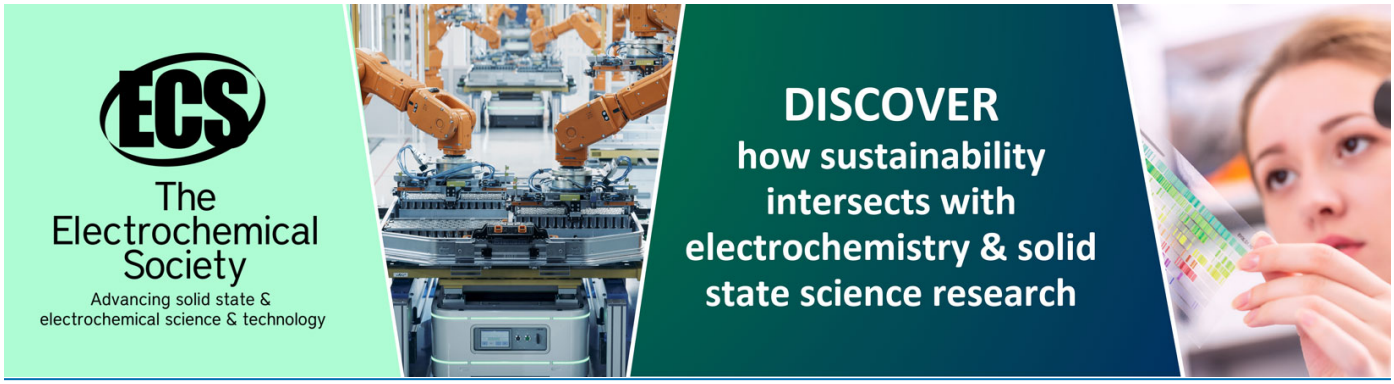
Promising Screw Piles Designs for Construction on Permafrost Soils



Promising Screw Piles Designs for Construction on Permafrost Soils

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Abstract. Promising designs of screw piles with improved technical characteristics have been developed, which reduce risk of buckling from soil as a result of influence of tangential forces of frost heave, reduce energy consumption when screwing piles into the soil, and also simplify designs and manufacturing techniques of blades. Usage of cryophobic coatings applied to trunk part placed in the active soil layer is proposed to reduce bulging of piles. Applying anti-friction coatings to the blades, as well as usage of greases filling slots at their edges is proposed to reduce friction when tightening. Strengthening adhesive interaction between pile and soil below active layer can be achieved by applying cryophilic coatings and freezing water in gap between pile shaft and soil. Simplification of pile design is assumed by replacing screw blades with segmented or cable blades

1. Introduction

Construction of buildings and structures in zone of permafrost distribution is carried out on pile foundations. Various designs of pile foundations are described in detail in scientific literature [1-7]. Reinforced concrete, steel, wood, reinforced plastics are used for manufacturing of piles. In recent years, especially in low-rise construction, metal and fiberglass screw piles have been widely used [8-10].

2. Topicality

Design of screw piles is quite simple and technologically advanced in production and, with relatively low weight, can provide sufficiently large bearing capacity. Main materials for screw piles manufacturing are various grades of corrosion-resistant steels, although results of fiberglass pultruded composites tests are also known recently [11-13].

When using screw piles in permafrost soils, they, as well as piles of other types, are affected by frost heaving, in our opinion, exacerbated by increased thermal conductivity of metal trunks. In summer period, soil penetration in depth and in halo of trunk occurs more intensively than in concrete and wooden piles and may be lower than level of seasonal penetration, which determines increase in tangential forces of frost heaving. In addition, disadvantages of screw piles include relatively high energy losses when screwing them into frozen soil.

Various methods are proposed to reduce frosty bulging of piles from the ground, for example, associated with expansion of pile base, installation of crossbars or screw blades that fix position of pile below active soil layer [11-13]. Disadvantage of such approaches is increasing of complexity of pile designs and installation technology.

There are also known ways to reduce effects of frost heaving tangential forces on piles by reducing adhesion of pile surface to ground when it is frozen by applying cryophobic coating on it – plastic grease or silicone enamel [14].

Disadvantages of this approach are low efficiency, since the coating provided for by recommendations on the entire lateral surface of the pile simultaneously reduces adhesion of soil to pile and below boundary of active layer.

One of the latest proposals to reduce effects of frost radiation is usage of coatings from heat-shrinkable shells made of thermoplastic polymers [15]. Shells cover lateral surface of piles considering thickness of active soil layer and significantly reduce their frosty bulging. Unfortunately, information about durability of shells is currently not available.

3. Problem definition

Further modification of screw pile design is necessary to simplify technology of their installation, increase reliability and durability and reduce the influence of the known disadvantages of screw piles.

4. Theoretical part. Developed designs

In contrast to well-known technical and technological solutions, the following is proposed to reduce bulging of piles:

- instead of greases and organosilicon enamels, use coatings based on polyurethane, polyurea and polymethyl methacrylate, which are characterized by high cryophobic properties and improved adhesion to metal and concrete, as well as wear resistance, and apply it above seasonal thawing border;
- when installing piles in leader well, fill the space between pile and ground with water below boundary of maximum possible seasonal thawing;
- apply heat-insulating polymer coating to side surface of piles from border of seasonal thawing layer.

Distinctive feature of modern polymer coatings is their manufacturability, which makes it possible to apply them on concrete and steel surfaces in wide range of ambient temperatures from minus 15 0C to 40 0C even under construction site conditions [16]. Mentioned polymers are characterized by high resistance to abrasive and hydroabrasive effects, which, combined with enhanced adhesion to steel and concrete, should lead to increase in durability of coating [17].

It should be noted that polymer composites usually have rather low coefficient of thermal conductivity and therefore can simultaneously perform thermal insulation functions. For example, in composites based on polymethylmethacrylate, thermal conductivity is about 0.2 W/m deg, and coating of it can be applied up to 20 mm thick and significantly reduce soil breakdown in halo of metal pile shaft [18].

When filling the space between soil and pile with water below zone of maximum seasonal thawing, it freezes quite quickly. Concrete and steel are characterized by high hydro- and cryophilic properties, therefore, process of freezing water is accompanied by freezing of piles to ground, neutralizes action of tangential forces of frost heaving and helps to maintain initial position of pile.

Simplification of screw piles blades design, for example, compared with design of piles [19], can be largely achieved by applying antifriction wear-resistant polymer coatings on their surface. For these coatings, various composites based on polytetrafluoroethylene, ultra-high molecular weight polyethylene, polyurethane, polyurea, polymethyl methacrylate and other polymers can be used. Most preferred are materials provided with technologies for applying to steel surfaces with sufficient adhesion and characterized by reduced coefficient of friction on frozen ground.

Another simple approach for solving problem of reducing energy costs when screwing piles into ground is to organize lubrication of contact surface of pile blade with ground. It is proposed to make slots in lower end of screw blade and its side part, filled with grease before installation, to do this. In process of interaction between blade and soil, there will be gradual filling of slots with soil particles, extrusion of lubricant on blade surface, which reduces friction and energy consumption for screwing pile.

It should be noted that when arranging foundations of buildings and structures on permafrost soils, it is recommended to use narrow-bladed piles, in which blade diameter does not exceed trunk diameter by more than 1,5 times [20, 21]. This circumstance can greatly simplify installation of blade on pile shaft. In this case, it is proposed that screw pile blade be made of metal or polymer cable stretched through radial holes located along helical line, ends of which are fixed after clamping by clamps placed in pile cavity (Figure 1). Cable diameter, number of revolutions around trunk and distance between holes must be determined by calculation considering results of geocryological surveys. Installation of such screw piles is carried out in leader well using known technologies.

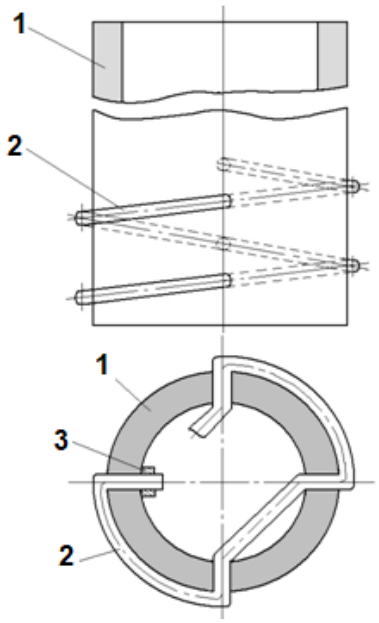

Figure 1. Screw pile with cable blade.
1 - trunk, 2 - cable, 3 – clamp.

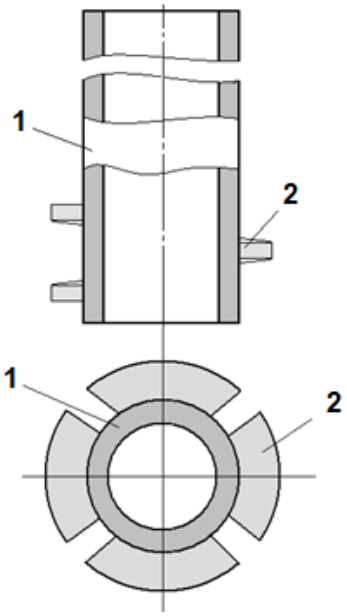

Figure 2. Screw pile with segmented blade.
1 - trunk, 2 - ring segments.

Another option to simplify shape of blades is to make them in form of annular segments attached to pile shaft along helix (Figure 2). Method of fastening segments to barrel can be any that provides necessary strength of connection (welding, soldering, gluing, bolting, etc.). Ring segments can be made of steel strips or sheets according to most known economical and productive technologies. It is possible to produce segment rings from reinforced polymers - fiberglass or carbon fiber.

5. Practical significance

Mentioned options for modernization of screw piles designs can significantly increase efficiency of their use, especially in permafrost zone. In one design of screw pile, it is possible to implement several proposed solutions, for example, applying antifriction cryophobic heat-insulating coatings in part of pile located in active soil layer, cryophilic coating in lower part, antifriction on blades, combined with making slots filled with elastic lubricant.

6. Conclusions

Modernized designs of screw piles with increased operational characteristics are designed and offered for widespread usage in practice of construction of buildings and structures on permafrost soils.

7. References

[1] Ilikheva V A and Mangusheva R A 2014 Handbook geotechnics Foundations, fundamental and underground structures (Moscow: ASV) p 728
[2] SNiP 1995 2.02.01-83* Foundations of buildings and structures (Moscow: Ministry of Construction of Russia) p 49
[3] SNiP 1995 2.02.03-85. Pile foundations (Moscow: GP TSPP) p 48
[4] Bakholdin B I 1981 Progressive structures of pile foundations Works of the NIIOSP named after N M Hertsevanov (Moscow: NIIOSP) pp 117-25
[5] Tomlinson M and Woodward J 2008 Pile design and construction practice (London and New York: Taylor & Francis) p 551
[6] Mangushev R A, Gotman A L, Znamenskiy V V and Ponomarev AB 2018 Pile and pile bases *Constructs, project and technology* (Moscow: ASV) p 320
[7] Vrublyauskas T M 2012 Piles of bases on vernous grunts (Moscow: Severgeotekh) pp 97-9
[8] Klevako V I, Sursanov D N and Shutova O A 2010 Rifle piles in low-rise construction Project and economic efficiency *Construction and reconstruction* **2(28)** pp 8-11
[9] Opalikhina A A 2018 Pile foundations on screw piles against the conditions of the Far North Innovation *Science* **6** pp 31-4
[10] Karlov V D 2010 Foundations and Foundations on Seasonal Freezing Soils (St. Petersburg: State Architectural and Construction University) p 125
[11] Noskov I V, Ananev S A and Surtaev A G 2019 Current state of screw piles in construction Messenger of the Eurasian science **3(11)** pp 42-7
[12] Zhelezkov V N 2004 Rifle piles in the energy and other sectors of construction (Sankt-Pererburg: Pragma) p 238
[13] Kondratev V G 2008 Attachment of contact system supports and overhead lines in cryolithozone straddling soils *Transport Russian Federation* **6(19)** pp 34-8
[14] 1980 Recommendations to reduce the tangent forces of frost bulging of foundations using plastic lubricants and organosilicon (Moscow: NIIOSP) p 37
[15] Alyavdin D V and Kuzmin A V 2017 Patent RF 77618 U1 Pile with an opposite shell 2016151230
[16] Mohotti D, Ngo T, Raman S N and Mendis P 2015 Analytical and numerical investigation of polyurea layered aluminium plates subjected to high velocity projectile impact *Materials and Design* **82** pp 1-17
[17] Toutanji H A, Choi H, Wong D, Gilbert J A and Alldredge D J 2013 Applying a polyurea coating to high-performance organic cementitious materials *Construction and Building Materials* Vol 38 pp 1170-9
[18] State standart 2009 R 53627 Cover polymer thin-layer roadway of bridges (Moscow: Standartinform) p 7
[19] Rudakov G V and Shumakov I K 2008 Patent RF 77618 U1 Screw pile (variant) 124782/22
[20] Zhelezkov V N, Romanov P I, Kachanovskaya L I and Ermoshina M S 2008 Development of the normative document "Design and arrangement of foundations for screw piles *Bulletin of civil engineers* **2(15)** pp 42-6
[21] Absimetov V E, Solovev D B 2020 The Use of Effective Design Solutions and High-Tech Building Materials for Reconstructing Residential Buildings of Mass Development in 1960-1990 *IOP Conf. Ser.: Mater. Sci. Eng.* **753** Paper № 032027. [Online]. Available: https://doi.org/10.1088/1757-899X/753/3/032027