An Improved Technology of Implementation of Foundations in the Rammed Pits

***[1] MakhmudKharun, [2]Alexander P. Svintsov**

Department of Architecture & Civil Engineering, RUDN University, Moscow, Russia

Department of Architecture & Civil Engineering, RUDN University, Moscow, Russia

Corresponding Author: MakhmudKharun

Email: miharun@yandex.ru

https://doi.org/10.26782/jmcms.2019.03.00012

Abstract

Implementation of foundations in the rammed pits allows to provide the construction of buildings on soft loess and subsidence soils, as well as on clay and loam grounds. Principle of the proposed pit ramming under foundation consists in the fact that a weight of 2.5-15 tons drops from a height of 6-12 m in a same spot. As a result of soil compaction the hollow is formed, in which the reinforcing rebar skeleton is installed and concrete is poured. Foundation in rammed pit, which created in this way, can hold the bearing capacity of up to 10,000 kN. Machineries based on the tractor, the crane-excavator or the ramming machine are used for pit ramming under the foundation. The main strike element is the rammer that falls under its own weight along the guiding rail trunk or the guiding rail road. Using of such machineries and foundation implementation in rammed pit can significantly reduce the volume of excavation work, material consumption and the complexity of implementation.

Pit ramming in the soil with water-saturated layer (aquifer) is associated with some technical difficulties. The softened soil collapses into the pit bottom. Water at the pit bottom contributes to the creation of vacuum, during the removal of rammer, which generates the effect of its suction. It makes the pit ramming without any special measures quite problematic. And at the same time it is necessary to prevent the entry of water into the pit cavity for foundation implementation in the soils with water-saturated layer. A way to successfully cross the water-saturated layer and to implement the foundations in rammed pits is proposed. The developed technology has been repeatedly tested in the constructions of industrial and livestock buildings.

Keywords : Rammed Pit, Water-Saturated Layer, Foundation, Technology of Pit Ramming

I. Introduction

Foundation implementation in the rammed pits is effective not only on soft soils, but also on soils with good bearing capacity. Principle of this method lies in the fact that the soil is not pulled out from the pit under the individual foundation, but rammed to the required depth. For this, a weight is used that drops to a point from a certain height. The created hollow in the ground, in this way, filled with concrete or reinforced concrete.

Foundation implementation method in rammed pits can significantly reduce the volume of excavation work, material consumption and the complexity of works compared to the conventional pillar and pile foundations.

Foundation implementation in the compacted pits is not possible without the special measures in soils with water-saturated layer (aquifer), because of the collapse of softened soil in pit bottom.

A tested effective technology that allows to successfully implement the foundation in soils with water-saturated layer is presented.

II. Analysis of the Stated Issue

Foundation implementation in the rammed soils is widely used in the contemporary construction. Most often the loess and subsidence soils are compacted, which are very common in the world. There are various methods for improving the soft soil compaction: dry compaction, polypropylene reinforcing fibers, low power direct current treatment with vacuuming etc. (Tang Chao-Sheng et al., 2010; Gaaver K.E., 2012; Feng Shi-Jin et al., 2014; Mao Dongfeng et al., 2015). Studies of Ibrahim K.M.H.I. (2014) have revealed the dependency of load-bearing capacity of subsidence soils on the angle of internal friction.

Foundation implementation in the soft soils is carried out not only after compacting and strengthening, but also through ramming. To increase the bearing capacity of soils under the foundations, in the bottom of rammed pit, the hard soil material (crushed stone, sand-gravel mix, coarse sand etc.) is ramming in portions. Pit ramming is made after the site planning with marking the floor base. By combining in a single process of soil compaction and pit formation the volume of excavation works, associated with extracting and backfilling of trenches, is greatly reduced (by 3-6 times) (Torgashova E.N., 2014; Glushkov V.E. and Glushkov A.V., 2014). Formworks are completely excluded at the concreting of foundations in the hollow. The presence of compacted area under foundation pit and around its slanted side walls can significantly reduce the sizes of foundations (Glukhov V.S. et al., 2015; Hryanina O.V. and Astafev M.V., 2015). As a result, the application of methods of foundation implementation in the rammed pits can significantly reduce the consumption of concrete and other materials, and the cost and complexity of work as compared to the conventional pillar, strip and pile foundations (Glushkov V.E. and Glushkov A.V., 2014; Gotman A.L. and Shemenkov Y.M., 2015).

For pit ramming, crane-excavators, tractors with hinged equipment with guiding rail rod, carriage and rammer are used (Svintsov A.P. et al., 2010; Kharun M. and Kvartenko K.V., 2012; Hryanina O.V. and Astafev M.V., 2015). Guiding rail rod of 8-12 m length provides the vertical falling of rammer in the one place. The rammer is made in the form of prospective pit. It can be square, circular, rectangular, hexagonal forms of 1 to 3.5 m height. The carriage allows sliding of rammer along the guiding rail rod.

According to Torgashova E.N. (2014), for pit ramming under the conventional pillar foundation up to a depth of 1 m without widening the base, it is required about 10-16 strokes - about 2-4 minutes, and for the pit up to a depth of 3 m with a widened base, taking into account the ramming of rigid material in the bottom, it is required about 40-60 strokes, i.e. 10-20 minutes.

Foundations in rammed pits are used depending on the soil conditions, such as, on subsidence loess soils that cover clay, bulk clay soils with plasticity index $I_p \geq 0.03$; with dry soil density $\rho_d \leq 1.6$ t/m3; at the degree of water saturation $S_w \leq 0.75$ for shallow foundations, and $S_w \leq 0.65$ for elongate foundations (Svintsov A.P. et al., 2010; Glukhov V.S. et al., 2015; Hryanina O.V. andAstafev M.V., 2015). As a result, an area of compacted soil is formed around the rammed pit (Glukhov V.S. et al., 2015; Kovalev V.A. and Kovalev A.C., 2016). Dry soil density and deformation modulus are increased within this field, and virtually the subsidence properties are eliminated.

One of the problems during the implementation of rammed pit is the bulging of soil in the pit cavity and formation of taper. It leads to the impossibility of rammer extraction from the pit. The increase of pulling force, during the removal of rammer, leads to the destruction of gears of power equipment, the tearing of ropes on which the rammer is fixed, and also the damage of head on the guiding rail trunk. To avoid this phenomenon, it is advisable to secure the pit neck by metal bushing (Svintsov A.P. et al., 2010). It can significantly increase the work efficiency by eliminating the jamming of rammer in the pit neck for the next cycle of ramming.

During the pit ramming under foundation, the soil compaction occurs at the pit bottom at the direction of rammer falling, as well as at the direction of pit walls along the contour. Soil compaction occurs due to the movement of its particles. At the pit bottom, where the movement is resisted by the array of soil, occurs its compaction. In the pit neck the movement of soil meets resistance in the direction of array and it is compacted. In this case the falling rammer meets not only the soil resistance at its compression, and also the frictional resistance. During the movement of soil to the pit cavity, its neck is narrowed, and a taper is formed which prevents the removal of rammer for the repeating cycle of ramming. In this case, some extra efforts require to exert for removal of rammer, which in some cases leads to the breakdowns of winch, flexible traction bodies, lifting system etc. These deficiencies cause the performance degradation and increase the cost of works.

To reduce the friction between the rammer and the soil during the pit ramming, it is advisable to periodically cover the rammer with a layer of

lubricant. Lubrication of rammer is carried out with the using of manual brush. In this case, often the lubricant layer is placed roughly, since the rammer surface is usually covered with soil remnants which fall off during the movement of rammer together with the lubricant.

To ensure a uniform lubrication of rammer surface and to reduce its friction between the rammer and the soil during the pit ramming, a lubricant soaked sponge can be fixed to the cavity of guiding rail trunk (Svintsov A.P. et al., 2010). It ensures a uniform and regular lubrication of rammer surface, and thereby reduces the friction between the rammer and the soil during the pit ramming, and also improve the work safety.

To increase the bearing capacity of foundation in rammed pits an extension at the bottom of pit is arranged with the crushed stone or gravel. In difficult soil conditions, for ramming of rigid material, the placing and compacting of sand layer is preceded (Svintsov A.P. et al., 2010; Glukhov V.S. et al., 2015). Ramming of rigid material and forming of extension can increase the bearing capacity of foundations by 2-2.5 times (Hryanina O.V. and Astafev M.V., 2015).

A special construction technology is required for the foundation implementation in rammed pits that cross the water-saturated layer of soil (Svintsov A.P. et al., 2010). The specificity consists in that during the pit ramming the softened soil collapses into the pit bottom. It creates a significant obstacle to implement the foundations of this type.

Analysis of the publications, devoted to the foundation implementation in rammed pits, shows that the most of their attention is focused on the tasks of increasing the bearing capacity of soils and foundations. Whereas on the construction technology for foundation implementation in rammed pits is not paid sufficient attention. It holds back the solution of increasing the efficiency of construction technology for implementation of foundations of this type. To this end, the aim of this research work was to improve the technology of implementation of foundations in the rammed pits.

III. Machines and Equipment for the Improved Technology

Tractor and crane, mounted with the guiding rail trunk or the guiding rail rod, are used for the foundation implementation in rammed pits (Fig. 1). As a compacting element the rammer of 2.5-15 tons of weight is used. Rammers shape and dimensions depend on the shape and dimensions of prospective foundation: square, circular etc. The diameter of rammer can be 0.6-3 m.

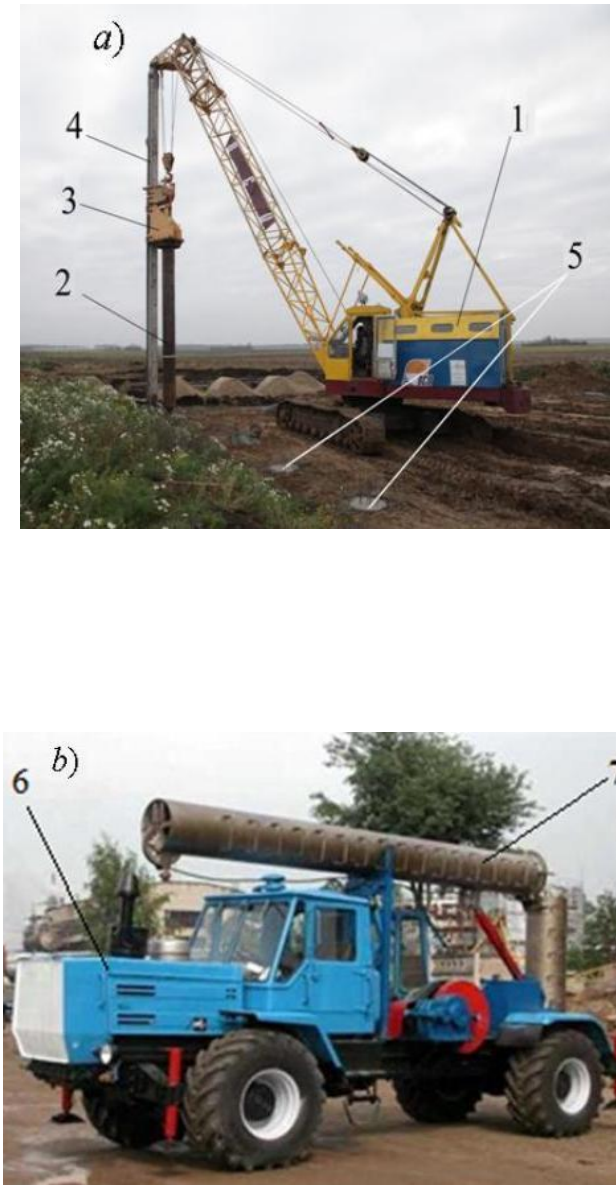

Fig. 1: Machines for the implementation of foundations in rammed pits
a) based on crane-excavator (working position)
b) based on tractor (transportation position)
1– crane-excavator; 2 – rammer; 3 – carriage;
4 – guiding rail rod; 5 – foundation head;
6 – tractor; 7 – guiding rail trunk

The use of machines with interchangeable equipment enables a flexible organization of works at the construction site depending on the tasks. Gradual

soil compaction by falling of rammer at one point allows to implement the technically reliable and economical foundations.

IV. Technology of Implementation of Foundations in the Rammed Pits

Construction technology for foundation implementation in rammed pits is well established not only on subsidence, but also on clay soils. Technological layout of the foundation implementation in rammed pits is as follows.

Ramming machine is installed on the foundation implementation point and penetrate the soil by gradual strikes from falling rammer up to the calculated level, by sprinkling of rigid material, such as crushed stone, to strengthen the pit walls in the process of compaction. Crushed stones of 40-70 mm size are also sprinkled on the pit bottom for the formation of foundation foot. During the ramming of rigid material on the pit bottom by rammer an extension in the shape of sphere or ellipsoid is formed. The maximum size of extension, that obtained by the ramming of rigid material, is taken not more than the double of diameter of the lower section of rammer. After the formation of foundation foot, the reinforcing skeleton is installed in the cavity of pit, concrete is placed and compacted to create a reinforced concrete trunk, sand or crushed stone and concrete preparation are arranged followed by the reinforced concrete grillage work.

One of the problems during the pit ramming under foundations by the shock-rope method is the impossibility of work in water-saturated soils. In these cases, the following situations can occur: breakout of underground water in the pit, bulging of soil base, collapse of soil in the pit cavity, loosening of soil, washouts, that forms mud, which sips the rammer when it falls at the end of pit bottom, by holding its removal for the next cycle of strikes. A large pulling force is required for removal of rammer, which in some cases leads to the breakdowns of winch, flexible traction bodies, lifting system. In this case the labor input is increased significantly, and in many cases the pit ramming is almost impossible if there is a passage of water-saturated layer.

To prevent the entry of water and soil collapse we developed a technology of ramming, which consists in tamponing of water-saturated layer along the pit contour. Principle of the developed technology lies in the fact that after the pit ramming until the water-saturated layer the concrete mix is placed in the pit bottom, after the setting of concrete mix the hole is punched in the formed tampon by the falling rammer and the process of pit ramming continues up to the calculated depth (Fig. 2).

Technology of foundation implementation in rammed pit in the presence of water-saturated layer is carried out as follows. Ramming machine is installed in accordance with the grid axis of foundation (Fig. 2*a*). By falling of rammer in the guiding rail trunk the pit ramming is produced. In order to strengthen its walls between the ramming cycles the crashed stones of 40-70 mm sizes are sprinkled into the pit cavity. During the rammer falling into the pit the crashed stones are extruded into the soil, strengthen the pit walls and reduce the intensity of soil bulging and its collapse into the bottom (Fig. 2*b*). Upon

reaching the water-saturated layer the tampon of concrete mix is placed into the pit cavity on the entire height of water-saturated layer. For such tamponing the low-graded concrete is required, even soil-concrete also can be used. Depending on the flow force of water-saturated layer the concrete mix is compacted by falling rammer or deep vibrator, and allows the concrete mix to setting up (Fig. 2*c*). Depending on the specific conditions the setting time of concrete is 30-50 minutes. After the setting of concrete mix, the hole is punched in the formed tampon by the falling rammer (Fig. 2*d*).

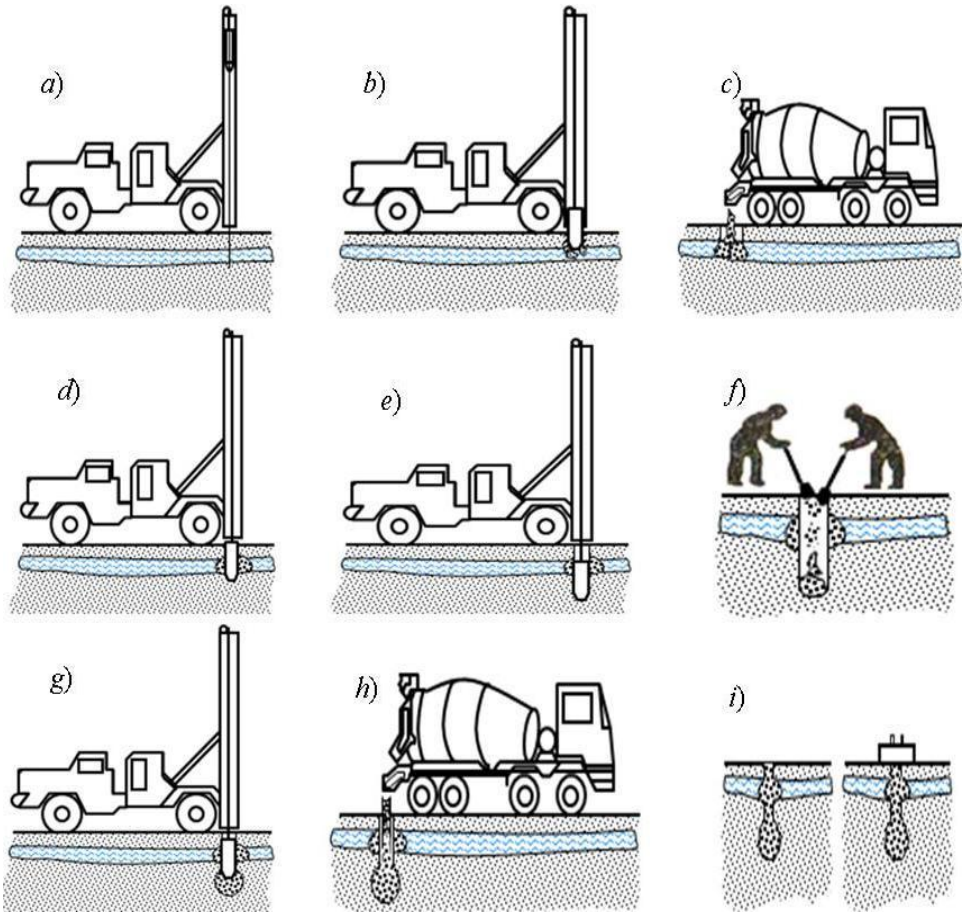

Fig. 2: Technological layout of pit ramming in the presence of water-saturated layer

a) positioning of the tamping machine; *b*) pit ramming until the water-saturated layer;

c) placing of concrete mix in the pit cavity; *d*) punching of technological hole in concrete tampon;

e) continuation of pit ramming; *f*) placing of concrete mix to form the foundation foot;

g) formation of foundation foot; *h*) concreting of the foundation trunk; *i*) foundation with grillage

Under the influence of falling rammer the concrete mix is expanded in the direction of water-saturated layer along the pit contour from its longitudinal axis. As a result of hardening the concrete tampon is formed that restrains the flow of water from the water-saturated layer into the pit. It can prevent the collapse of soil in the pit cavity and ensure its ramming up to the calculated level, despite the presence of water-saturated layer (Fig. 2*e*). After the pit ramming until the full calculated depth the crushed stones of 40-70 mm sizes are sprinkled on the pit bottom (Fig. 2*f*) and continue the compacting (ramming) that allows to obtain an extension of foundation foot in the pit bottom (Fig. 2g). Concrete can be used instead of crushed stones to create the foundation foot, but in this case the foundation implementation cost increases about four times.

Foundation trunk is produced by reinforced concrete. After the formation of extended foundation foot, the reinforcing rebar skeleton is installed into the pit cavity and concrete is poured (Fig. 2*h*). Reinforced concrete grillage is installed on the foundation head (Fig. 2*i*).

The most responsible operation in the process of foundation implementation in rammed pit is the pouring and compacting of concrete mix in the pit. In case of technological disorder, the collapse of soil in the concrete mix from the pit wall can take place that would violate the monolithic unity of foundation.

The developed technology has been tested in the construction sites. Foundations in the rammed pits, that cross the water-saturated layer, were implemented in the construction of livestock building (Fig. 1). Depth of the foundation foots were 1.8 m from the ground surface. The water-saturated layer of 0.45 m thick with coarse sand was at the depth of 0.9 m. As a result of engineering analysis and technical and economic comparison of different variants the implementation of foundations were carried out by the said technology.

Fig. 1 shows the implementation of foundations in rammed pits which were carried out by the said technology. The foundations were implemented without any excavation work. Foundation heads with rebar outlets are located on the ground surface. Implementation of reinforced concrete grillage was carried out by the known engineering solutions.

V. Conclusions

The proposed technology of foundation implementation in the rammed pit can significantly reduce the excavation work, material consumption and complexity of works. It is one of the factors of improving the economic indicators of the construction project.

For the implementation of foundations in rammed pits with the passage of water-saturated layer the tamponing of water-saturated layer by the low-graded concrete or soil-concrete is necessary. It allows to prevent the softening of the soil and its collapse on the pit bottom. Without the use of tamponing the foundation implementation in rammed pits with water-saturated layer in the

soil is quite difficult and is associated with a significant increase in the volume of work.

VI. Acknowledgement

This research work was supported by the Ministry of Education and Science of the Russian Federation (Agreement No. 02.A03.21.0008).

References

I. Gaaver K.E. (2012). Geotechnical properties of Egyptian collapsible soils. Alexandria Engineering Journal, 51(3): 205-210.

II. Feng Shi-Jin, Lu Shi-Feng, Shi Zhen-Ming andShui Wei-Hou. (2014). Densification of loosely deposited soft soils using the combined consolidation method. Engineering Geology, 181: 169-179.

III. Mao Dongfeng, Zhong Chao, Zhang Laibin and Chu Gui. (2015). Dynamic response of offshore jacket platform including foundation degradation under cyclic loadings. Ocean Engineering, 100: 35-45.

IV. Tang Chao-Sheng, Shi Bin and Zhao Li-Zheng. (2010). Interfacial shear strength of fiber reinforced soil. Geotextiles and Geomembranes, 28(1): 54-62.

V. Ibrahim K.M.H.I. (2014). Bearing capacity of circular footing resting on granular soil overlying soft clay. HBRC Journal, doi:10.1016/j.hbrcj.2014.07.004.

VI. Torgashova E.N. (2014). Implementation of foundations in rammed pits. Intellektual'nyipotentsial XXI veka: stupenipoznaniya (Intellectual Potential of the XXI Century: Stages of Cognition), 24: 94-98.Available online at: https://elibrary.ru/item.asp?id=22305480

VII. Glushkov V.E. andGlushkov A.V. (2014). Rammed foundations in soils with soft underlying layer. VestnikPermskogonatsional'nogoissledovatel'skogopolitekhnicheskogouniversiteta:Stroitel'stvoiarkhitektura (Bulletin of the Perm National Research Polytechnic University: Construction and Architecture), 4: 19-26. Available online at: https://elibrary.ru/item.asp?id=21615109

VIII. Glukhov V.S., Hryanina O.V. andGlukhova M.V. (2015). Study of the effect the broadening of the foundations in rammed pits on the draft. Sovremennyenauchnyeissledovaniyaiinnovatsii (Contemporary Scientific Research and Innovations), 4-1(48): 65-70. Available online at: https://elibrary.ru/item.asp?id=23770716

IX. Hryanina O.V. andAstafev M.V. (2015). Investigation of the effect of broadening and the length of the foundation in rammed pits to

carrying capacity. Sovremennyenauchnyeissledovaniyaiinnovatsii (Contemporary Scientific Research and Innovations), 6-2(50): 64-70. Available online at: https://elibrary.ru/item.asp?id=24121660

X. Gotman A.L. andShemenkov Y.M. (2015). Investigation of foundations behavior in tamped pits under the vertical load and their analysis. VestnikPermskogonatsional'nogoissledovatel'skogopolitekhnicheskogouniversiteta:Stroitel'stvoiarkhitektura (Bulletin of the Perm National Research Polytechnic University: Construction and Architecture), 3: 23-40. Available online at: https://elibrary.ru/item.asp?id=24373607

XI. Kharun M. and Kvartenko K.V. (2012). Perfecting of Technology of Foundation Construction in a Rammed Pit. VestnikRossiiskogouniversitetadruzhbynarodov, Seria: Inzhenernyeissledovaniya (Bulletin of the RUDN University, Series: Engineering Studies), 3: 114-119. Available online at: https://elibrary.ru/item.asp?id=17794743

XII. Svintsov A.P., Vorobiev A.E., Krivoshapko S.N. and Kvartenko K.V. (2010). Strengthening of ramming pit throat technology and device for it's realization. VestnikRossiiskogouniversitetadruzhbynarodov. Seria: Inzhenernyeissledovaniya (Bulletin of the RUDN University, Series: Engineering Studies), 2: 7-10. Available online at: https://elibrary.ru/item.asp?id=14999847

XIII. Glukhov V.S., Hryanina O.V. and Glukhova M.V. (2015). Comparative analysis of the bearing capacity of foundations in rammed pits on the combined soil bases. Sovremennyenauchnyeissledovaniyaiinnovatsii (Contemporary Scientific Research and Innovations), 5-1(49): 138-143. Available online at: https://elibrary.ru/item.asp?id=23770982

XIV. Kovalev V.A. and Kovalev A.C. (2016). Perfection of operational methods of control of bearing capacity of foundations. Uspekhisovremennoinaukiiobrazovaniya (Successes of Contemporary Science and Education), 2: 84-89. Available online at: https://elibrary.ru/item.asp?id=25447231

XV. Svintsov A.P., Rogov V.A., Kvartenko K.V. and Shkilenko A.S. (2010). Technique of foundation construction in a rammed pit. Promyshlennoeigrazhdanskoestroitel'stvo (Industrial and Civil Construction), 9: 59-61. Available online at: https://elibrary.ru/item.asp?id=15190791