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REASONS TO CHANGE THE TENDER PROJECT OF A TUNNEL DURING CONSTRUCTION

Lukić Dragan[1], Brčić Stanko[2], Zlatanović Elefterija[3]

[1]*Faculty of Civil Engineering, Subotica, Serbia, e.mail*drlukic.lukic@gmail.com
[2]*Faculty of Civil Engineering, Belgrade, Serbia*
[3]*Faculty of Civil Engineering and Architecture, Niš, Serbia*

SUMMARY

During construction, especially of tunnels, very often there is a need to change the tender technical documents, i.e. the documents upon which the construction permit is obtained and the tender is announced. The main reason for the change of documentation is, above all, unsuficient geotechnical investigations due to which technical solutions and calculations are inadequate. Very rearly documentation is changed due to errors in the calculation if the techncal review of documentation is correctly done. The paper presents an example of the change of documentation during construction and the reasons for that.

Key words: *tunnel, documents, construction, geotechnical investigations*

INTRODUCTION

Construction of geotechnical objects, especially underground ones, is followed by a large number of problems during design, and also later, during construction. The most frequent problems are unsufficient and inadequate geotechnical investigations. Investors of structures pay unsufficient attention to investigations. Namely, during planning of financial investment funds the Investors are devoting unsufficient funds to investigations before construction. With such funds performed investigations are unsufficient for required level of design, and also, some investigations are not even done. With such level of input data based on investigations the design stage begins.The Investor then turns the design to reviewers for revision. Now, in principle, there are two characteristic situations: one is that the reviewers do the revision in a correct way and point out to Investor that it is necessary to perform additional investigation upon which the documentation is then improved.

The second case (which is characteristic for Serbia and surrounding states) is that the Investor forces the reviewers to give the positive assessment without comments and detailed revision. After such revision the Investor obtains the construction permit and announces the tender for construction. If the Investor reserves enough funds and time for investigations and design (at the beginning or due to suggestions of reviewers), in most cases there is no change of documentation during construction. Changes in design are most often initiated at the request of Contructor company which is forced to negotiate low prices for construction works (which is afrequent situation in Serbia and surrounding states) and to engage another design company to make a rationalization of design, but without the standard legal procedure. Result of this is usually the bad quality of constructed object and very quickly the sanation of the structure is needed. If the Investor after the reviewers findings does not assign financial funds for additional investigations, justified changes in design are inevitable, with substantial losses for Investor.

In such cases additional investigations are performed during construction, which complicates design and construction. It is particularly necessary that all participants in realization of the project point out to Investor about the necessary time to do investigations and to make the correct design and revision of design. If it is done under the pressure of short and unrealistic time, the results are devastating to investment and the quality of the structure. The Investor realizes that finally, but unfortunately too late. This is repeating over years in Serbia and surrounding states.

This paper is presenting various changes in technical documentation during construction, due to unsufficient level of investigation before design process, using as the example changes of tender documentation related to tunnel Sarlah. The paper also presents situation when changes of tender documentation are justified.

CAUSES OF CHANGES OF TENDER DOCUMENTS

During construction of underground structures one of the most important causes of changes of thechnical documents are inadequate and unsufficient geotechnical investigations. Geotechnical investigations influence determination of rock pressures, determination of plastification zones, analysis of effects of underground and surface waters, determination of effects upon surface objects, slope stability etc.

Determination of rock pressures, i.e. effects of rock mass upon the structure, comes first when determining excavation phases and when dimensioning the tunnel support. At later phases it affects dimensions of the final structure. When dimensioning the tunnel support one determines the types of support and defines the sections of various types. If the investigations are inadequate designer may make the first mistake in determination of section lengths, and also may make a mistake in selection of support elements of various types. Determination of plastification zones is of particular importance for displacements of the rock mass in excavation and also the rock mass around the tunnel. The types of support depend upon the magnitude of plastification zones, since the plastification zones and pressures that appear are mutually dependant. It is particularly necessary to emphasise that determination of plastification zones is of a vital importance in determination of anchoring lengths when applying the contemporary tunneling methods. The plastification zone is also of a vital importance when determining geotechnical meassures for improvement of the rock mass around the tunnel excavation: freezing, injections etc.

For geotechnical objects, especially underground ones, great problems during construction represents the presence of water (surface or underground). The presence of water determines the technology of construction, design of measures to prevent disturbance of underground and especially surface waters. It is not rare that during construction of a tunnel in the soil above the tunnel landslides appear, due to disturbance of the water regime, and also may lead to drying of springs and other phenomena.
Also, during construction of tunnels (especially shallow ones), the settlements and damages of surface structures may appear. During design of a tunnel, designer must pay due attention to such aspects of construction.

The second very important cause of changes of technical documentation during construction is inadequate technical solution which may be a consequence of the following factors:

- Inadequate and insufficient investigations
- Inexperience of a designer
- Forcing the deadlines for making the technical documentation by the Investor
- Poorly done revision of the technical documentation

The third very frequent reason for changes in technical documentation is the low contract price of construction, so the Contractor is trying to change and rationalize design solution. Such approach is unjustified in most cases if the documentation is correctly done. This usually leads to solutions that cause poor quality of constructed structure. Exceptionally, justified cause of the change of technical documentation, initialized by the Contructor, may be the case of inadequate technical solution which appears during construction.

CONSEQUENCES OF CHANGES OF TECHNICAL DOCUMENTATION

Consequences of changes in technical documentation may be positive and negative. Consequences are positive if improved technical solution is obtained by changes in documentation and in that case request for changes in documentation is justified. If requests are unjustified (with purpose of rationalization), the consequences are negative since the obtained technical solution is worse.
If the changes are considered from the financial aspect and form aspect of dynamics of construction, consequences are in most cases negative (higher construction price, longer construction time).

EXAMPLE OF THE CHANGE OF TENDER DOCUMENTS RELATED TO TUNNEL SARLAH

As an example of the justified change of the tender documents this paper presents the change of tender documents of the tunnel Sarlah. In order to determine reasons for the change in documentation, the Contractor made analysis and calculation using the input geotechnical data upon which the tender documentation was made, and also with geotechnical data obtained by additional investigations. Calculation was done considering tunnel profiles that are between the profiles 320A and 325 in the tender documents.

Investigation upon which the teneder documents were made are unsufficient. In the entrance zone of the tunnel only one drill hole was made, B 225, upon which, as well as other sources, the geotechnical soil profile was made and design parameters were addopted.
The following deposits were isolated:

- Quaternary deluvial deposits ($d^{g\ dr}$)
- Pleistocene lake deposits (PI)
- Flysch complex - cretaceous sandstones, limestones, marl and shales ($_4K_2^3$)
- Massive limestone (K_1^3)

Contructor particularly pointed out the following deficiencies in the design tender documents:

- The total number of bore holes is inadequate for the significance of the object
- There are no bore holes in the area of the entrance portal. Hole B 225 has unsufficient depth
- Laboratory tests paid little attention to deformability parameters
- Performed geophysical investigations and indirect assessment of the deformation modulus led to overestimated values, and thus to design of inadequate support. By insight into tabulated values of geotechnical parameters one might conclude that the deformation modulusis in the range of 0.6-14.0 GPa

During construction works additional geotechnical investigations were made (holes G6, G7, G8, G8A, G9 and G9A) in the section from profile 319 to profile 327. Based upon additional geotechnical investigations new parameters were determined upon which the changes of design tender documentation were made. In that, ten deposits were isolated, [1]:

- GU 1- Quaternary deluvial deposits, from hard to very hard clays ($d^{g\ dr}$,g)
- GU 2- Quaternary deluvial deposits, from sand and gravel ($d^{g\ dr}$,p)

- GU 3- Pliocene-Pleistocene lake and aluvial deposits (PI)
- GU 4- Flysch of Upper Cretaceous (siltstone) ($_{34}K_2^3$-P)
- GU 5- Flysch of Upper Cretaceous (sandstone) ($_{34}K_2^3$-G)
- GU 6- Flysch of Upper Cretaceous (clearly changed, additionally weakened rock) ($_{34}K_2^3$**)
- GU 7- Flysch of Upper Cretaceous (totaly changed, very weakened rock) ($_{34}K_2^3$***)
- GU 8- Limestones of Upper Cretaceous (massivetoslightly fractured crystalline limestone) (K_1^{3k})
- GU 8a- Limestones of Upper Cretaceous(massive , broken rock) (K_1^{3k})
- GU 9- Limestones of Lower Cretaceous (rock that underwent intensive tectonic activity) (K_1^{3k}-t)

During additional investigations a detailed analysis of deformability was done and, based upon that, the change in tunnel support.

Additional investigations were of the outmost importance for determination of the real state of the geological medium – rock mass. The model obtained by additional investigations significantly deviates from the model according to tender documents in the following:

- In the tender documents four geological environments were isolated, while after additional investigations ten environments were isolated (as perviously presented)
- Differences in geological environments are in locations and depths of various layers, which led to changes in supports
- Strength parameters in tender documents were overestimated, as already pointed out

If one makes a comparative analysis of geotechnical parameters in tender documents and additional investigations, one may conclude that the largest deviations are related to values of cohesion and especially to deformation modulus, Tables 1 and 2.

Table 1.Characteristics of isolated rock masses

Formation	**γ (kN/m^3)**	**c (kPa)**	**φ (°)**	**E (GPa)**	**Poisson ratio ν**
Quaternary deposits ($d^{g,dr}$)	19 - 20	20	20 – 22	0.6 – 0.7	0.3
Pliocene – Pleistocene lake deposits (PI)	19	30	22	1.0	0.3
Flysch complex ($3,4K^2_3$)	22 - 23	100	26 - 28	5.0 – 6.0	0.25 – 0.28
Massive limestone (K^3_1)	25 - 27	100 - 300	40 - 44	10.7 – 14.0	0.24 – 0.26

Consequences of changes of input data according to additional investigations are the changed values of displacements, width of plastic zones and cross sectional forces.

Table 2. Characteristics of isolated rock masses during additional geotechnical investigations

Engineering – Geological Unit	GSI	GSI (design)	σ_{ci} (MPa)	m_i	E_i (GPa)	γ (kN/m^3)	c (kPa)	φ (°)	E or E_{rm} (GPa)	Poisson ratio ν
GU-1	-	-	-	-	-	19	20	25.0	0.020	0.30
GU-2	-	-	-	-	-	21	5	32.0	0.040	0.30
GU-3	-	-	-	-	-	19.5	30	23.0	0.050	0.30
GU-4	25-35	25	12	8	9	24	65	33.0	0.400	0.30
GU-5	30-40	30	25	14	12	25	100	42.0	0.600	0.30
GU-6	15-25	18	6	6	5	24	40	25.0	0.200	0.30
GU-7	-	-	-	-	-	21.5	10	32.0	0.050	0.30
GU-8	> 45, typically 65-80	50	40	12	20	25	240	47	2.150	0.25
GU-8a	25-45	30	30	10	15	25	129	38.9	0.660	0.25
GU-9	15-25	15	20	9	8	24	64	34.2	0.313	0.30

Displacements

Results of displacement analysis for each profile in the mentioned section (from profile 320A to profile 325) are presented in this paper, for both cases: according to tender documents and according to additional investigations, [2,3,8], Table 3.

Plastic zones

Results of plastic zone analysis for each profile in the mentioned section (from profile 320A to profile 325) are presented in this paper in the similar manner as for displacements, for both cases: according to tender documents and according to additional investigations, [2,3,4,5,6,7,8], Table 4.

Table 3. Displacements – Tender & Final Design

			Tender Design				Final Design			
			Max. Displacement (cm)				Max. Displacement (cm)			
Cross Section	Tunnel tube	k_o	Surface	Crown	Top Heading Sides	Bench Sides	Surface	Crown	Top Heading Sides	Bench Sides
320A	Left	0.5	~3.2	~3.9	~3.3	~2.0	~1.8	~2.4	~1.7	~0.9
		1.0	~2.1	~2.7	~2.5	~2.1	~1.1	~1.6	~1.5	~1.4
	Right	0.5	~1.9	~2.2	~1.7	~1.0	~1.8	~2.2	~1.5	~0.6
		1.0	~1.3	~1.7	~1.3	~1.0	~1.3	~1.7	~1.3	~0.8
324	Left	0.5	~2.0	~4.8	~3.9	~1.4	~1.4	~3.2	~2.1	~0.9
		1.0	~1.3	~3.7	~3.1	~2.0	~1.0	~2.3	~1.8	~1.0
	Right	0.5	~1.6	~2.3	~1.8	~0.7	~1.5	~2.2	~1.7	~0.6
		1.0	~1.0	~1.9	~1.8	~1.1	~0.9	~1.7	~1.6	~0.9
325	Left	0.5	~4.3	~8.6	~7.7	~1.0	~2.1	~4.5	~3.5	~1.5
		1.0	~2.8	~7.6	~7.0	~4.4	~1.4	~3.4	~2.9	~2.1
	Right	0.5	~1.1	~2.1	~1.7	~0.7	~1.1	~2.0	~1.6	~0.5
		1.0	~1.2	~1.9	~1.7	~1.0	~0.9	~1.7	~1.5	~0.9

Table 4. Plastic zone Width – Tender & Final Design

Cross Section	Tunnel tube	k_o	Tender Design – Plastic Zone Width (m) – Crown	Sides	Floor	Final Design – Plastic Zone Width (m) – Crown	Sides	Floor
320A	Left	0.5	~0.0	~5.0	~0.0	~0.0	~2.7	~0.0
		1.0	~0.5	~4.8	~4.3	~0.6	~2.2	~3.0
	Right	0.5	~0.0	~3.5	~1.8	~0.0	~3.7	~1.5
		1.0	~0.0	~3.2	~3.0	~0.0	~3.4	~1.2
324	Left	0.5	~0.7	~3.5	~1.1	~0.0	~2.6	~0.0
		1.0	~2.5	~2.5	~3.7	~0.0	~2.3	~2.4
	Right	0.5	~0.0	~3.5	~1.3	~0.0	~3.2	~1.2
		1.0	~1.7	~1.8	~1.5	~1.6	~2.4	~1.0
325	Left	0.5	~3.5	~6.0	~1.2	~1.0	~5.0	~0.0
		1.0	~4.0	~6.0	~5.3	~2.2	~2.9	~3.5
	Right	0.5	~0.0	~4.5	~1.1	~0.0	~3.8	~1.1
		1.0	~1.9	~2.9	~1.6	~1.3	~2.9	~1.5

Capacityofsupport – analysisof cross-sectional forces and stresses

Due to limited length of the paper, cross-sectiona forces and stresses are presented in Tables 5 and 6 for only one profile – 320A, for both tunnel tubes and for k_0=1, [8].

Table 5. Section 320A, Left tube,Tender design and Final design, ko=1.00.
Comparison of Max. stresses at the internal and external side of shotcrete

	N (kN)	**M (kNm)**	**Q (kN)**	**Shot. Thick. (m)**	**σ_{ci} (MPa)**	**σ_{ce} (MPa)**
Tender	340.9	19.2	17.7	0.15	**7.39**	-2.84
	531.3	-16.5	-14.4	0.15	-0.86	**7.95**
Final	384.1	18.3	18.9	0.25	**3.29**	-0.22
	239.9	-68.1	-48.1	0.25	-5.58	**7.50**

Table 6. Section 320A, Right tube, Tender design and Final design, ko=1.00.
Comparison of Max. stresses at the internal and external side of shotcrete [4]

	N (kN)	**M (kNm)**	**Q (kN)**	**Shot. Thick. (m)**	**σ_{ci} (MPa)**	**σ_{ce} (MPa)**
Tender	677.9	9.9	10.9	0.15	**7.16**	1.88
	814.8	-13.0	-9.7	0.15	1.97	**8.90**
Final	679.6	16.0	16.0	0.20	**5.80**	0.99
	602.7	-20.1	-27.6	0.20	0.00	**6.03**

Due to changes of input parameters and obtained results for cross-sectional forces, stresses and deformation quantities (displacements, width of plastic zones) the corresponding changes of support types and support elements are made. Changes of types of supports are not presented in this paper.

CONCLUSION

The paper present a concise analysis of causes and consequences of changes in technical documentation during construction works. This is ilustrated by example of the justified changes in technical documentation of the tunnel Sarlah and the following is pointed out:

- Displacements at the soil surface are greater when tunnel supports are calculated using parameters obtained from the tender documentation with respect to displacements obtained when supports are changed due to parameters from additional investigations. Some dispalcements obtained from tender documents may cause negative consequences at the soil surface.

- Plastic zones which are formed in the case of supports obtained by tender documents require wider area around tunnel when compared to plastic zones in the case of supports due to additional investigations. It should be pointed out that in some cases anchors, as support elements, are not long enough outside of the plastic zone.

- Values of stresses at the inner and outer side of shotcrete concrete support are substantially higher acording to analysis due to tender documents.

As a result of the previous discussion the change of support type is inevitable.

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