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FOLDED-PLATE SHELL FOUNDATION FOR POWER TRANSMISSION TOWERS

The article reviews the main structural solutions of foundation for tower structures of power lines, and proposed an alternative design solution of foundation, which is used on water-saturated and weak marshy soils.

Key words: gusseted foundation, system of fixed joints, transmission towers, folded-plate shell foundation.

Statement of problem. Reinforced concrete foundation of power transmission towers is a bearing structure used in energy construction of concrete or metal power transmission towers in order to increase the stability of the towers in the ground and correspondingly to increase their lifetime. Such foundations transmit significant weight and wind loads as well as wire tension and ground wire loads to the ground. The most appropriate and efficient types and solutions of such towers and foundations according to climatic and geological areas are determined based on long-term practice of energy construction, design and operation of high-voltage lines [1]. Special attention should be paid to the choice of the foundation type for power transmission towers under specific soil conditions, where application of umbrella or pile foundations is not always appropriate and cost-effective.

Purpose of the research. At the present stage of foundation engineering there is a need to develop more advanced designs of foundations, which will be more economical, technologically more perfect, and are able to be used in the difficult engineering and geological conditions. Such foundations are folded-plate shell foundations diversed in form, area and conditions of use. Purpose of the research is to determine optimal structural solutions of foundation for power transmission towers used on water-saturated, bog and weak soils.

Summary of the study. Research of folded shell foundation operation was conducted by many scientists of the industry. Vanyushkin S.G. investigated features of the interaction between folded shell foundation and footing [2]. For the research were chosen following types of foundations: slab and beam raft, multibarrel shell, folded-plate structure, folded-plate structure with voids filled with other than gravel and earth. The results obtained indicate that the depth of voltage attenuation is the same for all models regardless of the foundation design, and is determined by its dimension and the general level of stress and strain module of footing [2, 3].

Particular interest is the usage of folded-plate shell foundations in water-saturated soils and in the marshes, especially during the setting of foundations for power lines towers. In some cases, these foundations are used on weak soils which indicate an improvement of foundation work. If the soils at the base are characterized by high water absorption and compressibility, this leads to permanent settling of the earth's surface. In this case it is appropriate to use a floating foundation as a folded-plate shell. An example of such use was the construction of the USA embassy in Mexico City [4, 5].

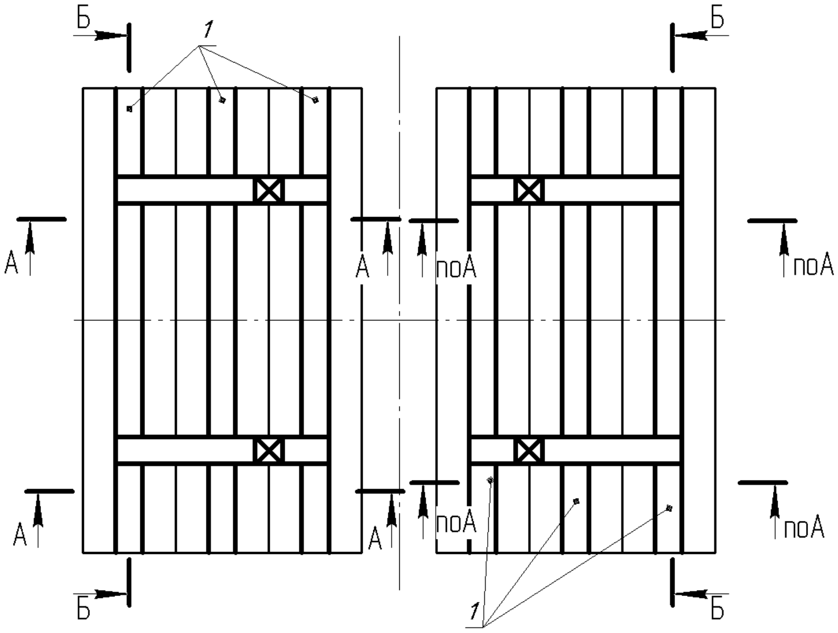
Multiwaves shell foundations for the towers of power lines were used in the construction of power lines of 220 kV in the Middle Urals and Tyumen region [6,7]. The foundations were built on marshes depth of 5-6 meters. Concrete folded foundations were constructed as separate thin folds that connected on top of by steel or concrete beam or farm. Electric poles with height of about 40 meters were installed on foundations. During the construction it was received a major economic effect. The construction cost was reduced by 37% compared with the traditional arrangement of foundations. Inadequate work of folds at uneven deformations of footing under foundation can be considered as a shortcoming of this foundation structure.

As an alternative design solution of the foundation for power transmission towers was offered the foundation used on water-saturated soil, the prototype of which is a folded-plate shell foundation [6].

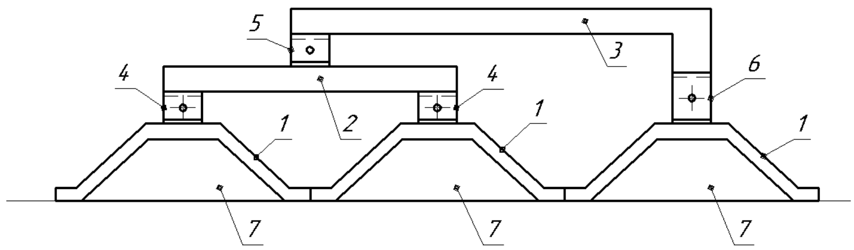
The aim of gusseted shell foundation is expanding the scope of use in difficult geotechnical conditions and also to improve the operation of folded foundation for transmission towers by creating a hinged system of folds fastening with supporting beams, which allows redistribute the load and emerging forces evenly in every fold of the foundation. Thus, it ensures high efficiency of each element of folded foundation and the system of folds in general.

The element of the fold has three horizontal plates and two sloping planes in cross-section. The upper horizontal fold is used to support steel or reinforced concrete beam. Two lower plates are required for fold installation during assembly and for load distribution, and also as bearing elements for the folds. Width of the upper plate is determined based on the calculation of concrete bending and on design reasons.

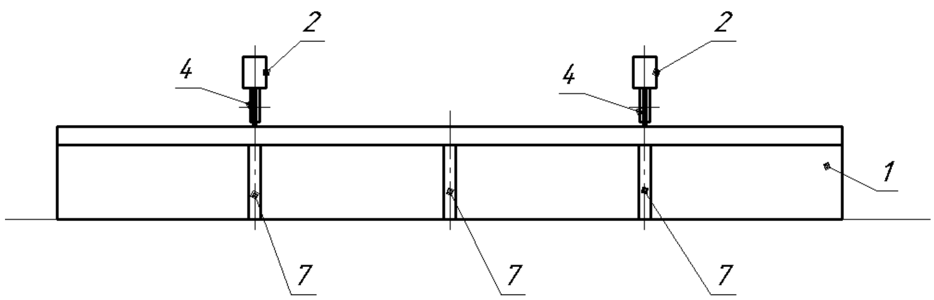
Folded foundation for transmission towers consists of thin reinforced folds which are interconnected on top by a steel or reinforced concrete beam. The first two folds are connected with a beam, while the third connects them with the same beam on the hinged joints, which is set over the first beam, forming a system of bearing beams with fixed hinges. The system of folded foundation consists of six prismatic folds; other three folds are interconnected symmetrically and in a similar manner to the first three folds (fig. 1).



a)



b)



c)

Fig.1. Foundations for power transmission towers
a) foundation; b) section А-А; c) section Б-Б
1 – thin prismatic reinforced concrete fold; 2 – bearing reinforced concrete beam; 3 – upper bearing reinforced concrete beam; 4,5,6 – metal hinge joints; 7 – vertical reinforced concrete diaphragms

The proposed system of structural foundation consists of six prismatic folds; the first three folds are joined similarly and symmetrically to other three folds.

For the structural elements of folded foundation to work jointly, all six folds are interconnected due to the combination of three separate folds through a system of fixed joints and bearing beams similar to other three folds.

The proposed foundation consists of six separate reinforced concrete thin folds 1; three of them are arranged symmetrically to other three folds in respect to power transmission tower axis. Two folds on the edges are joined with bearing reinforced concrete beam on the top 2 with metal hinge joint 4. The third prismatic fold is joined with the first two through the upper bearing reinforced concrete beam 3 with metal hinge joints 5 and 6. In the places of bearing beams 2 and 3 supporting folds 1 arranged vertical reinforced concrete diaphragms 7. This type of connection is performed on both edges of folds 1 longitudinally. The other three folds 1 are joined similarly.

The construction of the foundation claimed is implemented through the joint work of structural elements of gusseted foundation. Due to the hinged joint of prismatic folds with the bearing beams, more even distribution of external loads on the elements of the foundation system is achieved. The cavities of the folds are of prismatic form to provide the formation of a compact core of a certain value and to redistribute base pressure on the foundation.

According to the utility model prismatic folds 1 are joined by beams 2 and 3 on both sides longitudinally. Bearing beams 2 and 3 are installed in spaces designed for supporting the slabs of metal power transmission towers. In addition, folds 1 are designed with transverse diaphragms 7 located in spots of beams supporting 2 with 1 folded-plates and in the middle of the fold. Diaphragms 7 are used for fixing fold 1 to the beam 2 with bolts installed in diaphragm. These diaphragms are supporting and designed considering shear forces in fold on a support.

The lower horizontal plates which are the end beams reduce horizontal and vertical deformation of the fold's edges.

Significant loss of foundations weight is a result of shells use which work as spatial structures due to a curved shape and have a large carrying capacity with minimal thickness. The shells are also characterized as having compressive and stretching tensions at relatively small bending moments [8].

Uneven vertical displacements under power transmission towers, under footing, provoke the load growth, but contact pressure cannot exceed its limit; as a result there is an intensive fold's voids filling 1 with subsoil in these areas [9]. Whereas the power load is redistributed again: it is reduced in areas with high values and increased displacements of the fold's voids; accordingly it increases in areas with lower values and insignificant displacements of the fold's voids. Thus, process of contact pressure self-regulation of fold's voids is realized. All this allows to: smooth out uneven deformation of soil base; smooth the peaks of stress concentration in substructures and reduce the stress value in superstructures eliminating foundation tilt. Eventually when the effect of uneven vertical displacements stops, all components of folded-plate foundation gain new stable state of static equilibrium. At repeated uneven vertical displacements under power transmission towers, character of fold's voids work 1 is repeated according to a new scheme of load redistribution. The process of self-regulation is possible as long as there is free capacity in fold's voids.

The purpose of this construction is to limit (prevent) absolute and (or) relative foundation and superstructure displacements to the extent required for proper operation and durability of a structure [10].

Foundation stiffness impacts the distribution of contact pressure significantly. Therefore alteration of shell's stiffness may result in qualitative change in the form of contact pressure diagrams. The research results state that for the reinforced concrete thin shell foundations distribution of contact pressure can be taken as uniform in excess strength.

The foundation construction proposed responds to a number of requirements: minimum weight of prefabricated elements to be dispatched to remote zones; minimum materials consumption; the possibility to use weak structural strength of the soil and of water buoyancy force; uniformity of prefabricated elements; cavities formation in the bottom to create osculum effect in case of foundation separation; creation of porous lower surface to increase foundation resistance to horizontal displacement.

The alternative construction design of gusseted prismatic foundation for transmission towers is able to evenly redistribute the loads on the structural elements of the foundation system. In case of uneven base deformation, the redistribution of contact pressures occurs and the system comes into equilibrium under to a constructive solution.

Conclusions. Analysis of multiwaves shell foundations showed that these foundations are in many cases more effective solution not only in terms of conditions of interaction with the base, as well as economic reasons, as the material costs during the construction of such foundations are much lower than other foundations. The gusseted foundation proposed can be used for transmission towers which are applied in water-saturated, fen and soft soils and the uneven base deformation.

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Анотація

В статті розглядаються основні конструктивні рішення фундаментів для опор ліній електропередач, а також запропоновано альтернативне конструктивне рішення фундаменту для опор ЛЕП на водонасичених ґрунтах.

Ключові слова: складчастий фундамент, шарнірна система, опори ЛЕП, багатохвильові фундаменти

Анотация

В статье рассматриваются основные конструктивные решения фундаментов для опор линий электропередач, а также предложено альтернативное конструктивное решение фундамента для опор ЛЭП на водонасыщенных грунтах.

Ключевые слова: складчатый фундамент, шарнирная система, опоры ЛЭП, многоволновые фундаменты.