Review paper

Received: Februar 3, 2014
Accepted: March 1, 2014

Analysis of risk assessment and law basis for construction of underground structures

Analiza ocene tveganja in pravni okvirji gradnje podzemnih objektov

Mario Mazurek[1,*], Peter Grilc[2], Jakob Likar[3]
[1]Municipality Metlika, Naselje Borisa Kidriča 2, 8330 Metlika, Slovenia
[2]University of Ljubljana, Faculty of Law, Poljanski nasip 2, 1000 Ljubljana, Slovenia
[3]University of Ljubljana, Faculty of Natural Sciences and Engineering, Aškerčeva cesta 12, 1000 Ljubljana, Slovenia
*Corresponding author. E-mail: mario.mazurek@siol.net

Abstract

In the construction of underground structures are always present risks due to unexpected ground conditions, the most basic goal is to provide stability in the planning and construction phase. Due to influence of parameters, which are known as random variables, is expedient to develop risk analysis with probabilistic approach, which enable to research the reliability of groups of data from geotechnical investigations and safety against the failure. It is also important to have carefully determined contract relation and obligations between the client and the contractor. In this article there will be represented risk assessment for basic stability reliability of underground structure and general overview of valid legislation in the Republic of Slovenia for the field of structure construction, set of laws, international recommendations and guidelines and law harmonisation at construction of the underground structures and divisions of risk between the subscriber and the contractor.

Key words: underground structures, risk assessment, probability approach, reliability index, construction contract

Izvleček

Pri gradnji podzemnih objektov so vedno tveganja zaradi nepričakovanih hribinskih razmer, najosnovnejši cilj pa je zagotavljanje stabilnosti v fazi načrtovanja in gradnje. Zaradi vpliva parametrov, ki imajo lastnosti naključnih spremenljivk, je smotrno izdelati analize tveganja z verjetnostnim načinom, kjer se lahko preveri zanesljivost skupine podatkov iz geotehničnih raziskav ter varnost pred porušitvijo. Pomembno je tudi, da je natančno določeno pogodbeno razmerje ter obveznosti med naročnikom in izvajalcem. V članku bo predstavljena ocena tveganja za osnovno stabilnostno zanesljivost podzemnega objekta in splošen pregled veljavne zakonodaje v Republiki Sloveniji za področje graditve objektov, zakonikov, mednarodnih priporočil in smernic ter pravno usklajevanje pri gradnji podzemnih objektov in delitvi tveganja med naročnikom in izvajalcem.

Ključne besede: podzemni objekti, ocena tveganja, verjetnostni način, indeks zanesljivosti, gradbena pogodba

Introduction

Construction of underground structures is, because of its specificities, placed at the most demanding constructions with present risks due to unexpected ground condition. In spite of most contemporary knowledges and advanced global technology, construction of underground structures is an inimitable process with present risks. Unexpected ground conditions can cause rock mass failure during excavation, invasions of ground water, changes within structure and firmness of the ground, excess deformation and the injury of people and property. It is always the first and basic goal to ensure the stability of the underground structure in the planning and construction phase, stability must be ensured directly during excavation. Ground stability reliability, load-bearing support elements or system ground-support against failure or excess deformations must be adequately verified, evaluated and analyzed. Professional approach also depends on the principle of responsibility, conscientiousness and morality of the clients in the construction, because some risks can be expected but absolutely all risks are can't be expected. Due to the increased level of risk, and a large number of influences, ground and material characteristics, which have by physical laws properties of random variables, it is adequately to create a risk analysis with a probability approach. The statistical methods and tools can check the reliability of the geotechnical surveys data and measurements, reliability and safety against failure of individual structure or the whole system in interaction ground-support. In the construction of underground structures are included a large number of participants from various professional disciplines, including design engineers, engineers of different disciplines, specialists in the field of geotechnical engineering and tunneling, geologists, economic analysts and financial advisors, negotiation experts, lawyers and environmental specialists, supervisors, site managers, government organizations and companies, inspection and advisory services. At all stages, there are a number of risks that need to be continuously assessed and managed. This means that all participants in the project could on a professional basis and with sufficient information to timely respond and make the right decisions. Therefore, it is also important carefully regulated and defined contractual relationship and obligations between the subscriber and contractor and must be also provided appropriate interpersonal communication and coordination between all participants. Unprofessional conduct, inappropriate decisions, violations of the rights and duties can lead to disagreements, which can even lead to litigation on the courts and establishing legal liability. The first part of this article will present theory and method for assessing the risk of unreliable geotechnical parameters calculating the reliability index and probability against the failure during the planning phase, which is presented by summarizing of examples of several authors. The main advantage of the proposed method is that it is widely available, because all calculations can be performed in the Microsoft Excel program. In the second part of article are general overviews of the legislation in the Republic of Slovenia in the field of construction and construction of underground structures, codes, international recommendations and guidelines and legal harmonization. The significance of the law basis is important in the conclusion of construction contracts and negotiations, and further in the adoption and sharing of the risk between the subscriber and the contractor.

Risks at the construction of underground structures

Risk management means skill which represents making decisions with a certain degree of uncertainty. By the conclusion of the construction contract contractor undertake responsibility to achieve the final result which means to built the structure or other construction work, and he takes over the risk that this result will be finaly achieved[1]. Since the conclusion of the contract until its fulfillment passing a relatively long period in which it can occur a number of business risks. Therefore it is necessary to determine rules before the conclusion of the contract, about which client is involved to negative consequences of the realization of these risks[1].

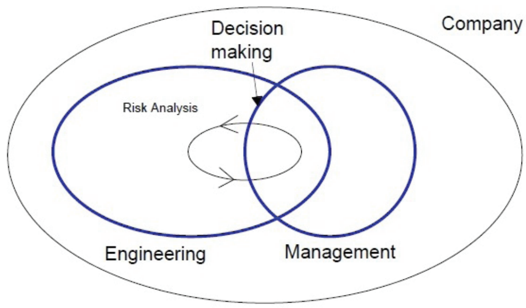

Figure 1: *Risk analysis as a part of a risk management process in organization[2].*

Unforeseen events and underground structures stability

Correspondently with second paragraph of 653. part of OZ are (necessary) unforeseen works that which must be done urgently in order to ensure the stability of the structure or to prevent the damage, the main cause of that can be unexpected difficult nature of the ground, unexpected water or some other unexpected event. In the project documents unforeseen work are not provided because they are unpredictable emergency work. Correspondently with OZ contractor may carry out such works without previously acquired subscriber's consent if such works have to be carried out immediately.

Conventional deterministic assessment of the stability of underground structures includes the calculation of the factor of safety and other indicators of stability. Limit state determines calculated boundary of structure, which must never be exceeded. The resistance of the material and the corresponding strength is never possible to identify with completely certainty.

Limit state of the structure is divided into:

— ultimate limit state – a partial or complete failure and instability of the structure,
— serviceability limit state – exceeded conditions of the structure applicability which are for example excessive displacements and damage vibration.

Risks management guidelines

Guidelines for the management of risks in the construction of tunnels and underground structures are prescribed by the International Tunnelling and Underground Space Association (ITA/AITES). The guidelines apply to all participants in the planning and management of risks in the construction of tunnels and underground structures. The guidelines are prescribed to subscribers and consultants, which are implementing risk assessment and taking into consideration the modern methods of risk assessment and describe the phases of risk management, from the initial to the final phase of the project.

Reliability analysis

Deterministic method for risk analysis is made only from the engineering data that are predetermined by the rules, terms and data. The method has no way of determining the probability of the limit values and the actual safety of the structure. Probabilistic method for the risk analysis is made on the mathematical models. The assumption is that all external influences and the strength characteristics of materials or structures are random variables, which are displayed as an appropriate statistical distribution, with a mean value and standard deviation. In this case, it is necessary to perform a series of calculations, in which each parameter systematically changing on the maximum possible interval for determination of the impact on the factor of safety (F) and on the stability sensitivity of each parameter.

In geotechnical engineering factor of safety and stability depends on the random variables and they all represents the strength parameters of the ground. Dependence of the stability are also a support system parameters, such as support pressure, steel or concrete strenght. Then it is necessary to properly analyze and assess the distribution of factor of safety (F), reliability index (β) and consequentially probability of failure (P_f). Reliability index (β) provides more information about the reliability of geotechnical designing and geotechnical structures.

Probabilistic assessment of limit states

Project design load capacity is usually designated as R and load that causes a force or load as S.

The boundary that separates the safe and unsafe side or failure is the limit state, defined by the following equation[3]:

$$G(X) = R - S = 0 \quad (1)$$

The following equation is also called as the performance function $G(X)$, determined by design engineer. Performed must be condition $G(X) \geq 0$ for the safe performance and structure stability. In the equation X = *vector of random variables*. Mathematically, in case if $R > S$ that means the safe side and failure happens in the case of $R < S$.

Approximation method First−Order Reliability Method (FORM)

The analysis with FORM provides one or more following results[4]:

- reliability index (β),
- probability of failure (P_f) or probability of a worst case scenario,
- the most likely combination of parameters which are representing the degree of failure,
- sensitivity of the result in any change in the parameter value.

The first step in analyzing the probability of failure using probabilistic methods is the mathematically assumption from the engineer which determines performance function $G(X)$ and impacts which causes unsatisfactory performance or failure. Calculations can be done with adverted FORM method in Microsoft Excel data sheet.

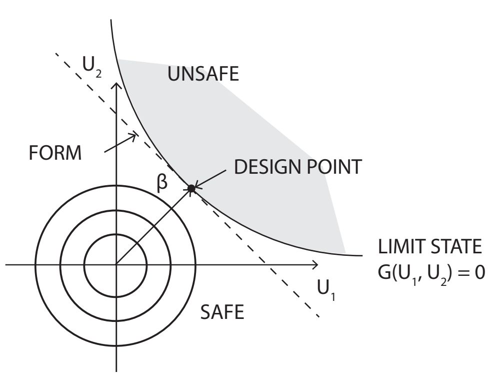

Figure 2: *The FORM approximation and definition of and design point[4].*

FORM approximation includes[4]:

- transformation of main random vector in a standard Gaussian vector,
- determination of the point of maximum of probability density (most likely point of failure or planned point which is (β) point) within the area of failure,
- assessing the probability of failure as $P_f \approx \Phi(-\beta)$ where Φ is the standard Gaussian cumulative distribution function.

In 2003 was by Low represented a method for calculating the reliability index (β). Approach is based on analysis with matrix system[4]:

$$\beta = min \sqrt{\left[\frac{x_i - \mu_i}{\sigma_i}\right]^T [R]^{-1} \left[\frac{x_i - \mu_i}{\sigma_i}\right]} \quad (2)$$

In case $\{X : G(X) = 0\}$

Training example with FORM method

Represented example of stucture reliability analysis is summarized from authors[5] and it was calculated in thesis[6]. Determined is performed function $G(X) = 0$ in case when support pressure $p_i = 0.4$ MPa and under hidrostatic stress field. In the data sheet are shown the mean values μ_i distributed by normal distribution and standard deviations σ_i of random variables which represents the ground parameters from which depents the design stability of underground structure. Inproper combination of represented main geotechnical parameters can cause excess plastic zone of excavated area which could be the main reason for excess radial displacement and structure damage or failure. The values in bottom represented Excel column of x_i^* are initialy set on the mean values μ_i. The next step is calculation of design point x_i^* with Excel considering with numerical changing initial values of μ_i under condition $G(X) = 0$. Finaly calculated values in column of x_i^* are the most critical values of ground parameters on limit state, which are in this example represented like random variables. Design point x_i^* shows the most critical values of φ, c, p_i, E_{rm}, which represents a combination of parameters of a ultimate limit state. Parameters φ and c, are in this example proposed with correlation coefficient −0.5. Calculated combination of parameters in column x_i^* ($\varphi = 21.09°$, $c = 0.2075$ MPa, $p_i = 0.3542$ MPa, $E_{rm} = 373$ MPa) are the most sensitive values which are representing the ultimate limit state. Perfomed function in this case is set as a criterium of plastic zone:

$$G_1(X) = L - \frac{R_{pl}}{R} \tag{3}$$

and second criterium is criterium of underground structure convergence:

$$G_2(X) = \varepsilon_{max} - \frac{u_{r\,pl}}{R} \tag{4}$$

- L is the maximum ratio by R_{pl},
- R_{pl} is radius of plastic zone of undergound structure [m],
- R is radius of cross section of underground structure [m],
- ε_{max} is maximum ratio by $u_{r\,pl}$,
- $u_{r\,pl}$, is total internal radial displacement of underground structure [mm].

Preliminarily proposed ratio for limit state of this example is:

$L = 2$
$\varepsilon_{max} = 2$ %

Calculations are based on performed function $G_1(X) = 0$ and assumed Mohr-Coulomb model. For this example are afforded next random variables:

- radius of underground structure or a tunnel (R),
- hidrostatic ground pressure (p_0),
- Poisson ratio (ν),
- cohesion (c),
- friction angle (φ),
- reactive support pressure on the edge of excavation p_i),
- Young modul of ground (E_{rm}).

Table 1: *Structure radius, ground and support pressure parameters*

	R/m	p_0 /MPa	ν	p_i/MPa
Random variables	2.5	2.5	0.3	0.4

Table 2: *Normal distributed ground parameters with calculated design point*

Random variables	Dist.	μ_i	St dev σ_i	x_i^*
φ/°	Norm	21.093	2.045	21.090 5
c/MPa	Norm	0.287	0.038	0.207 47
p_i /MPa	Norm	0.4	0.06	0.354 22
E_{rm} /MPa	Norm	373	48	373

Table 3: *Correlation matrix*

R			
1	−0.5	0	0
−0.5	1	0	0
0	0	1	0
0	0	0	1

Table 4: *Matrix system for calculating the reliability index (β)*

R^{-1}			
1.333	0.667	0	0
0.667	1.333	0	0
0	0	1	0
0	0	0	1

$[x_i - m_i]/\sigma_i$
−0.0012
−2.0930
0.7629
0.0000

$[[x_i - m_i]/\sigma_i]^T$			
−0.0012	−2.0930	0.7629	0.0000

$[R^{-1}][x_i - m_i]/\sigma_i$
−1.3970
−2.7915
0.7629
0.0000

$[[x_i - m_i]/\sigma_i]^T[R^{-1}][x_i - m_i]/\sigma_i$
0.0017

Table 5: *Limit state ratios and values of performed functions*

L	ε_{max}	$G_1(X)$	$G_2(X)$
2	0.02	0.000 227 82	0.001 594 784

Results of $G_1(X)$ and $G_2(X)$ are values from Excel analysis when $G_1(X)$ and $G_2(X)$ are by numerical calculating approaching to be equivalent to 0. For calculating needed condition $G(x_i^*) = 0$ was used function Solver in Excel.

Table 6: *Results of reliability index β and probability of failure P_f*

β	P_f /%
1.704	4.415

Training example for three cases of support pressure scenario

Input data and concept for this example was summarized from authors[7]. Perfomed function $G(X)$ in this case is set as a criterium of plastic zone, where is assumed equation (3). Analysis is made for circular tunnel under hidrostatic stress field. Method for calculating this results are the same like in a previous example. Following results and diagrams are summarized from[6]. The objective of following results is to represent the relation between p_i and β and between p_i and p_f.

Table 7: *Assumed support pressures*

Assumed support pressure	p_i = 0.0 MPa
Assumed support pressure	p_i = 0.3 MPa
Assumed support pressure	p_i = 0.8 MPa

Table 8: *Calculated values of β and P_f for different support pressures p_i*

p_i /MPa	$G_1(X)$	β	P_f /%
0.0	−0.000 001 0	0.707	23.989
0.3	– 0.000 000 6	3.238	0.060
0.8	– 0.000 000 9	8.844	0

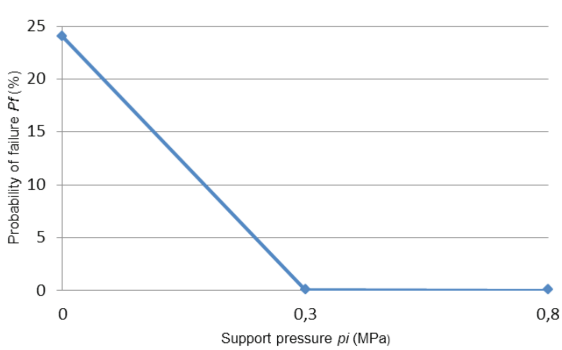

Figure 3: *Relation between p_i and β.*

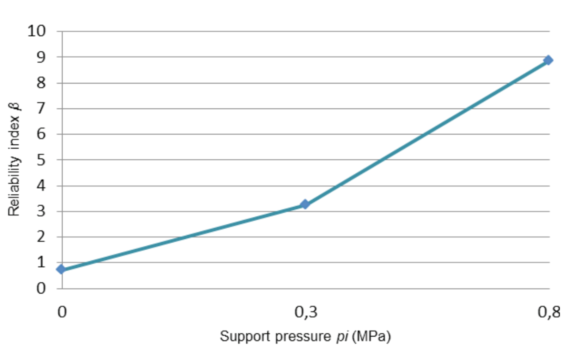

Figure 4: *Relation between p_i and P_f.*

From diagrams above it is visibly, when p_i increases also reliability index β increases and the probability of failure P_f in this case declines. Diagram functions are linear specialy for this case, because only three different points were taken into consideration.

Law basis and construction contract

The definition of the legal obligations in the following sections proceedings within the wider formal sense, especially are exposed regulations relating to the construction of underground structures. Following represented law basis for construction of underground structures are summarized from[6] where they are closely considered.

Legal rules are divided into:

— basic rights and obligations of the participants, the rules in the case if the participants agree otherwise,

— enforced rules from which the participants can not resign, this rules protects certain fundamental values of contract law.

The basis for the creation of obligations contracted for the construction and construction contract in Republic of Slovenia are Obligacijski zakonik (Code of Obligations; hereinafter OZ), which replaced Zakon o obligacijskih razmerjih (Law of Obligations; hereinafter ZOR) and Zakon o graditvi objektov[8] (Construction Act; hereinafter ZGO-1) (Ur. l. RS 110/2002)[9]. In the first phase of the contract proposal shall be reviewed general terms and in the second phase shall be drawed special or tender conditions.

Regulations and legal obligations

Obligacijski zakonik (Code of Obligations)

Obligacijski zakonik in Slovenia determines the relationships of the obligation law and in the field of commercial contract law contains the basic principles and general rules for all obligations. It is a branch of civil law, which governs the legal law relations and as a result means an obligation[1–10].

FIDIC - General conditions for construction contracts

FIDIC (Federation Internationale des Ingenieurs-Conseils) is a French acronym for the International world alliance of consulting engineers, which has been established in 1913. FIDIC publishes guidelines used by consulting engineers. General provisions includes guidelines, standard forms, contract documents and the contracts between the subscriber and the consultant. In the Slovenian language is in printed form available 10 FIDIC recommendations. ”FIDIC contract“ means: a contractual agreement, a letter of tender acceptance, tender letter, the general and special conditions, census (specification), drawings (plans), and all other documents (if they are available) which are listed in the ”contractual agreement“or in a ”a letter of tender acceptance“[11]. FIDIC general contract conditions are the same for all contracts around the world, but special conditions are always based on the individual contract or on a single specific object[11].

Posebne gradbene uzance – Ur. l. SFRJ 1. april, št. 18/1977 (Special Usages for Construction)

Posebne gradbene uzance (Special Usages for Construction; hereinafter PGU) takes its source from France, issued by the Privredna komora Jugoslavije (Commerce Chamber of Yugoslavia). In a similar way as an international FIDIC conditions they defines the relationships and other activities in the construction sector and further substantiates the individual concepts that are important in the construction phase. Basically, they are subordinated to the Obligacijski zakonik. The same as the typed legal rules of OZ, the provisions of PGU are also used in the subordinate way, means only if the clients did not otherwise regulate the specific issues with specific and individual provisions of the contract. They should be necessary adapted to the current Slovenian legislation. PGU have been used for many years and if participants agree in that case they are still valid. They are also used in the case law, if there is no other legal norms[11].

Special cases

In accordance with the 2. term of Obligacijski zakonik participants can arange their contractual obligation on the otherwise than it is determined in OZ, unless if the specific provision of this legal code (OZ) or of its meaning does not show anything else. In accordance with the 3. term of OZ participants are free to regulate obligations, but they should not edit them in conflict with the constitution, with the mandatory provisions or with the principles of morality.

Construction supervision

Building legislation of the Republic of Slovenia supervisory role in the construction defines the manual Priročnik za nadzor pri gradnji issued by Inženirska zbornica Slovenije (Slovenian Chamber of Engineers). The contractor is obliged to allow to the subscriber the constant control over parts and control over the quantity and quality of the used material[1].

Slovenian legislation in the field of construction provides the following participants at construction of structures: investor - the subscriber which orders and finances the project and the services, design engineer, superintendent for construction works, and the contractor carrying out the work and builds the structure. In the case of complex structures construction is also present the reviser. Construction supervision has control of tasks and responsibilities to oversee compliance of the construction with the project documentation, approvals and regulations.

Good business practices

Morality do not provide the content of required conduct, but the extreme limits of permissible conduct. The prohibition of conduct that opposes to the morality is protecting the fundamental social values. Conscientiousness and honesty of the participants requires that the conclusions and implementations of the rights and fulfilling their obligations do not only strive to achieve their own interests, but also to the interests of the other party.

Prohibited are dishonorable treatments, and treatments that are contradicted to the morality, and practices that are dishonorable to the interests of the counterparty. For example, in the German legal system are general restrictive standards of good practice (*gute Sitten*, comparable to the standards of the morality by OZ) and the loyalty and trust (*Treu und Glauben*, comparable with conscientiousness and honesty by OZ). Restrictive standards of the U.S. economic contract law are good faith and the injustice or unfairness (unconscionability). General restrictive standards of autonomous rules are good faith, fair dealing, inconsistent behaviour[10].

Careful treatment of a good specialist

General contract law also refers to careful treatment. When participants complete their obligations under their occupation, they must deal with a greater degree of careful treatment – careful treatment of a good specialist. Economic activity is a professional activity. The rules of the profession are not the average knowledge, but that means a narrow business area knowledge of the participants. The most important criteria for assessing careful treatment of a good specialist are rules and practices of the profession[10].

Business practices

Business practice is the conduct that is expected from persons of certain properties between the economic subjects. Their defined elements are[10]:

— determination of conduct,
— expectedness and
— qualification of subjects to which it relates.

Rules of business practices shall apply in every case. Correspodently with the OZ business practices have a normative nature[10].

The responsibilities of project participants

The contractor's liability for defects

Construction works contractor which takes the part of the project works, which was submitted by the investor as the subscriber shall be responsible only for the professional and technical mistakes and defects in the project, if the investor was not adverted from contractor, although the contractor as an expert knew or should have known the project mistakes and defects. But the contractor is not responsible as well for economically rashly performance which is proposed in the project[1].

The contractor of construction works can not figure out the mistakes and errors in static calculations, which were the basis for the preparation of project documentation, resulting in a too small quantity of stell reinforcement which depends from a load capacity which must be ensured for the building structure. Based only on the basis of a of project documentation review this cannot be figured out. But this can be determined when during construction works the consequences are shown – for example, when cracks on the construction are starting to show up[1].

Responsibility for the object errors, which are caused by deficiencies of the ground

In view of the ground complexity, the terrain must be necessary investigated with the geological and geotechnical studies. Nature of the ground must be taken into consideration by design engineer. The findings of such deficiencies of project documentation exceed the contractor's obligations in connection with the project documentation[1].

During construction (for example, during excavation pit excavation) circumstances may arise (such as intrusion of groundwater) that even when the contractor (depending on experience and knowledge that contractor has) can wake doubt about it that these (actual) properties of land are properly taken into account in project solutions (such as the depth of the foundation). In this case (and only in this case) is to these shortcomings contractor obliged to warn the subscriber, because otherwise its liability for defective building will not be able to relieve[1]. Under English law is one of general obligation on the design engineer to review the ground, whether it is appropriate for the construction of the facility by the subscriber needs. Error of project documentation goes so well that they have been used in the design of irregular baseline specifications and load capacity of the ground, or if the latter is based on the false static calculations[1].

Reduction and exclusion of liability

The contractor shall not be relieved of liability if the error has occurred because the implementation of each part of the work by demand of the subscriber. However, if it is before the implementation of each part according to subscriber requirements contractor puts his attention to the risk of errors, contractor‘s liability is reduced, in the circumstances of the each case can also be eliminated[1].

Construction contract

Construction contract is a work contract between the subscriber and the contractor and must be made in writing shape specialy to protect the interests of the participants and evidentiary purposes[1]. Both clients must be unanimous in all links of the contract. The subscriber does not require from the contractor to use of certain means and method of construction, but the subscriber is interested in the result of this work[1]. Business relationships in which this task relates primarily to contractual relationships of certain persons – economic subjects, addresses the economic contract law, which is a part of commercial law and in most legal systems recognized the existence of this specific law branch[10]. At the conclusion of the construction contract occurs bilateral contractual obligation.

The importance of the principle of contract clients conscientiousness and honesty

The principle of conscientiousness and honesty requires that contract client in the exercise of the rights acquired by the conclusion of the contract, and the fulfillment of contractual obligations not only seeks to achieve its own interests, which concluded the contract, but with the right amount and in an appropriate manner is also responsible for the realization and protection of the interests of the other contract client[1].

In concluding construction contracts under Austrian standards following provisions shall apply:

— ground is the property of the subscriber and also represents a subscriber‘s risk,
— the contracts are determined and applied in unit prices,
— the means and methods for unchanged ground conditions are contractor’s risk.

Special terms in construction contract which are related to the excavation and support system of a tunnel

The subscriber and the contractor mutually agree about the main steps in the progress of the excavation and primary tunnel support. The subscriber puts special attention to ensure the stability of the underground structure and the contractor has to put special attention to safety work and to the workers health. The contractor shall be responsible for technically correct and timely installation of appropriate support elements[12]. Contractor shall not be entitled to additional payment for better features of built-in material if such be installed, otherwise it is not a mistake, even if such material is not intended to project documentation. However, if the properties of the material are worse than anticipated with the project documentation, there is a mistake and contract unrespecting. The contractor in this case can not be held responsible for mistake[1].

Conclusions

The advantages of the presented FORM method approach is simple use comparing with other standard mathematical approaches. Level of mathematical computing depents from project pretentiousness and determined limit state function. When structural analyis are computing there is investigated the design point x_i^* which represents the most probably point of structural failure on limit state. There must be performed a condition which means $G(x_i^*) = 0$. Summarized experiences from other authors which were the references for thesis and this article are representing that gained results with this method are almost equivalent to the results from standard mathematical approaches. Design point shows also the sensitivity of the ground parameters, which is very important characteristic of reliability analysis. The analysis with FORM provides the calculation of reliability index (β) and consequentially probability of failure (P_f) which can also show a worst case scenario of underground structures designing.

Slovenian legislation in the field of construction provides the following participants in the construction: investor - the subscriber that orders and finances the project and the services, the design engineer, supervisor which overseeing work, and the contractor carrying out the work and builds. The contractor by signing and conclusion of the contract undertakes responsibility to carry out the necessary work or built underground structure, thereby assumes the risk to be successful and to reach the ultimate goal. The subscriber has the right to executes the professional supervision of the contractor's parts to verify and ensure their proper implementation, in particular concerning the kind, quantity and quality of work, materials and equipment and on schedule. Conscientiousness and honesty of the participants require that the conclusion and implementation of the rights and fulfilling their obligations not only strive to achieve their own interests, but also to the interests of the other contract client. When determining the legal rules is important to consider the enforced rules, which both clients must take into consideration, and the optional basic rules which may clients agree otherwise. Potencial risks can be reduced or avoided with next approaches:

— designing in more apropriate location of underground structure or a tunnel road,
— material designing with appropriate mechanical and geometrical characteristics,
— appropriate dimensional designing and reliability analysis,
— professional, conscientious and honest work,
— good communication of all participants in the project,
— supervisoring, measurements and monitoring,
— protection of surrounding objects, enviromental and machines protection,
— with the timely measure in foreseen, unforeseen and critical situations.

References

[1] Juhart, M., Plavšak, N. (2004): *Obligacijski zakonik (OZ) (posebni del) s komentarjem, 3. knjiga (435. do 703. člen)*. Ljubljana: GV Založba, 1205 p. ISBN 86–7061–349–2.

[2] Nývlt, O., Prívara, S., Ferkl, R. (2011): Probabilistic risk assessment of highway tunnels. *Tunnelling and Underground Space Technology,* 26, pp. 71–82.

[3] Zhang, W., Goh, A.T.C. (2012): Reliability assessment on ultimate and serviceability limit states and determination of critical factor of safety for underground rock caverns. *Tunnelling and Underground Space Technology*, 32, pp. 221–230.

[4] Griffiths, D., V., Fenton, G., A. (2007): *Probabilistic methods in geotechnical engineering*. Udine: CISM. 346 p. ISBN 978–3–211–73365–3.

[5] Low, B., K., Li, H–Z. (2010): Reliability analysis of circular tunnel under hydrostatic stress field. *Computers and Geotechnics*, 37, pp. 50–58.

[6 Mazurek M. (2013): *Analiza ocene tveganja in pravni okvirji gradnje podzemnih objektov*: Magistrsko delo. Ljubljana, 73 p.

[7] Low, B., K., Lü, Q. (2011): Probabilistic analysis of underground rock excavations using response surface method and SORM. *Computers and Geotechnics*, 38, pp. 1008–1021.

[8] Breznik, J., Duhovnik, J. (2005): *Zakon o graditvi objektov (ZGO–1) s komentarjem*. Ljubljana: GV Založba. 837 p. ISBN 86–7061–386–7.

[9] Žemva, Š. (2010): *Gradbene kalkulacije z osnovami operativnega planiranja in obračunom gradnje objektov: priročnik za prakso*. Ljubljana: CPU – Center za poslovno usposabljanje, Gospodarska zbornica Slovenije, 672 p. ISBN 978–961–6666–37–4.

[10] Kranjc, V. (2006): *Gospodarsko pogodbeno pravo*. Ljubljana: GV Založba, 496 p. ISBN 86–7061–429–4.

[11] Šajna, A. (2012): *Priročnik za nadzor pri gradnji*. Ljubljana: Inženirska zbornica Slovenije, 62 p. ISBN 978–961–6724–17–3 (pdf).

[12] Galler, R. (2010): Fair contracts in the field of tunnelling. *International NATM Workshop Singapore*.