DOI 10.52209/1609-1825_2023_2_212 UDC 338

Regulatory Support in the Field of Designing Soil Ground Regarding to Freezing in Domestic Construction

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Abstract. *Information is provided on a new regulatory system in the field of designing soil foundations in housing construction in Kazakhstan. The main goal is to show the difference between the old and new regulatory systems. The main conclusions from the regulations for the design of the soil base in the area of the influence of freezing-thawing on the stability of soil bases and foundations are presented. For the study, methods of analytical comparison of the new harmonized standards SP RK EN (Harmonized Eurocodes) with the old previous SNiPs standards were used. According to the new internalized standards, the risk of frost heaving can be assessed according to the classification characteristics of the soil or laboratory tests of test specimens in their natural state. The authors give in the work formulas for determining the stability of foundations with tangential and normative heaving, the depth of freezing of soil foundations. According to the analysis and research carried out, the regulatory prerequisites for determining frost heave soils were determined.*

Keywords: *Eurocode, soil ground, prevention of frost heaving of soils, geotechnical engineering, standard, freezing-thawing of soil.*

Introduction

Harmonization of the Eurocode standards with regional standards was begun from 2012 in Kazakhstan. The development of the new regulatory standards was maintained mainly during 2012 and 2016. The implementation and usage in construction the old and new regulatory system was used equally from 2016 to 2020. Such normative documents as the State standard (hereinafter referred to as GOST) remained unchanged, while Building Codes and Regulations (hereinafter referred to as SNiP) were replaced by new standards. Therefore, it is important to conduct research in this area to determine the changes that will occur during the introduction of new regulatory documents in the field of construction. In all honesty, it is important to take it into account, when designing soil ground for frost hazard and their interaction with foundations. This is especially true when designing shallow depth foundations. The following new normative documents are available in the proposed area: SN RK 5.01-02-2013 Foundations of buildings and structures [1]; SN RK 5.01-01-2013 Earthworks, grounds and foundations [2]; SN RK 1.02-02-2016 Engineering survey for construction. Seismic microzoning [3]; SP RK 5.01-102-2013 Foundations of buildings and structures [4]; NTP 7-01.4 Geotechnical Design [5].

According to the new regulatory documents introduced in construction, which are harmonized with the Eurocodes and introduced from 2020, there are big changes in design of construction. According to the standard [6] the following factor is included in the geotechnical design as impacts: 1) swelling and shrinkage caused by changes in vegetation cover, climate or humidity; 2) temperature effects, including freezing; ice loads. According to the same standard, for geotechnical design, a typical detailed description of design situations should include: the consequences of freezing; general suitability of the structure's foundation for overall stability and displacement of the foundation. Also, when determining the design situation and limit states, the following factors should be taken into account: – environmental influences (seasonal changes in temperature and moisture) [6]. There is also a separate chapter «Determination of susceptibility to freezing (sensitivity to frost)» where the risk of heaving of soils and classification, prerequisites for laboratory tests are assessed.

Before the introduction of harmonized standards with Eurocodes, SNiP (Construction Normatives and

Rules) [7] was actively used in Kazakhstan. Foundations of buildings and structures where there is a separate chapter called «Features of designing the foundations of structures erected on heaving soils». According to this standard, forces in structures caused by climatic temperature effects when calculating deformations should not be taken into account if the distance between temperature-shrinkage joints does not exceed the values specified in the SNiP for the design of the corresponding structure [7]. The depth of the foundation should be taken taking into account the depth of seasonal freezing. The depth of the outer foundation is assigned regardless of the calculated freezing depth, if: the foundations are based on fine sands under the conditions that they do not have heaving properties and deformation of the base soils during freezing and thawing do not violate the operational suitability of the structure, or special technical measures are provided to exclude freezing of soils [8]. Findings section is presented with the obtained findings, graphs or tables, important findings are expressed, a possible explanation, comparison or generalization with other studies can be made.

Materials and Methods

This article provides methods for the analytical comparison of the harmonized new standards with the old previous standards in the field of the influence of freezing-thawing on the stability of soil foundations. In particular, SNiPs [1-4] were widely used earlier in the design of soil bases and foundations, while at the moment these standards have been completely replaced by the SP RK EN (Harmonized Eurocodes). In the area of influence of freezing-thawing of soil bases [7].

In particular, according to the old regulatory system, there is a 1979 «Guide for the design of soil ground and foundations on heaving soils» [9], which provides the main provisions for the design of foundations. Formulas are given for determining the stability of foundations with tangential and normative heaving, the depth of freezing of soil foundations. Also, in the same document measures are given to reduce frost heaving on foundations: engineering and reclamation measures, construction and construction measures, thermal insulation measures, measures during operation.

In addition, there are «Recommendations for accounting and prevention of deformations and forces of frost heaving of soils» in 1986 [10], which indicate analytical-empirical ways of calculating and predicting frost heaving of soil bases (Table). In particular, the influence of design factors such as granulometric, mineralogical and chemical composition on the frost heaving of soils. The assignment of the initial data for short-term and long-term forecast of frost heaving of soils, calculations of the characteristics of heaving of soils (calculation of the characteristics of heaving of water-saturated and incomplete water-saturated soils), calculation of frost-hazardous foundations and foundations erected on them according to limit states, measures to eliminate or reduce frost heaving of soils are also given.

Results and Discussion

The frost susceptibility properties of ground bases are important for the design of foundations for buildings and structures. The recommendations provide important characteristics for determining the frost heave properties of soil foundations [10]. One of the important characteristics is the frost heave of soil ground, which is determined differently depending on the type of soil and the presence of load on the subsoil. Therefore, the following formulas for determining frost heave are available.

$$h_f = \left(\frac{p_d}{p_w} i_{ef} - 0.5\delta_{(0,pi)} P_{(g,pi)} \right) d_f, \quad (1)$$

where: p_d – dry density, p_w – water density, i_{ef} – excessive ice deposition, d_f – freezing depth, $\delta_{(0,pi)}$ – the compressibility factor of the thawed soil and the external load, $P_{(g,pi)}$ – external load.

For clay soils which $w > w_{pr}$ (where w_{pr} – frost heave moisture:

$$w_{pr} = 0.92 \frac{p_s - p_d}{p_s p_d} + 0.08 w_w (T_{up}), \quad (2)$$

Determination of soil classification by frost heaving

TRRL (U.K.)			JGS (Japan)		CRREL (U.S.)		GOST (C.I.S)	
Judgment	Frost heave ratio (%)	Frost heave rate (mm/hr)	Judgment	Frost heave rate (mm/hr)	Judgment	Frost heave rate (mm/hr)	Judgment	Relative frost heave deformation of the soil sample
Negligible frost susceptibility (NFS)	Less than 12	Less than 0.375	Low	Less than 0.1	Negligible	Less than 0.021	Non-heaving	$\varepsilon_{fh} < 0{,}01$
					Very low	0.021-0.042		
Possible frost susceptibility (PFS)	Over 12	Over 0.375	Medium	0.1-0.3	Medium	0.042-0.083	Low	$0{,}01 \le \varepsilon_{fh} < 0{,}04$
					Medium	0.083-0.167	Medium	$0{,}04 \le \varepsilon_{fh} < 0{,}07$
			High	Over 0.3	High	0.167-0.333	High	$0{,}07 \le \varepsilon_{fh} < 0{,}10$
					Very high	Over 0.333	Very high	$0{,}10 \le \varepsilon_{fh}$

$$h_f = \frac{p_d d_f}{p_w} + s_f(p_g), \quad (3)$$

where ($p_i = 0$).

$$h_f = \frac{p_d d_f}{p_w}\{0.09[w_{pi} - w_w(T_{up})] + 1.09 B_{pi}\psi_{t(pi)}\} - \quad (4)$$
$$- s_f(P_{(g,pi)}),$$

where $p_i = 0$.

For clay soils which $w \le w_{pr}$:

$$h_f = \frac{p_d}{p_w} d_f i_{ef} - s_f(p_g), \quad (5)$$

where ($p_i = 0$).

$$h_f = \frac{p d_i}{p_w} d_f \psi_{t(pi)} [0.09 B_{pi} + w_{pi} - w_{pr(pi)} - s_f(P_{(g,pi)})], \quad (6)$$

where $p_i = 0$.

The value of ground frost heave and its determination has also been well described in the work of L.N. Nevzorov. According to it, the frost heave should be determined taking into account the migration of water during freezing. It can be determined by the following formula:

$$h_f = h_I + h_{II} = 0.09\,(w_{tot} + w_w)\frac{p_d}{p_w} z + 1.09 \int_0^{t_f} q_{wf}\, dt, \quad (7)$$

where: h_I – frost heave due to water initially contained in the pores, h_{II} – frost heave due to ice migration, $\frac{p_d}{p_w}$ – conversion factor from mass moisture to volumetric moisture, z – frost depth, q_{wf} – intensity of moisture inflow to the frost front.

The above formula can also be written in another form by using the SP segregation potential in the design of structures:

$$hf = 0,09\,(w_{tot} + w_w)\frac{p_d}{p_w} z + 1.09\, SP \cdot t \cdot grad\, T, \quad (8)$$

where: $grad\, T$ to simplify the calculations, the entire frozen soil layer is calculated instead of the frost rim.

The ground surface elevation during freezing can also be determined by the simplified formula:

$$h_f = \varepsilon_{fh} d_f, \quad (9)$$

where ε_{fh} – frost deformation.

It is also very important to consider the elevation of the foundation, not only the frost heave of the ground during freezing. Foundation uplift can be noted as h_{ff}, accordingly, we can use the following formula to determine the elevation:

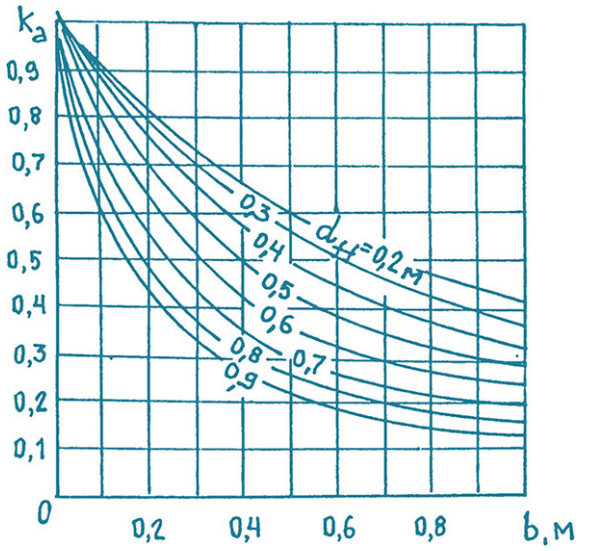
$$h_{ff} = h_f m_f^n \left(1 - \frac{\beta p}{p_{fh}}\right), \quad (10)$$

where n – a degree value of 1,5 for construction in flat, wet areas, 1 – in excessively humid lowland areas; β – coefficient taking into account the impact of the pillow, for strip foundations with low pillows ($h_n < 0{,}8\, b$) can be accepte $d\ \beta = 1$.

For strip foundations:

$$p_{fh} = \frac{2 k_a d_{ff} \sigma_s}{b}, \quad (11)$$

where k_a – ration of the working condition of the foundation (Figure); σ_s – resistance to movement of frozen ground relative to the foundation.



Ratio value of k_a for strip foundation width b

Regarding to new standards, it is given a lot of recommendations and instructions for frozen soil grounds in construction. New testing methods also introduced by usage of the new standards. Also, it helps to internationalize designing of building and structures on frozen soil grounds. But it is need to keep of next regulatory documents, such as «Guide for the design of foundations and foundations on heaving soils» and «Recommendations for accounting and prevention of deformations and forces of frost heaving of soils». These standards helps to more detailed calculation and design of frozen soil ground. Because it helps to find frozen soil ground parameters, as like frost heaving, icing of soil sample, temperature of freezing and so on.

According to the new normative document [1]. Soil investigation and testing there is a chapter Determination of frost susceptibility where ways of determining the frost susceptibility of soils are given. In particular, it is mentioned that the frost susceptibility of soils plays an important role in the design of foundations placed over the frost front. The frost heaving risk can be estimated according to the properties of the soil classification (particle size distribution, capillary lift height and/or fine-grained content) or by laboratory tests of test samples in the natural state as well as overmolded, overpressed or reconstructed soil samples.

According to the above-mentioned standard there are the following requirements for frost heave testing:

- if the assessment of frost susceptibility based on the classification properties of the soil does not indicate that there is no risk of frost heaving, a laboratory frost heave test must be performed. Examples of soil types that indicate the need for laboratory testing in addition to correlation with classification properties include organic, peat, saline, artificial and coarse-grained soils with a wide range of grain sizes;

- to determine freezing susceptibility of soils in their natural state, natural samples must be tested, and in the case of bulk soils, frost heave tests must be conducted on precompacted and then molded or remolded test pieces

- the laboratory frost heave test are freeze frost heave tests. If the risk of weakening on thawing is to be tested, the load-bearing capacity (shear strength) of the soil must be tested after the specimen has been thawed by the Californian method. A compacted or reconstructed specimen shall be subjected to one or more freeze-thaw cycles before testing.

Conclusions

According to the analysis and research carried out, the regulatory prerequisites for determining frost heave soils were determined. Therefore, the following main conclusions were drawn:

1. The new normative documents mention laboratory tests of sample soils in more detail and even specify what the requirements should be in it, while the old normative documents in the form of SNiPs only mention it insignificantly.

2. Despite the abolition of SNiPs, it is necessary to keep or reissue normative documents such as «Recommendations» and «Guidelines», where ways of determining frost heave of soils by analytical means using formulas are given.

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Тұрғын үй құрылысындағы қатуды ескере отырып, топырақ негіздерін жобалау саласының нормативтік-құқықтық ерекшеліктері

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Аңдатпа. *Қазақстандағы тұрғын үй құрылысында топырақ негіздерін жобалау. Негізгі мақсат-бұрынғы және жаңа реттеу жүйелерінің айырмашылығын көрсету. Мұздату-ерітудің топырақ негіздері мен Іргетастардың тұрақтылығына әсері саласындағы топырақ негізін жобалау ережелерінен негізгі тұжырымдар келтірілген. Зерттеу жүргізу үшін SP RK EN (Harmonized Eurocodes) үйлестірілген жаңа стандарттарын ҚНжЕ-нің бұрынғы ескі стандарттарымен аналитикалық салыстыру әдістері қолданылды. Жаңа стандарттарға сәйкес, аяздың пайда болу қаупін топырақтың жіктелу сипаттамаларына немесе табиғи күйдегі сынақ үлгілерінің зертханалық сынақтарына сәйкес бағалауға болады. Авторлар жұмыста тангенциалды және нормативті негіздердің тұрақтылығын, топырақ негіздерінің қату тереңдігін анықтауға арналған формулаларды келтіреді. Жүргізілген талдау және зерттеу нәтижелері бойынша топырақтың аязға төзімділігін анықтаудың нормативтік алғышарттары көрсетілген.*

Кілт сөздер: *Еурокод, топырақ негіздері, топырақтың аязды жиналуын болдырмау, геотехникалық жобалау, стандарт, топырақты мұздату-еріту.*

Нормативно-правовые особенности области проектирования грунтовых оснований с учетом промерзания в жилищном строительстве

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Аннотация. *Представлена информация о новой нормативной системе в сфере проектирования грунтовых оснований в жилищном строительстве в Казахстане. Основная цель – показать отличие прежней и новой систем регулирования. Приведены основные выводы из регламентов проектирования грунтового основания в области влияния промерзания-оттаивания на устойчивость грунтовых оснований и фундаментов. Для проведения исследования были использованы методы аналитического сравнения гармонизированных новых стандартов SP RK EN (Harmonized Eurocodes) со старыми предыдущими стандартами СНиП. Согласно новым стандартам, риск морозного пучения можно оценить в соответствии с классификационными характеристиками грунта или лабораторными испытаниями тестовых образцов в естественном состоянии. Авторы приводят в работе формулы для определения устойчивости фундаментов с тангенциальным и нормативным пучением, глубины промерзания грунтовых оснований. По результатам проведенного анализа и исследований указаны нормативные предпосылки для определения морозостойкости грунтов.*

Ключевые слова: *Еврокод, грунтовые основания, предотвращение морозного пучения грунтов, геотехническое проектирование, стандарт, замораживание-оттаивание грунта.*

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