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SELECTION OF DESIGN APPROACH FOR DESIGNING SPREAD FOUNDATONS IN OUR REGION ACCORDING TO EUROCODE 7

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Abstract. *The existing civil engineering standards for designing are to be replaced with a set of Eurocodes. Eurocode 7 is related to a geotechnical design, but its implementation is difficult, due to different geological, geographical and climate conditions which lead to development of different local designing traditions all over Europe. In order to overcome them, Eurocode 7 offers three design approaches and sets of partial factors to be used within. After accepting it, each country has to declare on the selection of design approach according to which designing is going to be performed and to define appropriate partial factors. This paper presents methodology for selection of appropriate design approach for spread foundations in our region where the process of introduction of Eurocodes is still active. The method based on keeping up with the similar designing procedure may also be used for other geotechnical structures.*

Key words: *Eurocode 7, geotechnical design, design approach, spread foundations*

1. GENERAL REVIEW OF CODES

The purpose of the codes and standards is to define the processes and procedures of design, to set their basic content and identify different limits that are acceptable in practice. In most cases, that includes society, users, data, and analysis, which include engineering design. They allow applied methods of analysis and domains of factors of safety, demarcate the states of failure and regular states in practice, and link the designer's practice with the requirements of society, with safety and serviceability as its primary concerns, and these requirements are then transferred into actions and numbers. As such, codes and standards can be found everywhere in our daily and professional environment.

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But, both society and users also demand safety and serviceability to be balanced with the cost effectiveness, especially when material resources are scarce, which imposes even greater responsibility to those who work on codes, among whom those dedicated to geotechnics are outstanding in many respects [25]. Namely, the geotechnical engineers rely on the knowledge and judgment, which is quite subjective as it depends on training and experience, but is also of invaluable importance. Though, the experience can also be negative, but former mistakes are the main resource of information and learning: as a matter of fact, the cases of failure of geotechnical structures have given a rise to rapid development of soil mechanics and improvement of codes helping to avoid their recurrence, thus contributing to the progress of science and practices in accordance with the best that is currently available.

Unfortunately, "forensic" analyses have found that collapsing of structures is most likely to occur due to unexpected loading conditions that were not taken into account, and not so much because of the variations of input parameters on which designers focus most of their attention. That is why it is important and necessary for engineers to consider certain domain of limit states that need to be taken into account during the analysis, which is just the basic philosophy of modern designing: when those states are exceeded, the structure no longer meets the relevant designing criteria, which practically means that the structure or some of its parts, for any reason is no longer functional, i.e. usable.

Designing according to limit states means that the analyzed state near the failure should not occur, or the probability of its occurrence is very low, so the calculations, in fact, are performed for a virtual state. This may confuse engineers, because until now they have been dealing with states whose existence is certain. Namely, the attention at working conditions is directed to the expected states that a structure is able to carry in expected loading conditions. But, their disadvantage was reported primarily in structural engineering, in a case of cancellation of favourable and unfavourable forces in expected state, when a small increase of unfavourable forces leads to significant increase in stress. Such failures have led to their rejection and acceptance of the design according to limit states, first in structural engineering and later in geotechnics. It is necessary to consider the circumstances in which ultimate values of parameters lead the construction to the state near to failure, and to factorize those before combining, thus transferring them from characteristic to design (calculation) values.

2. SHORT HISTORY OF DEVELOPMENT OF THE EUROCODE 7

The unification of Europe led to creation of a large market with many corporations from different countries that once used to operate in accordance with existing state standards. But, that is what brought them at a disadvantage when applying for jobs abroad, which especially and primarily affected the construction companies. In order to overcome inequalities, the European Commission signed the Treaty of Rome in 1975, and at the joint initiative of universities and engineers made a decision to start eliminating technical obstacles set out in various government recommendations, guidelines, standards and specifications in the construction industry between Member States of the European Union (EU). Within this action program, the Commission took the initiative to prepare a set of harmonized technical rules, known as Eurocodes (EC) [9], which now include 58 books from EC 0 to 9. The aim was to establish the set of common unified technical rules for designing of civil engineering structures, products and works to replace different policies in its Member States.

The very beginning introduced one great novelty, at least for the majority of (geotechnical) engineers, because it was decided that the EC are going to be based on the method of ultimate loads and the application of partial factors, which is consistent with EC 0 and other construction codes, but which was not quite acceptable for engineers from developed countries. Soon, namely 1980/81, in collaboration with the International Society for Soil Mechanics and Foundation Engineering was formed the first group responsible for drafting the European standard in geotechnics, named No. 7. The group included representatives of associations of geotechnics of the 10 Member States of the EU. After 6-7 years of work and study of differences in geotechnical practice across Europe, the first model with general guidelines for the geotechnical design was issued. During 1990, the mission to work on building codes and construction works has been completely assigned to the European Committee for Standardization (CEN), within which was established the Technical Committee 250 responsible for all construction codes, and its Subcommittee 7 responsible for geotechnical Eurocode 7 (EC7), with Niels Krebs Ovesen from Denmark as its first president [17]. This was crucial for successful development of EC7, considering that it was Denmark (basing on works of Jørgen Brinch Hansen early in the second half of the 20th century, having accepted the proposal of Taylor in 1948), that officially introduced the world's first partial factors (PF) in geotechnical standards when calculating the bearing capacity [15].

However, a number of countries in Europe did not accept a completely new concept of calculation so easy. In November 1992, the way of using PF in geotechnics was widely discussed, which resulted with adoption of the concept of three possible combinations, which were expanded with additional two 6 years later. The combinations allowed three different and independent design approaches later marked as 1, 2 and 3.

In 1994, CEN published prestandard ENV 1997-1, and three years later a critical role in the conversion from ENV to standard/norm (EN) played the CEN’s recognition of uniqueness of geotechnical design and that it can not be considered as equal to other design practices in construction. This concession was brought about through different models commonly used in various countries which can not easily be harmonized because of the different geological conditions, and thus the phrase "local traditions" was coined [7]. All these reasons have led to a slowdown in development and acceptance of EC7, but it still was attractive to many countries around the world, because they certainly could (at least partially) find something common with their own traditions. Unlike this one, other EC were readily adopted and implemented. Transition from ENV 1997-1 to EN 1997-1 was carried out in the period 1997-2003 (released in 2004) and three years later they were joined by other standard which includes geotechnical investigations and testing.

Each part of the EC contains data that is left to countries to choose - so-called nationally determined parameters (NDP). Their choice depends on the safety, durability and cost-effectiveness of the structures that have been and remain in domain of the single countries, and not the EU, but also on the recommended parameters that Member States are required to apply. Even more, EC7 offers three procedures to perform geotechnical design. To enable dimensioning according to unique principles at international level and to overcome the differences in geotechnical dimensioning caused by geologic, geographic and climatic varieties, soil conditions, different methods of investigation and testing, design requirements, design methods and calculation models, design traditions successfully applied for many years, legal restrictions, as well as varying degrees of protection and safety, EC7 is carefully prepared to allow each country to choose the design approach (DA) and partially change these parameters, which is performed through National Annexes (NA) prepared by each beneficiary country after publication of EC.

3. Description of Design Approaches

As noted above, EC7 consists of two parts - the first part concentrates on general rules for geotechnical dimensioning of pad foundations, piles, anchors, retaining structures, embankments, etc. In addition to NDP, this part offers three ways of designing geotechnical structures and countries are allowed to decide on the most appropriate dimensioning approach, i.e. design approach and to incorporate individual NDP. The first edition of the EC7 prescribes that testing of the ultimate bearing state in conditions of constant and variable impacts shall be performed for two formats of action combination: one takes into account the insecurity of structure loadings, while the other discusses the insecurity of shear resistance of the ground. Some countries accepted to perform double calculation check, while most opted for one of the two formats. Agreement between structural and geotechnical engineers opened the door for creation of three different design approaches (DA1, DA2 and DA3), one of which considers the resistance of the ground, which resembled the most of the design approaches used in the EU.

Yet, disappointing at first glance seems the absence of specific instructions in EC7, especially in section 7-1, which is, however, obvious considering the uniqueness of geotechnical designs and the necessity to "produce" guidelines for designing that will meet a number of requirements and be widely acceptable. In fact, due to the above mentioned, it provides general formulations, rarely (in)equations and constant advice to comply with, e.g., following condition:

$$E_d \leq R_d \tag{1}$$

Where: E_d – design force, R_d – design resistance. Some suggestions are provided in appendices, while explanations are given in just a couple of published books, such as [8] and [3]. In the context of expression (1) we should emphasize that it indicates one of the novelties of this Eurocode that puts it above the current geotechnical designs, because it introduces force as a basis for comparison, instead of stress. It is interesting that this requirement, i.e. factorized force to be lower than the reduced resistance, originates from Denmark. Based on the above, EC7 developed and offered three different approaches.

Within design approach 1 (DA1) it is necessary to examine two combinations. Combination 1 (DA1, combination 1: DA1 C1) tends to provide a safe dimensioning against the adverse deviations of effects from their characteristic values. Therefore in the C1, partial factors (PF) γ_A larger than 1.0 are set to permanent and variable effects from ground and structure. Unlike those, the designing of shear strength of the ground is carried out with characteristic values, i.e. PF γ_M with amount of 1.0 is applicable to shearing resistance parameters (SRP), and PF for ground resistance γ_R has the same value. Combination 2 (DA1 C2) ensures safe design against unfavourable deviations of the SRP of the ground from their characteristic values and against imperfections in the design model, where it is assumed that permanent actions suit their expected values, and the adverse variable effects only slightly deviate from their characteristic amount.

Due to the fact that PF is set at the beginning of the work (for both combinations), the whole procedure is carried out with the design values, but relevant is the one that leads to higher dimensions. To keep designing in accordance with EC7 it is always necessary to do the analysis for both combinations of PF, what means that the same structure has to be calculated twice, even though it is often obvious which calculation is relevant. Even though the background of "necessity" of dual calculation is clear, it is also a major drawback, at least from a practical, engineering point of view. This is especially the case in our region (Macedonia, Serbia, Montenegro, Bosnia and Herzegovina) with absolutely no tradition of application, because it is always performed using only one approach. For this reason, it will not be taken as eventual DA for further consideration in our region. Unlike this approach, in DA 2 and DA 3 it is enough to do only one calculation. We should respect local customs and habits and use them to find approaches recommended in NA for application in dimensioning according to the EC.

In the approach 2 (DA2), PF related to geotechnical actions and their effects are the same as those that derive from actions on or from the construction in the first DA1 C1. Characteristic values of SRPs of the ground are also the design ones, while the resistance of the ground in vertical and horizontal direction decreases. But, here are two possible ways to implement the design. In the approach originally referred as 2, PF are applied to characteristic impacts at the beginning of calculation, thus the analysis is carried out with the design values. However, this leads to a certain lack of logic when considering bearing capacity: the characteristic bearing capacity value is calculated by the design values of the actions, after which PF for resistance is divided in order to get its design value [27]. This lack was the starting point for Germany to establish and recommend DA2*, where the whole design is implemented with characteristic values, since PF is added in the final analysis during the testing of ultimate limit state.

Approach 3 (DA3) is similar to DA1 C1 and DA1 C2, unifying them indirectly, as PF are applied to the forces, effects and shear resistance of the ground, so only one calculation is needed. However, there are two types of PF for force, depending on whether they derive from structures or have geotechnical origin. In doing so, the PF is included at the beginning, and thus whole calculation is performed with design values for actions and shear resistance.

In order to adopt some of them for specific structures, it is necessary to do comparisons that will be presented and commented below.

4. Initial Hypothesis

Although EC7 has become mandatory in the EU, there is almost no significant activity in our region in regard to defining and adopting PF and DA. Thus, some geotechnical structures still use outdated methods, already discarded in developed countries: working stress state and global safety factors. Open market requires the acceptance of EC and supplements in form of NA in which to fit the valuable local experience and historical knowledge.

Namely, the domestic civil engineering and geotechnical regulation is respected for many years and successfully applied in the region, being at the same time upgraded. In 1990, this resulted with the publication, still valid and enhanced version of the "Regulations on technical standards for building foundations" (hereinafter the "Regulations") of 1974. Interestingly, 4 decades ago former Yugoslavia introduced the concept of limit states – among first countries in the world and following the example of Denmark, Yugoslavia introduced partial factors in geotechnics for calculation of the ground bearing capacity. Since the safety of facilities/building structures with respect to construction has not been compromised, it is made possible to adopt hypothesis to maintain the current level of safety, and thus to rely on the existing design methods as relevant, because nothing indicated the need to change them. Other principles that should be followed when choosing the appropriate DA are:

- Similarity of design approaches, thus ensuring continuity of designing traditions in dimensioning geotechnical structures;
- Selection of approach that will not require user intervention in the middle parts of the calculation [26];
- Reproduction of the current design, level of safety, durability, cost-effectiveness and sustainability;
- New designs should guarantee a sufficient degree of safety;
- Coverage and applicability to all situations and constructions, which tends towards unification of the DA and enables simultaneous problem solving;
- Compatibility with the designing of the upper structure, which leads to similarity in calculation, and the possibility that the entire structure is treated in a unified mutual joint action (interaction): upper structure - foundation structure - ground;
- Entering of partial factor only in places where the insecurity occurs and for measurable factors;
- The possibility of modelling and application of contemporary numerical methods, such as finite elements method.

Otherwise, i.e. non-compliance with the above principles would lead to adoption of inadequate design approach (and partial factors) which would, as the final and perhaps the most important result, lead to large dispersion between dimensions, threaten the stability and safety of facilities and their implementation, and certainly would confuse both designers and builders, especially if a particular existing structure, designed according to current standards, undergoes interventions using Eurocodes. We should also keep in mind that different DA with corresponding PF does not always lead to the same or similar level of safety that was previously provided with the concept of a global factor [27], so if individual structures are built according to particular conservative approaches, they may be unsafe; but if they are safe, then all the other structures are extremely overdesigned and therefore inefficient [24], which requires special attention when choosing the DA.

When selecting a design approach one should take into account that it is simple to use and applicable in applications based on finite elements, which have found its place in geotechnics, after its regular application in civil engineering. In doing so, DA1 C2 and DA3, that perform the reduction of material properties, are very effective for application within FEM in almost every geotechnical situation, and those are particularly useful for the analysis of problems involving the limit states of a soil bearing capacity. In this case, the analysis may be performed using design values from the very beginning, or characteristic values that are eventually reduced to the level of achievement of the failure may be applied. Unlike them, DA1 C1 and DA2 are approaches in which loads are increased and intervention on resistance is performed, and then the factorized loads and resistances at different stages of the analysis are compared. Its application is limited and can be used only for problems where the limit state is reached by increasing of the external load and when no effect is caused by the ground, so it is of interest only to those who are more involved in the analysis of interactions between the ground and structure [2]. For these reasons, and in terms of routine and simple analysis, the user has the advantage to perform approaches in which material properties are reduced. It is preferable especially when the loading history plays an important role, which is almost a regular case with the soil.

Among those with the greatest practical significance is certainly a decision on the future design of the soil bearing capacity. Namely, from all of the current recommendations of the "Regulations" conceptually closest to European standards is the one on bearing capacity, but it - besides other things - differs in terms of the treated impacts. It is therefore essential for this geotechnical problem to be analyzed along with existing and proposed methods. The condition of "similarity" of the "old" and the new design approach will allow selection of the appropriate DA, which would, at the same time, meet the demand that engineers get familiar with Eurocode 7 and also to design geotechnical structures according to limit states only. At the same time, the proposed approach (just as PF) should be acceptable in terms of subsequent calculation of existing structures in case any intervention, such as their upgrading, rehabilitation or reconstruction, as it will be required that both approaches - those once used when the construction has been designed, dimensioned and built, and those used when the construction undergoes construction activity at the present time - result in almost identical size of geotechnical structures. This will prevent and eliminate any possible distrust in Eurocode 7.

5. Determining Design Approach for Spread Foundations

According to the “Regulations”, the above mentioned equation used to design load bearing capacity is based on one of the equations proposed by Brinch Hansen:

$$R/A' = 0{,}5\gamma' B' N_\gamma s_\gamma i_\gamma + (c_m + q\tan\phi_m) N_c s_c d_c i_c + q \tag{2}$$

Where the most relevant parameters are:

R – Total allowable vertical loading of a foundation, where constant and temporal loading forces are multiplied by corresponding factors of safety;

ϕ_m – Allowable mobilized angle of shear strength;

$$\tan\phi_m = \frac{\tan\phi}{F_\phi} \tag{3}$$

Where ϕ is the angle of shear strength, and $F_\cdot$ is the corresponding safety factor;

N_γ, N_c – Bearing capacity factors depending on ϕ_m ;

c_m – Allowable mobilized cohesion;

$$c_m = \frac{c}{F_c} \tag{4}$$

Where c is cohesion and F_c is corresponding factor of safety;

s_γ, s_c – Factors of shape;

d_c – Factor of depth;

i_γ, i_c – Factors of inclination of the force depending on ϕ_m, intensity of the components of factorized force, reduced SRP, size etc.

One may notice that design, i.e. factorized forces, are used to calculate these factors, as well to calculate limit bearing capacity.

The described equation by Hansen is extended proposal by Terzaghi and Skempton. After intensive work in the `50's, he introduced the following three equations:

$$R/A' = 0{,}5\gamma' B' N_\gamma d_\gamma s_\gamma i_\gamma + c' N_c d_c s_c i_c + q' N_q d_q s_q i_q \quad \text{General} \tag{5}$$

$$R/A' = 0{,}5\gamma' B' N_\gamma d_\gamma s_\gamma i_\gamma + (q' + c\cot\phi) N_q s_q d_q i_q - c\cot\phi \quad \text{For } c = 0 \text{ kPa} \tag{6}$$

$$R/A' = 0{,}5\gamma' B' N_\gamma d_\gamma s_\gamma i_\gamma + (c + q'\tan\phi) N_c s_c d_c i_c + q' \quad \text{For } \phi = 0 \tag{7}$$

In 1968, he developed the first equation by including some of the general factors and introduced it as general equation:

$$R/A' = 0{,}5\gamma' B' N_\gamma b_\gamma s_\gamma i_\gamma d_\gamma g_\gamma + c' N_c b_c s_c i_c d_c g_c + q' N_q b_q s_q i_q d_q g_q \tag{8}$$

The general equations are still known as Brinch Hansen's, while the other two are simpler and widely applicable for limited soil conditions: one for soil without cohesion, and the other for soil without friction. The author states that latter one is more applicable for clay in undrained conditions, while in the same study, he recommends it as appropriate for all types of soil [11]. Just a few years later, this equation was accepted by the Committee for Standardization in former Yugoslavia.

The method introduced in the "Regulations" is, therefore, slightly simplified form of the equations published by Brinch Hansen during the 1960s, and which have been applied for decades (not just) in Denmark, whose geotechnical society is European leader in the field of bearing capacity. Brinch Hansen promoted partial factor of safety in geotechnics and soon after Denmark, the former Yugoslavia introduced a new designing approach of the allowable bearing capacity, which was not followed by other countries, especially in Western Europe, unlike some of the Eastern European countries, like the Czech Republic, which still has a significant contribution to the improvements of the elements of DA and PF, and South American countries. However, this specific feature allows us to easily adapt Eurocodes, but also perform the corrections by introducing its advantages, because the "Regulations" does not distinguish between drained and undrained conditions, it discriminates SRP, does not take into account foundations with inclined base, as well as soil with sloped surface, and the bearing capacity does not depend on the direction of the horizontal component. Brinch Hansen, however, included most of these coefficients in the general form of his equation, so it serves as a starting point in formation of the pattern, published in Annex D of the Eurocode 7 almost forty years later. In a meantime it helped to overcome all noted limitations, so the following equation was introduced:

$$R/A' = 0{,}5\gamma' B' N_\gamma b_\gamma s_\gamma i_\gamma + c' N_c b_c s_c i_c + q' N_q b_q s_q i_q \tag{9}$$

Reduced SRP of the soil is applied in the suggested equation and its members:

$$\tan\phi' = \frac{\tan\phi}{\gamma_\phi} \tag{10}$$

$$c' = \frac{c}{\gamma_c} \tag{11}$$

As well factorized forces:

$$R = \gamma_P \cdot P \tag{12}$$

Still, in order to choose the appropriate design approach which would be a continuation of the traditions and customs of the design during the decades of application of the "Regulations", it will be necessary to conduct a careful comparative analysis of designing process according to existing methods and procedures, especially 2, 2* and 3.

As it is known, when calculating the bearing capacity according to the "Regulations" factorized force and reduced SRP are applied, while there is no mention of resistance. Specifically, the value obtained for the loading at the same time is the final value, because it does not undergo any additional interventions or reductions. This observation leads us to elimination of approach 2, and thus its variant 2*, since they are - unlike most Western European countries which used to calculate the allowable bearing capacity according to the global safety factor (e.g., according to Terzaghi model) - inadequate for our region due to the reducing of the normal resistance of the soil, and not the SRP. Thus, the approach 3 and its features are left to be considered. It is known that its application allows both SRP of the soil to be reduced, which is important because parameters that are possible sources of insecurity are reduced, as well as the nonlinearity of the friction angle with the loading and soil pressures that are highly sensitive to changes in angle, thus gaining the reactive force under the foundation R_d, while all actions - both constant and variable – increase because of the design loading E_d. Besides that, in terms of factorizing it the similarity of the analysis according to the "Regulations" and DA3 can be established, because it is performed at the beginning of the analysis, and thus the whole analysis is performed using design values. Such approach - increase of forces and reduction of soil strength - is actually the same as the approach in “Regulations”, which leads to the conclusion that the approach described in the “Regulations” is identical with the Design Approach 3. Thus, given that the Brinch Hansen's general equation for calculation of bearing capacity served as a basis for the expression in EC7 - and taking into account that our engineers use current "Regulations" more than 20 years, and before that for 15 years with the described variation of Brinch Hansen's equation, because it as in the original form was part of the "Regulations" of 1974, as well as recommendations of Eurocode on respect of the "local design traditions" - it is recommended to apply DA3 for calculation of bearing capacity. Inspection of the so far published national annexes shows that Denmark and other countries that have used the Brinch Hansen’s equation (Scandinavian countries, the Netherlands, etc.) accepted it, which is another proof of the proper selection and proper approach. Still, in order to remove any doubt, it is necessary to prove the choice numerically, with calculations to prove that the current level of safety is going to be retained with the selected PF, which also is the case, but it will be shown in some other paper.

6. FEW MORE EXPLANATIONS

Above considerations demonstrate that this methodology can maintain the current proven level of structural safety and successfully introduce the design according to the EC7. The conclusion can be drawn due to a selection of the DA3 and adoption of certain relevant partial factors whose analysis and calculations are not shown here. Choosing of the DA3 is also due to same author of the equations for calculation of capacity given in Eurocode 7 and the "Regulations": Jørgen Brinch Hansen; as noted above, this was the case with other countries which have used his calculations even before the publication of the EC7. However, in order to complete the calculation and reject some criticism towards the equation proposed in EC7, during the next revision of Eurocode 7 and the Annex we should be fully consistent with the author and adopt a shape that he originally proposed, in which, among others, there is the contented factor of depth *d* (excluded from the proposed equation), which is, on the other hand, part of the equation in the "Regulations".

The Eurocode 0 points to the "non-linear analysis" in terms of a small increase of some input parameters and great increase in corresponding output parameters, but it does not pay attention to a similar relationship between strength and resistance. Namely, this observation is the most pronounced in case of soil, because the strength results mostly from friction, so this disproportion is indicative for angle of friction and factors of bearing capacity [24], which requires to reduce the angle instead of resistance or bearing capacity, as it is case in the DA3. The forces in this approach are factorized before the start of the design in order to avoid their possible mutual cancellation and results that would lead to unsafe construction. This also opens up the possibility to carry out the analysis during the nonlinear description of the shear resistance of the soil, especially of a hyperbolic type [14], where it can be interpreted only through a variable angle of shearing resistance as a function of normal stress.

The distinctive feature is that in most cases, the approach 3 obtains the largest required dimensions of a foundation [16] and this is further noted in almost all the researches and analysis conducted for drafting of National Annexes. We may further say that the number of calculations of the authors of this study have shown that the "Regulations" obtain amounts higher than those in DA3, which is, however, a consequence of the amount of partial factors, which will not be described here as already mentioned. Above mentioned consideration suggests that DA3 offers a slightly higher level of safety when compared to other approaches. This statement is appropriate in terms of foundation building, because the foundation remains hidden in the ground below the structure, so there is no direct visual insight in its behaviour and development of deformation, so any possible damage could not be repaired. Upper structure is the only way to indicate and warn when something is wrong with foundations, when damage is much larger, and therefore the question of the justification of the level of safety in DA3 is unnecessary. Besides that, DA3 in many ways resembles the upper structure designing, because forces and materials are also factorized, providing consistency in its designing and designing of the foundation, which is, of course, of great importance for designers. The introduction of DA2*, where there already exists an inconsistency between the design approach for allowable bearing capacity and sliding [25] would lead to disagreement between the method of designing of the upper structure and its underlying foundation, which only would get exacerbated, noting that the Approach 2* obtains smallest dimensions that would greatly vary from those adopted so far. If you do not consider the proposed Design Approach when, for example, dimensioning and expanding an existing facility, it will result in a smaller sized foundations, which will create great confusion among engineers, and certainly cause a reasonable sense of fear and distrust in the Eurocodes in general, while the second extreme case encountered by some EU countries (western and eastern) would imply the need to reinforce existing structure that has been used for many decades, using new design approaches.

Yet another confirmation can be found in the regulations for reinforced concrete as a material usually used for foundation, when the limit strains for a concrete in the foundation, instead of 3.50‰ is limited down to 2.00‰, because of the unavailability and inability to perform examination of the foundation.

Keeping in mind that the finite element method (FEM), which offers great potential for the design, is becoming regular practice, it is reasonable to expect that the design in accordance with Eurocodes can easily be performed within it, although Eurocodes are developed in the direction of the limit state of failure, and not in the way applicable with FEM. However, all of this is possible only if input parameters are factorized, such as the forces and strengths of the soil, or the results of the analysis, such as moments and resultant forces. The former is performed in the design approach 3, which allows successful application in FEM based software.

A schedule of PF by parameters is suitable from this point of view, but also from the possibility of obtaining results in FEM based software, which all makes strong argument in favour of accepting DA3.

CONCLUSIONS

Due to different geological, geomechanical, climatic, geographic and other conditions, Europe developed a variety of geotechnical design habits, out of which came a number of geotechnical investigations, design models and approaches, which led to their endemicity and deviation from dimensioning of other structures in civil engineering. To unify this variety of designing of geotechnical structures and to make it applicable in a single large market of the EU and beyond, which in turn would contribute to the creation and acceptance of EC7 as the uniform standard for geotechnical designing, it is essential for EC7 to adapt those valuable local experiences, taking into account the specific features of the soil that contributed to the unique nature of geotechnical designs in a form acceptable to a broader European engineering community. All this is achievable only in the way in which EC7 is published: in the form of code, thus providing its acceptance in many countries, but also the inclusion of other standards. The outlined task of the EC7 is achieved through non-binding methods for design of any situation, and only providing the principles for the process of designing and influences and factors that should be considered, using different methods of application of a PF and acceptance of a single DA out of three offered. In doing so, in addition to the DA each country should determine the amount of PF to be applied to the selected DA in designing of geotechnical structures in that country. The process of selection of appropriate DA and determination of the amount of the PF is time consuming and complex, because they are intended to meet the requirements of engineers (when it is necessary that the selected design approaches are similar to those so far) and the country that prescribes the level of safety that may also be determined by the amount of PF.

Although the EC7 was not developed in the direction of application of numerical methods, which are still not in the foreground, regular application of the finite element method in contemporary geotechnics sets another condition and also the limitation in the selection process, because all design approaches may not be directly applied within numerical modelling in the application of FEM. Because of this, the work in this field requires a lot of effort and attention, as evidenced by all the countries that have so far accepted the EC7, where the research took several years.

This paper elaborates spread foundations, while we used DA3 as a continuity of the previous way to calculate bearing capacity. The study provided strong support for DA3 where reduction of SRP is carried out, and some reasons are: continuity with most of the previous analysis; similarity with the design approach for the upper structure; nonlinearity or disproportion of the relationship between soil strength and resistance; distinguishing between the effects of actions and resistance, as required by the Eurocodes, which is very hard to accomplish in geotechnics, since the establishment of the soil strength on friction leads to the existence of numerous cases, such as walls, foundations and slopes, where the difference is unclear, but the application of DA3 and PF to effects and strength of the material avoids some confusion; equally successful for manual calculations, simple software applications, and complex numerical analysis, and easily modelling of soil using nonlinear hyperbolic-type fracture envelope.

Regarding the selection of DA for foundations, it seems that we differ from most countries, although we only continue our own tradition, but also the tradition of the countries that were first to start using PF and ultimate limit state for designing of the foundations, while the majority of countries used working state and global factors. However, it is expected that the selected DA will be of a great benefit to our engineers as it will enable them to facilitate and accelerate the acceptance of the EC7, but also prepare them for some of the possible future scenarios in terms of bearing capacity calculation when, perhaps, some DA will gradually be excluded until only one is left. It is possible that during harmonization, two DA to be eliminated, thus if there is suggestion DA2/2* to replace the existing one, then our engineers will not see the possible transfer as problem, because they will have enough time to gain experience with the EC. On the other hand, the selected approach is very similar to the most authoritative combination in DA1, which makes us more prepared for its acceptance in case it replaces all other. However, given that we are still in the early stages of acceptance and adaptation of the EC generally at the European level, and that the harmonization will last for decades, it is proposed to adhere to DA3.

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IZBOR POSTUPKA PRORAČUNA PLITKIH TEMELJA PREMA EVROKODU 7 ZA NAŠ REGION

Kako bi se na tržištu EU prevazišla neravnopravnost usled brojnih građevinskih standarda, pristupljeno je njihovom uklanjanju i zamenom kompletom harmonizovanih tehničkih pravila, poznatih kao Evrokodovi. Evrokod 7 se odnosi na geotehnički proračun, ali njegova priprema je, usled različitih geoloških, geografskih i klimatskih uslova koji su doveli do razvoja različitih lokalnih načina proračuna, bila otežana. Zbog toga su u njemu ponuđena tri postupka za proračun, kao i kompleti parcijalnih koeficijenata koji se trebaju primeniti u njima. Nakon prihvatanja Evrokoda 7 svaka zemlja treba da donese još dve veoma važne odluke koje se odnese upravo na izbor proračunskog postupka prema kome bi se vršilo dimenzionisanje geotehničkih konstrukcija i na definisanje njemu odgovarajućim parcijalnim koeficijentima. Ovde je prikazan postupak donošenja odluke o odgovarajućem proračunskom postupku za plitke temelje za naš region gde je process uvođenja Evrokodova još uvek aktuelan, a isti pristup se, zasnovan na zadržavanju sličnosti proračuna kao do sada, može primeniti i za ostale geotehničke konstrukcije.

Ključne reči: *Evrokod 7, geotehnički proračun, proračunski postupak, plitki temelji*