AUSTRIAN PRACTICE OF TUNNELING CONTRACTS

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DEALING WITH UNCERTAINTIES

- The geological model and the design contain uncertainties. In the design all expected behaviours should be considered, and construction methods assigned to each ground behavior and local requirements
- Even with very good investigation and design the exact distribution and location of the different behaviours will not be known prior to construction
- If using the observational approach with adjusting the construction to the actual ground conditions, the final quantities and construction time will differ from the tender estimate in most cases
- Construction contracts thus should contain appropriate stipualations dealing with those uncertainties, allowing a fair compensation of the work done

RISK SHARING

- It is commonly accepted that the so called geological risks are with the owner. This means that additional costs or benefits due to the deviation in the geological conditions from the predicted ones are the responsibility of the owner
- The contractor bears the risk of construction performance, quality and safety
- This sounds rather simple, but in practice has a few pitfalls, as design may be adjusted during construction to better suit actual ground behaviours
- To keep claims and discussions on compensation at a low level, the construction contract should contain clauses dealing with those minor variations

EXAMPLE

- The designer for a blocky rock mass has specified the support to consist of, say 20cm reinforced shotcrete, lattice girders, and 8 grouted bolts per round of 2m.
- During construction it shows that blocks in general are well interlocked, and the probability of block falls is not too high. It is thus decided to omit the lattice girders, and change the bolting to 6 grouted bolts plus 3 friction bolts to keep potential failing blocks in place
- The contractor might claim, the change in the support causes a lower performance, etc.

OWNER TRYING TO AVOID RISK

- Owners have a tendency to shift risks to the contractor. This leads to lump sum contracts with fixed time schedule or other regulations
- Usually the contractor has even less knowledge about the ground conditions than the owner, making it difficult to estimate the involved risk from the variations in geological conditions. He has two options:
  - Estimate geological risk on the conservative side, thus reducing his chances to win the tender due to high price
  - „Forget" the geological risk, and hope to claim additional costs during and after construction
- View of the owner: in the first case he might be paying too much, in the second case he will be confronted with endless discussions and even law suits

OWNER TRYING TO AVOID RISK

- With design-construct contracts usually detailed site investigation and design is responsibility of the contractor
- As contractors are bound to earn money, they are reluctant to invest reasonable sums into investigation and design
- Designers often forced to focus rather on easy to construct or profitable solutions, than on technically sound ones
- Case histories show when quality assurance is also left to the contractor, troubles are practically unavoidable

AUSTRIAN CONCEPT

- Unit price contracts
- Special regulations for time dependent costs allow for fair compensation also in cases where design is modified during construction or ground conditions deviate from the predicted
- Austrian standard ON B2203-1 shows the concept of the contract setup (will be published in English end of 2008)

AUSTRIAN CONTRACT

- Based on the investigation typical excavation and support methods are designed for the range of expected behaviours
  - The distribution of expected construction measures is shown on a baseline construction plan
  - Contractor estimates time requirement for typical combinations of excavation and support. This serves as a basis for the compensation of the construction time (theoretical construction time)
  - To allow for modifications of support during construction, equivalent time requirement for each support element is assigned
  - Materials installed are paid on a unit price basis
- Excavation classes are determined on the basis of round length and equivalent support rating

TIME RELEVANT RATING OF SUPPORT

Support elements and additional measures		Rating value per unit	unit
Bolts	Friction bolt (Swellex or equivalent)	0,8	m
	Grouted bolt	1,1	m
	Self drilling bolt	1,7	m
	Grouted tube bolt	2,0	m
	Prestressed grouted bolt	2,5	m
Face bolts	Number of bolts in face	8,0	pc
	Installation of face plate	1,7	pc
	Installation of face plate and pretensioning	5,0	pc
Forepoling	Driven forepoles	0,5	m
	Non-grouted bars	0,6	m
	Grouted bars	0,9	m
	Self drilling forepoles	1,3	m
	Grouted tube forepoles	1,6	m
Grouting in excess of 10 kg per bolt, forepole or foot pile		0,1	kg
Wire mesh	Outside with steel arch	1,0	m²
	Inside with steel arch	1,5	m²
	Outside without steel arch	2,0	m²
	Temporary invert	0,8	m²
	Additional mesh, face	2,0	m²
Steel arches		2,0	m
Shotcrete	Top heading and bench	20,0	m³
	Top heading invert, elephant foot	12,0	m³
	face	14,0	m³
	Filling of overbreak	14,0	m³
Deformation slots	Without ductile elements	3,5	m
	With ductile elements	5,0	m
Lagging		5,5	m²
Foot pile	Foot pile Ø< 38 mm	4,5	m
	Foot pile Ø> 38 mm	5,0	m
Partial excavation		22,0	pc
Excavation elephant foot		50,0	m
Demolition of temporary invert		50,0	m

Austrian standard B 2203-1

DETERMINATION OF EXCAVATION CLASS

- For the support elements installed the respective weighting factors are applied, those are summarized and then divided by the face area. A support number is the result
- The range of round length forms the first organizing number of the matrix, while the normalized support number forms the second organizing number.
- To the support number evaluated a tolerance is added

EXAMPLE FOR EVALUATION OF SUPPORT NUMBER

	height top heading (m)			5				
	Rating area top heading (m2)			47,7				
Top heading	round length 1.3 m first ordinal number = 6							
Support	per lin m	unit	thickness / length	unit	quantity/m	unit	rating factor	rating
shotcrete	16,60	m2	0,25	m	4,15	m3	20	83,00
face shotcrete	28,00	m2	0,10	m	2,80	m3	14	39,20
invert shotcrete	11,00	m2	0,20	m	2,20	m3	12	26,40
Exc. elephant foot	1,00	m2	1,00	_	1,00	m3	50	50,00
wiremesh 1st layer	16,60	m	1,00	m	16,60	m2	1	16,60
wiremesh 2nd layer	16,60	m	1,00	m	16,60	m2	1,5	24,90
wiremesh invert	11,00	m	1,00	m	11,00	m2	0,8	8,80
wiremesh face	2,10	m	1,00	m	2,10	m2	2	4,20
steel arch	12,77	m	1,00	_	12,77	m	2	25,54
spiles grouted	18,00	units	3,00	m	54,00	m	0,9	48,60
grouted bolts	4,61	units	4,00	m	18,44	m	1,1	20,28
grouted bolts	1,54	units	6,00	m	9,24	m	1,1	10,16
							sum	357,68
support number =2nd ordinal number= rating sum/rating area								7,50
	applies for tunnelling class top heading					6/7,50		

EXCAVATION CLASS MATRIX

First ordinal number	Round length up to: Top heading or top heading + bench	Round length up to: bench	Second ordinal number / Normalized support rating: 1	2	3	4	5	6	7	8	9	
1	No limit	Project specific definition										
2	4,0m											
3	3,0m											
4	2,2m				▲ 4/2,4	▲ 4/3,6						
5	1,7m						▲ 5/4,5		▲ 5/6,1			
6	1,3m							▲ 6/5,5		▲ 6/7,5		
7	1,0m											
8	0,8m											
9	0,6m											

CONTRACTUAL CONSTRUCTION TIME

- For each of the excavation classes shown in the matrix, the contractor provides a performance (m/day). This is the basis for the contractual construction time, and for the compensation of the time dependent site costs
- The risk of the contractor is his performance. In case his performance is better than originally estimated/guaranteed he is still paid for the contractual construction time. He does not get more when his performance is below the guaranteed value

EXAMPLE

- The tunnel has a length of 1000 m. Following excavation classes have been provided in the tender, and the contractor has filled in the progress in each class. With the distribution of the classes as tendered, the total (tender) construction time is evaluated

Excavation class	Contractual progress (m/d)	tendered length (m)	construction time (d) (tender)
3/4,6	10,2	80	7,84
3/6,2	9,6	70	7,29
4/6,5	8,4	300	35,71
5/8,1	7,5	60	8,00
6/8,2	6,8	70	10,29
6/9,6	6,4	160	25,00
6/10,4	5,8	90	15,52
7/12,4	4,0	100	25,00
7/16,2	3,0	70	23,33
		total days (tender)	157,99

EXAMPLE

- During construction it is found that the distribution of the classes is different from the tender. The contractual construction time is evaluated based on the actual distribution with the fixed contractual progress rates

Excavation class	Contractual progress (m/d)	tendered length (m)	construction time (d) (tender)	actual length (m)	construction time (d) (contractual)
3/4,6	10,2	80	7,84	80	7,84
3/6,2	9,6	70	7,29	130	13,54
4/6,5	8,4	300	35,71	160	19,05
5/8,1	7,5	60	8,00	70	9,33
6/8,2	6,8	70	10,29	0	0,00
6/9,6	6,4	160	25,00	70	10,94
6/10,4	5,8	90	15,52	250	43,10
7/12,4	4,0	100	25,00	50	12,50
7/16,2	3,0	70	23,33	190	63,33
		total days (tender)	157,99	total days (actual)	179,64

CONCLUSION

- Based on the actual distribution of excavation classes, the contractor is paid about 20 days more in time dependent costs
- This is independent of his actual performance
- The method allows that the owner compensates the increased time demand due to geological conditions different from the tendered scenario, while the contractor is responsible for the performance
- There are also regulations how to extrapolate contractual construction times, in case a "new" class has to be developed during construction
- The system is extremely flexible and prevents practically all disputes on changed conditions