor et al.	
3,786,874 A	1/1974	Demichelis et al.	
3,808,820 A	5/1974	Bodine	
3,828,864 A	8/1974	Haverkamp et al.	
3,865,501 A	2/1975	Kniep	
3,871,617 A	3/1975	Majima	
3,874,244 A	4/1975	Rasmussen et al.	
3,891,186 A	6/1975	Thorsell	
3,907,042 A	9/1975	Halwas et al.	
3,909,149 A	9/1975	Century	
3,952,796 A	4/1976	Larson	
3,999,392 A	12/1976	Fukushima et al.	
4,033,419 A	7/1977	Pennington	
4,067,369 A	1/1978	Harmon	
4,082,361 A	4/1978	Lanfermann	
4,100,974 A	7/1978	Pepe	
4,113,034 A	9/1978	Carlson	
4,143,985 A	3/1979	Axelsson et al.	
4,144,939 A	3/1979	Knothe	
4,155,600 A	5/1979	Lanfermann et al.	
4,166,508 A	9/1979	van den Berg	
4,195,698 A	4/1980	Nakagawasai	
4,274,761 A	6/1981	Boguth	
4,285,405 A	8/1981	Weir	
4,297,056 A *	10/1981	Nottingham	E02D 5/72 405/232
4,312,413 A	1/1982	Loftis	
4,351,624 A	9/1982	Barber	
4,375,927 A	3/1983	Kniep	
4,397,199 A	8/1983	Jahn	
4,428,699 A	1/1984	Juhola	
4,455,105 A	6/1984	Juhola	
4,519,729 A	5/1985	Clarke et al.	
4,522,304 A	6/1985	Walter	
4,537,527 A	8/1985	Juhola et al.	
4,547,110 A	10/1985	Davidson	
4,553,443 A	11/1985	Rossfelder et al.	
4,601,615 A	7/1986	Cavalli	
4,603,748 A	8/1986	Rossfelder et al.	
4,606,427 A	8/1986	Beer	
4,616,716 A	10/1986	Bouplon	
4,625,811 A	12/1986	Tuenkers	
4,627,768 A	12/1986	Thomas et al.	
4,632,602 A	12/1986	Hovnanian	
4,637,475 A	1/1987	England et al.	
4,645,017 A	2/1987	Bodine	
4,650,008 A	3/1987	Simson	
4,735,270 A	4/1988	Fenyvesi	
4,755,080 A	7/1988	Cortlever et al.	
4,768,900 A	9/1988	Burland	
4,813,814 A	3/1989	Shibuta et al.	
4,819,740 A	4/1989	Warrington	
4,863,312 A	9/1989	Cavalli	
4,915,180 A	4/1990	Schisler	
5,004,055 A	4/1991	Porritt et al.	
5,088,565 A	2/1992	Evarts	
5,106,233 A	4/1992	Breaux	
5,117,925 A	6/1992	White	
5,213,449 A	5/1993	Morris	
5,240,348 A	8/1993	Breaux	
5,244,316 A	9/1993	Wright et al.	
5,253,542 A	10/1993	Houze	
RE34,460 E	11/1993	Ishiguro et al.	
5,263,544 A	11/1993	White	
5,281,775 A	1/1994	Gremillion	
5,343,002 A	8/1994	Gremillion	
5,355,964 A	10/1994	White	
5,388,931 A	2/1995	Carlson	
5,410,879 A	5/1995	Houze	
5,439,326 A	8/1995	Goughnour et al.	
5,529,132 A	6/1996	Evarts	
5,540,295 A	7/1996	Serrette	
5,544,979 A	8/1996	White	
5,549,168 A	8/1996	Sadler et al.	
5,549,170 A	8/1996	Barrow	
5,562,169 A	10/1996	Barrow	
5,609,380 A	3/1997	White	
5,653,556 A	8/1997	White	
5,658,091 A	8/1997	Goughnour et al.	
5,794,716 A	8/1998	White	
5,800,096 A	9/1998	Barrow	
5,811,741 A	9/1998	Coast et al.	
5,860,482 A	1/1999	Gremillion et al.	
6,039,508 A	3/2000	White	
6,129,159 A	10/2000	Scott et al.	
6,179,527 B1	1/2001	Goughnour	
6,234,260 B1	5/2001	Coast et al.	
6,250,426 B1	6/2001	Lombard	
6,360,829 B1	3/2002	Naber et al.	
6,386,295 B1	5/2002	Suver	
6,394,704 B1	5/2002	Saeki et al.	
6,427,402 B1	8/2002	White	
6,431,795 B2	8/2002	White	
6,447,036 B1	9/2002	White	
6,543,966 B2	4/2003	White	
6,557,647 B2	5/2003	White	
6,582,158 B1	6/2003	Van Stein	
6,648,556 B1	11/2003	White	
6,672,805 B1	1/2004	White	
6,732,483 B1	5/2004	White	
6,736,218 B1	5/2004	White	
6,896,448 B1	5/2005	White	
6,908,262 B1	6/2005	White	
6,942,430 B1	9/2005	Suver	
6,988,564 B2	1/2006	White	
7,080,958 B1	7/2006	Morris	
7,168,890 B1	1/2007	Evarts	
7,392,855 B1	7/2008	White	
7,694,747 B1	4/2010	White	
7,708,499 B1	5/2010	Evarts et al.	
7,824,132 B1	11/2010	White	
7,854,571 B1	12/2010	Evarts	
7,914,236 B2	3/2011	Neville	
7,950,877 B2	5/2011	Evarts	

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,070,391	B2	12/2011	White
8,181,713	B2	5/2012	White
8,186,452	B1	5/2012	White et al.
8,434,969	B2	5/2013	White
8,496,072	B2	7/2013	White
8,763,719	B2	7/2014	White
9,249,551	B1	2/2016	White
9,255,375	B2	2/2016	Yingling et al.
2001/0002230	A1	5/2001	White
2005/0039952	A1	2/2005	Hill et al.
2006/0198706	A1	9/2006	Neville
2010/0266344	A1	10/2010	Plotkin et al.
2010/0303552	A1	12/2010	Yingling et al.
2011/0162859	A1	7/2011	White
2012/0292062	A1	11/2012	White
2013/0149040	A1	6/2013	Evarts
2014/0056652	A1 *	2/2014	Suver E02D 7/22 405/249
2014/0377011	A1	12/2014	Yingling et al.
2015/0016893	A1	1/2015	Suver et al.
2016/0356294	A1	12/2016	Fenwick et al.
2017/0101759	A1	4/2017	Suver
2017/0138133	A1	5/2017	Fenwick

FOREIGN PATENT DOCUMENTS

CN	102296608	B		7/2015
DE	4010357	A1		10/1990
EP	0172960A1	A1		3/1986
EP	362158			4/1990
EP	0526743	B1		8/1995
FR	838717			3/1939
FR	2560247			8/1985
GB	2003769			3/1979
GB	2023496			1/1980
GB	2028902			3/1980
GB	2043755			10/1980
GB	2060742			5/1981
GB	2069659	A		8/1981
JP	5494703			7/1979
JP	355098526			7/1980
JP	356034828			4/1981
JP	57169130			10/1982
JP	59228529	A		12/1984
JP	61221416			10/1986
JP	0258627			2/1990
JP	473035			2/1992
JP	497015	A		3/1992
JP	6136751			5/1994
JP	2005256500	A		9/2005
JP	2005315050	A		11/2005
JP	2006089933	A		4/2006
JP	2006177125	A		7/2006
JP	2006312825	A		11/2006
JP	2009138487	A		6/2009
NL	42349			1/1938
NL	65252			2/1950
NL	7710385			3/1978
NL	7707303			1/1979
NL	7805153			11/1979
NO	46428			4/1929
RU	2109881		*	4/1998
SU	1027357			7/1983
WO	WO8707673			12/1987
WO	WO8805843			8/1988
WO	9600326	A1		1/1996
WO	2012031108	A1		3/2012

OTHER PUBLICATIONS

"Castle Board Drain Method", Japanese brochure, Reference Nos. APE00857 through APE00863, Aug. 1976.

"Kony Drain Board," undated, 1 page.

"The 1.sup.st Report on the Treatment of Soft Foundation of Juck Hyun Industrial Site", Ref. Nos. APE00854 through APE00856, Mar. 1976.

A report identifying systems for driving mandrels carrying wick drain material into the earth, identified by Ref. Nos. APE0510 through APE0536, (undated).

A series of photographs identified by reference Nos. APE01147 through APE01159. 1990-1993.

International Construction Equipment, Inc "Hydraulic Vibratory Driver/Extractors for Piling and Caisson Work," 10 pages.

International Construction Equipment, Inc "Hydraulic Vibratory Driver/Extractors for Piling and Caisson Work," Ref. No. V7-0890-51, 1974, 3 pages.

Schematic drawings identified by Ref. Nos. APE01038, APE01039, (updated).

USPTO, "Non-Final Office Action, U.S. Appl. No. 15/285,326," dated Dec. 28, 2017, 17 pages.

USPTO, "Final Office Action, U.S. Appl. No. 15/285,326,", dated Aug. 14, 2017, 10 pages.

* cited by examiner

FIG. 1

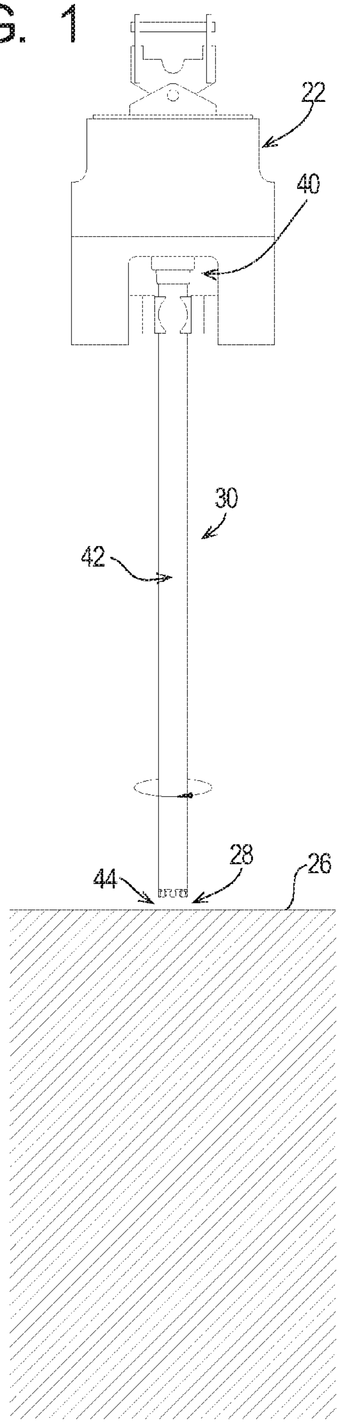


FIG. 2

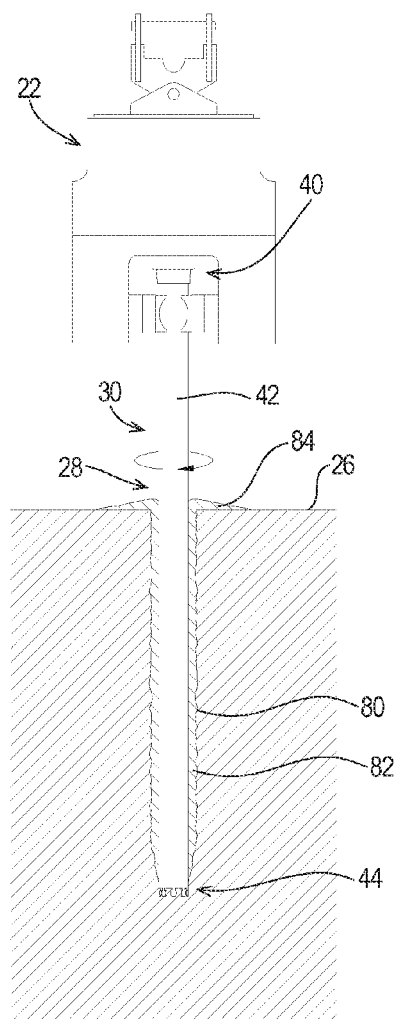


FIG. 3

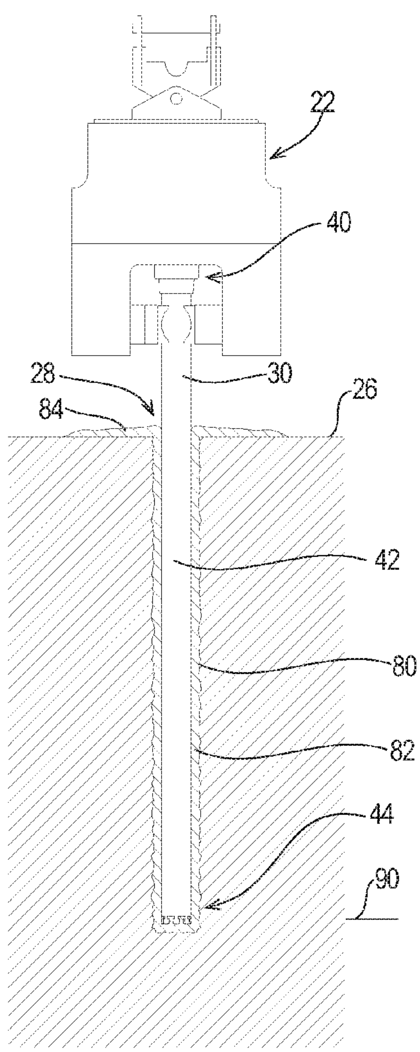


FIG. 4

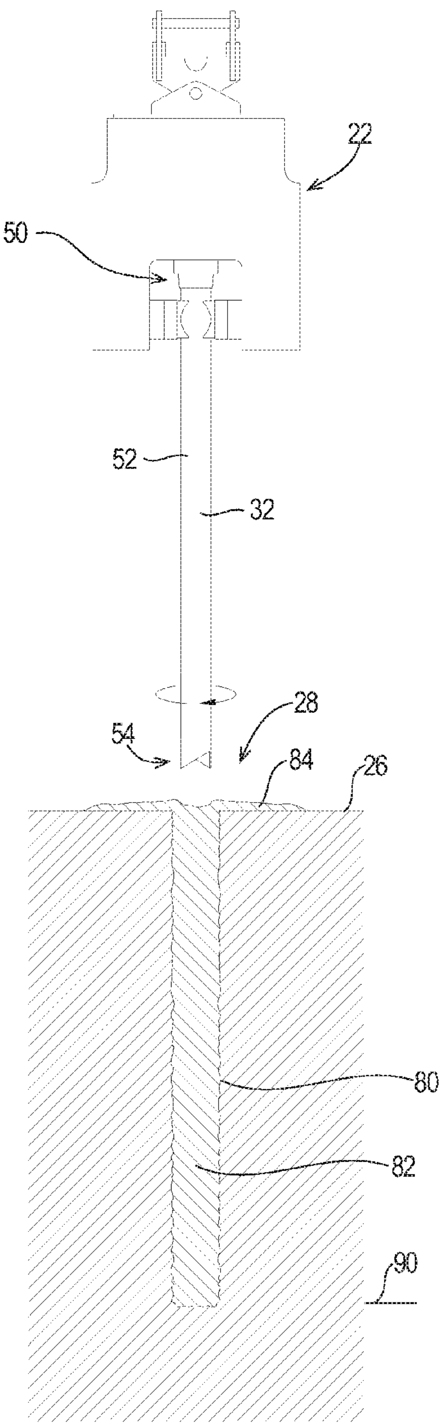


FIG. 5

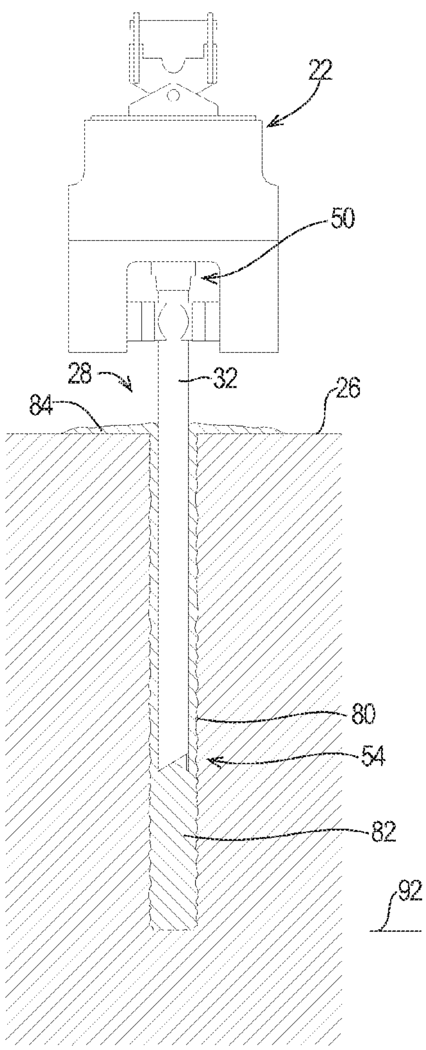


FIG. 6

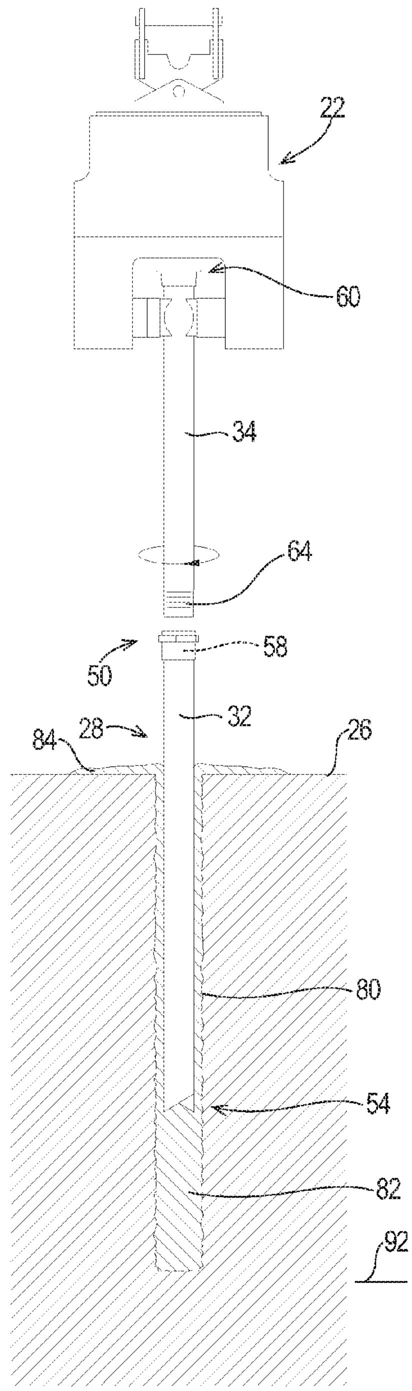


FIG. 7

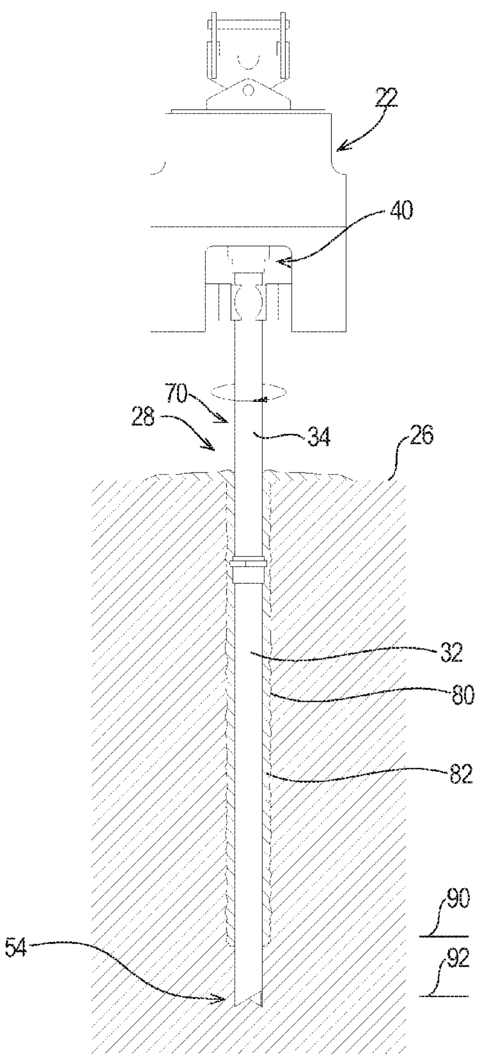

22
40
70
28
34
26
32
80
82
90
54
92

FIG. 8

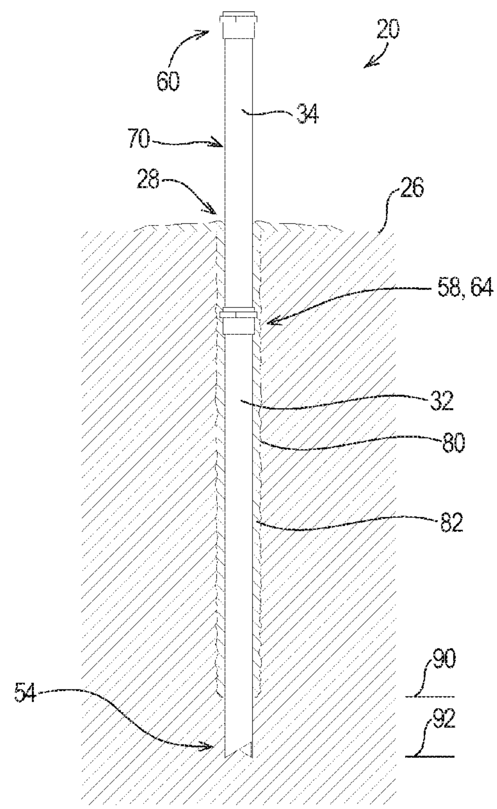

20
60
34
70
28
26
58, 64
32
80
82
90
54
92

FIG. 9

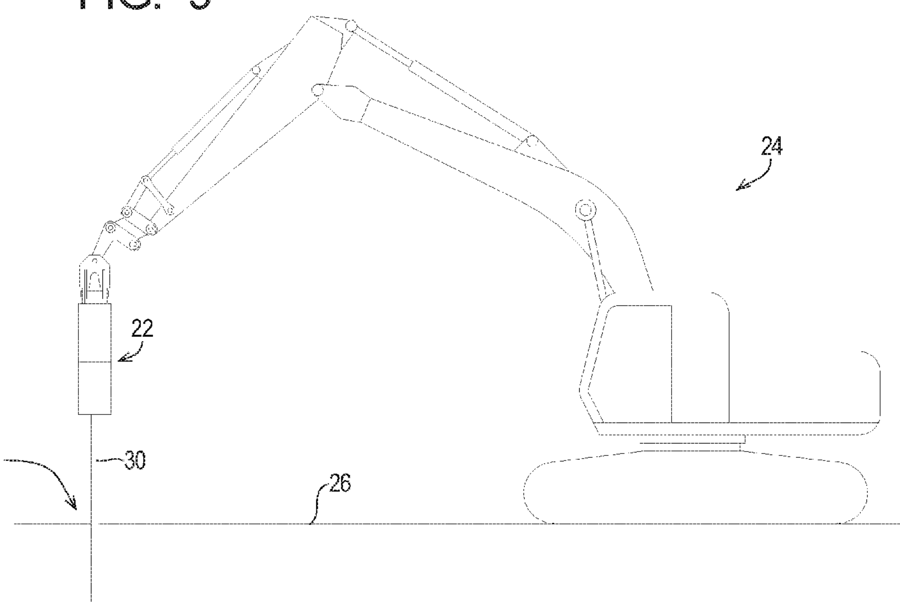


FIG. 10

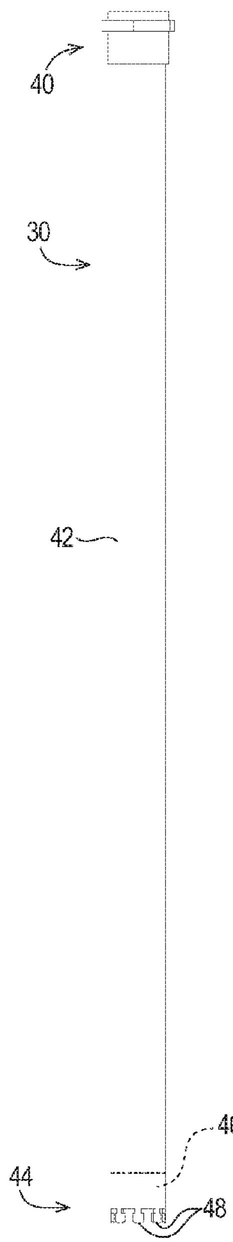


FIG. 11

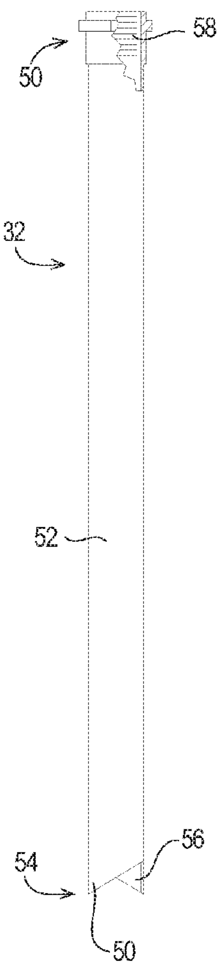
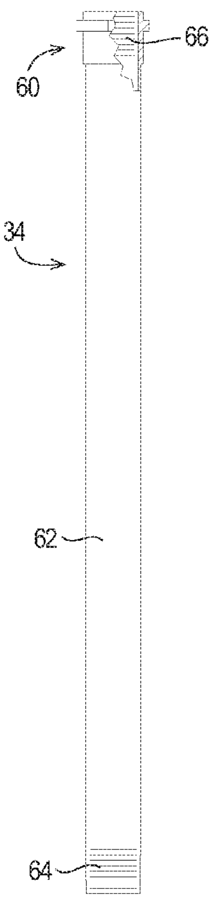


FIG. 12



SYSTEMS AND METHODS FOR INSTALLING PILE STRUCTURES IN PERMAFROST

RELATED APPLICATIONS

This application, U.S. patent application Ser. No. 15/372,196 filed Dec. 7, 2016 claims benefit of U.S. Provisional Application Ser. No. 62/266,379 filed Dec. 11, 2015, the contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to pile driving systems and methods and, in particular, to systems and methods for installing pile structures in permafrost ground.

BACKGROUND

In construction projects, the need often exists to support a structure relative to a desired location of the ground. Piles may be used to support the structure relative to the ground. In particular, a predetermined type of pile may be driven into the ground at the desired location to a predetermined pile depth. The type of pile and pile depth are typically predetermined based on conditions such as the nature of the structure (e.g., load) to be supported by the pile and the conditions of the ground at and below the desired location.

The term "permafrost" is typically used to refer to ground, including rock or soil, at or below the freezing point of water. While many of the techniques employed when driving piles in conventional (e.g., non-frozen) soil may be used in permafrost, the characteristics of permafrost present a unique set of considerations when a pile is to be driven into permafrost.

The need thus exists for pile driving systems and methods optimized for use in permafrost.

SUMMARY

The present invention is a pile system for permafrost comprising a pilot hole, at least one pile, and frozen slurry. The pilot hole is formed to a pilot hole depth. The at least one pile is arranged at least partly within the pilot hole and extending to a pile string depth. The frozen slurry is within the pilot hole and is at least partly around the at least one pile.

The present invention is a method of forming a pile system for permafrost comprising the following steps. A mandrel is displaced to form a pilot hole to a pilot hole depth and to create a slurry at least partly within the pilot hole. The mandrel is removed from the pilot hole. While the slurry is at least partly flowable, at least one pile is arranged at least partly within the pilot hole to a pile string depth. Slurry is allowed to freeze within the pilot hole at least partly around the at least one pile.

The present invention may also be embodied as a method of forming a pile system for permafrost comprising the following steps. A mandrel, a lead pile, and an extension pile are provided. A drive system is operated to rotate the mandrel to form a pilot hole to a pilot hole depth and to create a slurry at least partly within the pilot hole. The mandrel is removed from the pilot hole. While the slurry is at least partly flowable, the drive system is operated to rotate the lead such that the lead pile is arranged at least partly within the pilot hole. The extension pile is connected to the lead pile to form at least part of a pile string. While the slurry is at least partly flowable, the drive system is operated to rotate the extension pile such that the lead pile is arranged within the pile hole and the extension pile is arranged at least partly within the pilot hole. The slurry is allowed to freeze within the pilot hole at least partly around the lead pile and the extension pile.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view illustrating a first point in time during a process of installing a pile structure in accordance with the principles of the present invention;

FIG. **2** is a side elevation view illustrating a second point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **3** is a side elevation view illustrating a third point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **4** is a side elevation view illustrating a third point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **5** is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **6** is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **7** is a side elevation view illustrating a fourth point in time during the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **8** is a side elevation view of a pile structure installed in accordance with the principles of the present invention;

FIG. **9** illustrates a side elevation view of a system that may be used to perform the process of installing a pile structure in accordance with the principles of the present invention;

FIG. **10** is a side elevation view of an example mandrel that may be used by a pile driving system of the present invention;

FIG. **11** is a side elevation view of an example lead pile that may be used by a pile driving system of the present invention; and

FIG. **12** is a side elevation of an example extension pile that may be used by a pile driving system of the present invention.

DETAILED DESCRIPTION

FIGS. **1**-**7** of the drawing illustrate various points during the process of installing an example pile system **20** as depicted in FIG. **8**. FIGS. **1**-**7** also depict a drive system **22** capable of supporting an elongate member and rotating the elongate member that may be used as part of the method of forming the example pile system **20**. The example drive system **22** may be or incorporate, for example, a pile driving system as disclosed in the Applicant's copending U.S. patent application Ser. No. 14/321,632. As shown in FIG. **9**, the drive system **22** may be supported by a support system **24**. In the example, depicted in FIG. **9**, the support system **24** is a conventional excavator, but any other system capable of supporting a drive system such the example drive system **22** may be used in place of the excavator. Together, the support system **24** and drive system **22** allow an elongate member to be driven into the ground **26** at a desired location **28** as will be described in further detail below.

In FIGS. **1**-**3**, the drive system **22** is shown rotating an elongate member in the form of a mandrel **30**. In FIGS. **4**-**7**, the drive system **22** is shown rotating an elongate member in the form of a lead pile **32** and one or more extension piles **34**. In the example shown in FIGS. **1-8**, only one extension pile **34** is used, but more extension piles may be used depending on the circumstances. For purposes of simplicity and clarity, FIG. **9** illustrates the drive system **30** supporting the mandrel **30**, but the drive system **30** is also capable of supporting the lead pile **32** (see, e.g., FIGS. **4** and **5**) or the extension piles **34** (see, e.g., FIGS. **6** and **7**).

FIG. **10** depicts the example mandrel **30**. The example mandrel assembly **30** comprises a drive portion **40**, a shaft portion **42**, and a bit portion **44**. The drive portion **40** is or may be conventional and is adapted to engage the drive system **22** to allow the drive system to axially rotate of the mandrel **30**. The example bit portion **44** is formed by a prefabricated insert **46** made of 4140 steel that houses replaceable teeth **48**. The use of the insert **46** with replaceable teeth **48** allows the integrity of the bit portion **44** to be maintained as it is used and provides the ability for rapid rebuild if necessary. Other characteristics of the bit portion **44** will be described below.

FIG. **11** depicts the example lead pile **32**. The example lead pile **32** comprises a drive portion **50**, a shaft portion **52**, and a cutter portion **54**. Like the drive portion **40** of the mandrel **30**, the drive portion **50** is or may be conventional and is adapted to engage the drive system **22** to allow the drive system to axially rotate of the lead pile **32**. The example cutter portion **54** is formed by a Z-cut on the end of the lead pile **32** defining two or more integral cutting teeth **56**. The integral cutting teeth **56** provide the lead piles **32** with limited short term cutting ability as will be described below, but without the durability or replaceability of the bit portion **44** of the lead pile **32**. FIG. **11** further illustrate a trailing threaded portion **58** formed within the lead pile **32** at the upper end adjacent to the drive portion **50**. The example trailing threaded portion **58** takes the form of internal threads.

FIG. **12** depicts the example extension piles **34**. The example extension pile(s) **34** comprises a drive portion **60**, a shaft portion **62**, a leading threaded portion **64**, and a trailing threaded portion **66**. Like the drive portion **40** of the mandrel **30** and the drive portion **50** of the lead pile **32**, the drive portion **60** is or may be conventional and is adapted to engage the drive system **22** to allow the drive system to axially rotate of the extension pile **34**. The example leading threaded portion **64** is takes the form of external threads on the end of the pile **32**. The internally threaded trailing threaded portion **58** of the lead pile **32** receives the externally threaded leading portion **64** of the extension pile **34**. If more than one extension pile is used, the internally threaded trailing threaded portion **66** of the first extension pile receives the externally threaded leading portion **64** of the next extension pile **34**. In this manner a string of one lead pile **32** and at least one extension pile **34** may be used to form a pile string. FIGS. **7** and **8** illustrate a pile string **70** comprising a single lead pile **32** and a single extension pile **34**.

Additionally, an internally threaded trailing threaded portion (not shown) may be formed on the mandrel **30**. One or more extension piles **34** may be coupled to the mandrel **30** to allow the mandrel **30** to be driven to a depth greater than its length.

Referring now back to FIG. **1-7**, the process of forming the example pile system **20** comprising the example pile string **70** will now be described in further detail. Initially, it should be noted that pile string is particularly suited to be used when the ground **26** is formed by what is commonly referred to as permafrost. The ground **26** is thus very cold, and any moisture therein will be frozen.

The mandrel **30** is coupled to the drive system **22** and axially rotated while suspended above the desired location **28** in the ground **26** as shown in FIG. **1**. The drive system **22** and mandrel **30** are then lowered or crowded into the ground **26** while the mandrel **30** is axially rotated such that the mandrel **30** penetrates the ground **26** and forms a pilot hole **80** in the ground **26** at the desired location **28** as shown in FIG. **2**. As the mandrel **30** penetrates the ground **26**, the teeth **46** cut into and abrade the dirt and rock of the ground **26** around the pilot hole **80**, creating friction.

The friction created by the teeth **46** heats up the mandrel **30**, and the mandrel **30** in turn heats up the ground **26**. Liquids in the heated ground **26** melt, creating a slurry **82** within the pilot hole **80**. The teeth **46**, the material from which the teeth **46** are made, the diameter of the mandrel **30**, and speed at which the mandrel **30** is rotated are all controlled such that melted liquids forming at least part of the slurry **82** heat up and expand such that at least a portion of the slurry **82** flows to the surface. Accordingly, at least a portion of the slurry **82** will typically be forced up the pilot hole **80** and form a pool **84** of the slurry **82** on the ground surface where the mandrel enters the ground **26**.

After the mandrel **30** reaches a pilot hole target depth **90** predetermined based on factors such as characteristics of the ground **26** and characteristics of the load (not shown) to be supported by the pile string **70** as shown in FIG. **3**, the mandrel **30** is removed and detached from the drive system **22**. Extensions to the mandrel **30** may be used to allow the example mandrel to reach the pilot hole target depth **90**.

At this point, while the slurry **82** is still melted and at least partly flowable, the lead pile **32** is connected to the drive system **22** and supported above the pilot hole **80** as shown in FIG. **4**. The drive system **22** and lead pile **32** are then lowered and the lead pile **32** rotated such that the cutter portion **54** of the lead pile **32** enters the pilot hole **80**. While the cutter portion **54** of the lead pile **32** does not have the cutting capacity of the bit portion **44** of the mandrel **30**, the cutter portion **54** is sufficiently strong and durable to cut through the slurry **82** still in the flowable state. Further, the cutter portion **54** will create friction that will add heat to the slurry **82** as the lead pile **32** is axially rotated while being inserted into the pilot hole **80**. The lead pile **32** is inserted to a depth at which the drive portion **50** thereof is still accessible as shown in FIG. **5**, after which the drive system **22** is disconnected from the lead pile **32**.

Again, while the slurry **82** is still melted and flowable, the extension pile **34** is connected to the drive system **22**. The extension pile **34** is supported above the pilot hole **80** as shown in FIG. **6** and then rotated such that the threaded portion **58** on the lead pile **32** receives the threaded portion **64** on the extension pile **34** to connect the extension pile **34** to the lead pile **32** to form the pile string **70**. The drive system **22** and pile string **70** are then lowered and the pile string **70** axially rotated such that the cutter portion **54** of the lead pile **32** continues through the slurry **82** within the pilot hole **80**. Again, the cutter portion **54** is sufficiently strong and durable to cut through the slurry **82** still in the flowable state and will create friction that will add heat to the slurry **82** as the pile string **70** is axially rotated while being inserted into the pilot hole **80**. Further, the cutter portion **54** of the lead pile **32** is sufficiently strong to penetrate beyond the pilot hole depth **90** as shown in FIG. **7**.

Accordingly, additional rotation of the pile string **70** will continue to cut into the ground **26** beyond the pilot hole depth **90**. When the drill string **70** reaches a target drill string depth **92** that is below the pilot hole depth **90** as shown in FIG. **7**, the rotational and crowding forces are no longer applied to the drill string **70**. Again, the target drill string depth **92**, and possibly the distance between the pilot hole depth and the target string depth **92**, will typically be predetermined based on requirements of the load and characteristics (e.g., soil conditions) of the ground **26** at the desired location **28**. The drive system **22** is then removed from the drill string **70**, and the slurry **82** is allowed to refreeze, securing the pile string **70** in a desired orientation at the desired location **28** as shown in FIG. **8**.

When the pile string **70** is secured in the desired orientation at the desired location **28** as shown in FIG. **8**, the example pile system **20** is formed by the pile string **70**, the ground **26** around the pile string **70**, and the frozen slurry **82** adjacent to the pile string **70**. At this point, a structure or load may be supported by the pile string **70** in a conventional manner. The Applicant's copending U.S. Provisional patent application Ser. No. 15/174,724 discloses Systems and Methods for Connecting a Structural Member to a Pile that may be used on the uppermost extension pile **34** of the pile string **70** depicted in FIG. **8**. However, other systems and methods may be used to secure a structure to the pile string **70**.

In this specification, the use of a letter suffix with any reference character does not necessarily indicate that an element generically identified by that reference character is different from an element specifically identified by the reference character with a letter suffix. Accordingly, any reference character used without a letter suffix in the specification may generally refer to the same reference character used with a letter suffix in the drawing.

What is claimed is:

1. A method of forming a pile system for permafrost comprising the steps of:
- rotating a mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole;
- removing the mandrel from the pilot hole;
- while the slurry is at least partly flowable, arranging at least one pile at least partly within the pilot hole to a pile string depth; and
- allowing slurry to freeze within the pilot hole at least partly around the at least one pile.

2. The method as recited in claim **1**, in which the at least one pile comprises a lead pile.

3. The method as recited in claim **1**, in which the at least one pile comprises an extension pile.

4. The method as recited in claim **1**, in which the step of arranging the at least one pile at least partly within the pilot hole comprises the steps of:
- providing a plurality of piles; and
- forming a pile string comprising a plurality of piles.

5. The method as recited in claim **4**, in which the step of providing a plurality of piles comprises the step of providing a lead pile and at least one extension pile.

6. The method as recited in claim **4**, in which the step of forming the pile string further comprises the steps of:
- arranging the lead pile at least partly within the pilot hole;
- connecting a first extension pile to the lead pile to form at least part of the pile string; and
- displacing the at least part of the pile string formed by the lead pile and the first extension pile such that the first extension pile is arranged at least partly within the pilot hole.

7. The method as recited in claim **6**, in which the step of forming the pile string further comprises the steps of:
- connecting a second extension pile to the first extension pile to form at least part of the pile string; and
- displacing the at least part of the pile string formed by the lead pile and the first and second extension piles such that the second extension pile is arranged at least partly within the pilot hole.

8. The method as recited in claim **1**, in which the pile string depth extends beyond the pilot hole depth.

9. The method as recited in claim **1**, further comprising the step of predetermining the pile string depth based on at least one of:
- ground characteristics at a desired location at which the pilot hole is to be formed; and
- a load to be supported by the pile string after the slurry has been allowed to freeze.

10. A method of forming a pile system for permafrost comprising the steps of:
- providing a mandrel;
- providing a lead pile;
- providing at least one extension pile;
- operating a drive system to rotate the mandrel to form a pilot hole to a pilot hole depth, where friction created by engagement with the mandrel and the permafrost melts liquids in the permafrost, thereby creating a flowable slurry at least partly within the pilot hole;
- removing the mandrel from the pilot hole;
- while the slurry is at least partly flowable, operating the drive system to rotate the lead pile such that the lead pile is arranged at least partly within the pilot hole;
- connecting the at least one extension pile to the lead pile to form at least part of a pile string;
- while the slurry is at least partly flowable, operating the drive system to rotate the at least one extension pile such that the lead pile is arranged within the pile hole and the at least one extension pile is arranged at least partly within the pilot hole; and
- allowing slurry to freeze within the pilot hole at least partly around the lead pile and the at least one extension pile.

11. The method as recited in claim **10**, in which the step of arranging the lead pile and the at least one extension pile at least partly within the pilot hole comprises the steps of:
- providing a plurality of extension piles; and
- forming the pile string by connecting one of the plurality of extension piles to the lead pile and one of the plurality of extension pile to the extension pile connected to the lead pile.

12. The method as recited in claim **11**, further comprising the step of rotating at least a portion of the pile string such that the pile string extends to a pile string depth.

13. The method as recited in claim **12**, in which the pile string depth extends beyond the pilot hole depth.

14. The method as recited in claim **12**, further comprising the step of predetermining the pile string depth based on at least one of:
- ground characteristics at a desired location at which the pilot hole is to be formed; and
- a load to be supported by the pile string after the slurry has been allowed to freeze.

* * * * *