Austrian Standards ÖN B2203-1 and -2 for Underground Works

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Die Österreichischen Normen ÖN B2203-1 und -2 für Untertagearbeiten

Während eine anpassungsfähige Tunnelbauweise den Planenden eine Fülle von Möglichkeiten bietet, den Vortrieb und die Stützung den erwarteten vielfältigen Verhaltensformen des Gebirges anzupassen, wird diese Flexibilität für die Preisbildung und Abrechnung der Leistungen meist zu einem Problem. Stellt man zusätzlich die Forderung der Objektivierbarkeit und Nachvollziehbarkeit der Kalkulation und der Abrechnung, so wird das Problem zusätzlich verschärft.

Um diesen Anforderungen gerecht zu werden, wurde bei der Neufassung ÖN B2203-1 im Jahr 1994 ein vollkommen neuer Weg der Vortriebsklassifizierung – nämlich der zahlenmäßigen Bewertung des Stützmittelaufwands und der Abschlagslängen für die Kalotte und Strosse – eingeschlagen. Für die Sohle erfolgt die Vortriebsklassifizierung nach der Öffnungslänge und der Ausbauart (offene Sohle, Sohlplatte, Sohlgewölbe) ohne zahlenmäßige Bewertung.

Die neue ÖN B2203 wurde in Österreich in den acht Jahren seit dem Inkrafttreten bei 15 Eisenbahn- und Straßentunneln angewandt. Es kann daher festgehalten werden, dass das Ziel der neuen ÖNORM, nämlich objektivierbare und nachvollziehbare Grundlagen für die Kalkulation und Abrechnung zu schaffen, erreicht werden konnte.

Teil 2 der neuen ÖNORM für TBM-Vortriebe baut auf der vorgängig erarbeiteten Norm für konventionelle Vortriebe auf. In wesentlichen Punkten betritt sie aber echtes Neuland. Die Neuerungen betreffen insbesondere die Definition der Vortriebsklassen, die wie in Teil 1 in Matrixform dargestellt werden, aber teilweise auf anderen Parametern basieren, und die Formulierung von Abrechnungsregeln für Ausbruch, Ausbau sowie Erschwernisse, Zusatz- und Sondermaßnahmen. Es wird erwartet, dass die neue Norm bei den für die nächste Zeit in Österreich geplanten Eisenbahntunneln ihre erste Anwendung finden wird.

Flexible tunnelling methods allow a wide range of in applicable methods of excavation and support for a wide range of rock mass behaviours. This flexibility often creates problems with respect to pricing and payment regulations. Together with the demand that the measuring and cost compensation rules should be comprehensible and objectively comparable, the problem becomes even more complex.

To meet these requirements, the ÖN B2203-1 introduced a completely new approach to classify excavation – namely a numerical evaluation of the amount of support and the round length for top heading and bench. The excavation class for the invert is determined by the round length and on the type of support (open invert, invert slab or invert arch).

In the eight years since its enforcement, the new ÖN B2203 has been used in 15 railway and road tunnels in Austria. It can therefore be stated that the objectives of the new Standard, that is, to create an objective and reliable basis for cost estimation, measuring and compensation have been reached.

Part 2 of the new ÖNORM is about TBM tunnelling and is based on the above mentioned standard for conventional excavation. A new approach is taken, however, in major points. The novelties in particular concern the definition of excavation classes, which are displayed as a matrix similar as in Part 1, and the formulation of rules for measuring and compensation of major items like excavation, support, hindrances, and difficulties, additional and special measures. It is expected that the new standard will be applied for the first time to the railway tunnels planned in Austria over the next few years.

Part 1 – Conventional tunnelling

Introduction

Adaptable tunnelling methods provide a number of possibilities for adjusting tunnel excavation and support measures to a wide field of ground behaviour. This flexibility generally poses pricing and compensation problems. Where objectification and accountability are demanded in quotes and accounts, the problem is further aggravated. To meet these demands, an entirely new approach to the classification of excavation was chosen with the Austrian Standard ÖN B2203 of October 1994 (1, 2). After six years of experience some adaptations were necessary and a revised standard was worked out and went into effect with beginning of December 2001.

Main features of the "Classification of excavation"

Achievable performance, and with it also the costs of conventional tunnelling, mainly depend on round lengths and the amount of support installed. Performance is also influenced by the subdivision of the cross-section and the rock mass behaviour.

The excavation classes of top heading and bench are defined by two characteristic values. On the one hand by round length and on the other hand by the support factor (sf), which reflects the influence of supporting measures on the advance rate.

Supporting measures include various types of support, each of which influences excavation progress in a different degree. An evaluation of individual supporting measures was thus necessary.

The rating factors (rf), a dimensionless quantity per support unit, indirectly reflects the time needed for installation. The rating factors were evaluated from back analysed cases of tunnels in Austria and abroad. Prior to the standard taking effect, the factors were verified in a number of projects. These factors do not claim to be a true measure of the time actually needed for implementation; they rather reflect the relative influence of different support types and quantities on tunnel excavation.

As an example, shotcrete has a rating factor (rf) of 20.0/m³ and SN anchors a factor of 1.1/m. The product of rating factors (rf) and planned/implemented quantities of supporting elements per linear meter of tunnel (sq) per rating area (ar) yields the so-called support factor (sf).

$$sf = \frac{\sum sq \cdot rf}{ar}$$

The calculation of the rating area is defined in the standard according to the subdivision of the cross-section (top heading, bench, full face).

Round lengths and support factors (Figure 1) are mapped to a matrix to yield the excavation class. Because point by point entries in the matrix would lead to an infinite number of classes, round length ranges are defined and support factors are delimited by a tolerance of ± 0,35 to ± 2,1 , depending on the round length. This ensures that minor deviations in round lengths or quantities of support elements do not immediately result in a change of excavation class.

maximum Round Length		SUPPORT FACTOR (sf) 1,0	2,0	3,0	4,0	5,0	6,0	7,0	9,0	
1	no limit									
2	4,00 m									
3	3,00 m									
4	2,20 m									
5	1,70 m			3,4			5,0			
6	1,30 m									
7	1,00 m									
8	0,80 m									
9	0,60 m									
10	0,45 m									

Fig. 1 Excavation Class Matrix.
Bild 1 *Vortriebsklassenmatrix.*

Implementation of excavation classes

On the basis of geological and geotechnical studies, the designer subdivides the rock into rock mass behaviour types (3) and develops models to calculate support measures and round lengths. Necessary or meaningful empirical or numerical analysis must also be taken into account. Different excavation methods and sequence of excavation steps will demand a further subdivision, which means separate matrices or designations. The classification thus encompasses all excavation and support influences. Other factors influencing excavation performance, such as water problems, are not considered in the excavation class but are separately compensated.

Because the excavation time depends on the actually realised excavation classes, and the time-dependent site costs in turn depend on this, the bidder supplies a daily excavation rate for each tendered top heading excavation class. This contractually agreed rate and the actually realised distribution of the excavation classes yield the contractual excavation period, which forms the basis for payment of time-dependent site costs.

During excavation, excavation classes are not, as may incorrectly be assumed, prescribed. The contracting parties agree jointly on the necessary measures (round lengths, type, positioning and quantity of supporting measures) on site. Only after this mutual agreement has been reached, the measures are correlated to excavation classes and hence to prices.

Other topics of B2203-1

The standard gives detailed regulations for the measurement and payment of over-excavation, deformation tolerances, and influence of groundwater, calculation of payable construction period and for inner lining.

Project overhead costs

With these costs, both parts of the new ÖNORM follow the well established Austrian practice of providing separate items for all time-dependent costs like salaries or wages and the equipment costs.

The continuous tunnelling with TBM requires another subdivision. The draft provides to capture the one-time costs as well as the time-dependent costs of the TBM system in separate items. In addition, the time-dependent costs and the equipment costs must be subdivided in accordance with construction progress into the following phases:

- Phase 1 Start of construction to start of excavation,
- Phase 2 Excavation,
- Phase 3 Additional charge for excavation with simultaneous lining,
- Phase 4 Lining after contractual end of excavation,
- Phase 5 Work after excavation and lining.

Fixed time limits must be agreed for Phases 1 and 5 and, if permitted by the conditions, also for Phase 4, for which lump-sums may be laid down for compensation.

Variable times must be agreed for Phases 2, 3 and, if circumstances require, for Phase 4. Tenders must include information on the advance rates for different excavation classes.

For idle periods, separate items must be provided for project overhead costs and time-dependent equipment costs per heading respectively per TBM system.

Construction time model

For determining the construction time, the construction schedule must be described and a so called construction time model must be given. Overlaps must be taken into consideration if there are several simultaneous headings for one project or other underground or surface construction works undertaken simultaneously. Mutual dependencies and the critical path must be described.

Conclusion

The introduction of a precise evaluation procedure for establishing excavation classes was a completely new approach in Austria. Initially it was subject to scepticism by clients, contractors and designers. Eight years of experience with the new standard on a considerable number of sites have shown a few shortcomings, but confirmed the essential quality of the approach.

It can therefore be stated that the objective of the standard ON B2203-1, namely to create an objective and accountable basis for cost estimate, measurement and compensation has been successfully achieved.

Part 2 – TBM-tunnelling

Range of application

Part 2 of the new Austrian standard for underground works deals with TBM tunnelling. In contrast to the prior issue of 1994, the range of application was extended to all kinds of underground work with continuous excavation in which the tunnel can be entered by man. The main fields of application are TBM excavation in solid rock and shield driving in soil. The standard also applies to tunnels lined by pipes as long as they are accessible by man. Tunnels not accessible by man (microtunnels) and tunnels built by open cut methods are not subject of the standard.

Novelties

Even while a large part of the contents was adopted from Part 1 with only details being adjusted or supplemented, some chapters such as the one on excavation classes had to be prepared more or less from scratch. The same applies to the chapters on support measures and on segmental linings.

In accordance with the objective of the standard on contractual rules, the notes on describing the geological situation of the 1994 issue were discarded just as in Part 1. That topic is now dealt with in a separate guideline on the geotechnical planning of underground works with TBM. That guideline is produced parallel to the contract standard. A separate guideline was prepared dealing with matters of planning (7). It will come into force soon as RVS 9.251 for road tunnels (4) and in similar form also for railway tunnels.

Definitions

In addition to the (already mentioned) adaptation of the texts of Part 1 to the conditions of excavation by TBM, considerable emphasis has been placed on the selection and description of the expressions used. Similar to the two DAUB recommendations for the selection and evaluation of tunnel boring machines (5) and for the design and operation of shield machines (6), it has been tried – hopefully with success – to harmonise the expressions common in rock tunnelling with those mostly used in shield driving. In addition, a number of new expressions were introduced, such as the tunnel section. The latter is defined as: "*Subdivision of a tunnel into sections for which geological properties concerning advance rate, wear etc. can be expressed by a common distribution curve, and which therefore display similar cost structures. Tunnel sections may also be determined by other conditions, such as matters of construction management or different system behaviour*".

The expression "tunnel section" replaces the older, frequently used designation of "homogeneous section", which was criticised by various parties for good reason.

Excavation classes

The tunnel must be subdivided into sections in accordance with the above criteria and those sections must be divided into excavation classes. Just like in Part 1, these excavation classes are characterised by two sub-groups.

The first sub-group (tunnel section) is defined depending on the excavation behaviour (type of rock, minerals, degree of fracturing etc. or penetration, wear etc.). Further subdivisions are possible, taking into account rock mass behaviour and matters concerning construction management.

The second sub-group deals with the type and extent of the measures determining the performance of the TBM system. With open TBMs or gripper TBMs, the criterion for the 2nd sub-group is the support factor. That figure results from the type, extent and location of installation of the support measures used per linear meter of tunnel. Values for each of these items are given in a table contained in the standard. They are normalized to the planned cross-section. If very different support measures lead to equal values there must be further subdivision by the prevalent type of support measure.

For shield TBMs used in solid rock, the second sub-group is determined by the features determining the performance of the advance system used. These could be:

- Gripper respectively support system,
- Lining system,
- Face support method.

For Shield Machines used in loose rock, the following criteria are considered sensible from a system-specific point of view:

- Type of segment, as far as it influences advance rate,
- Excavation method (type of face support),
- Mode of operation (open, closed).

Bill of quantities

Excavation

The tender documents may offer two options:

- One item each per excavation class for wages and miscellaneous,
- One item for the wage costs of the personnel per time unit and tunnel section. The amount of time units is calculated from the offered advance rates and from the excavation classes analogously to the way time-dependent costs are determined. A separate item must be provided for the non-time-dependent "miscellaneous" component for each class.

Other rules determine the compensation for excavation work concerning that part of the excavation exceeding the planned cross section. The overbore, which includes the wear of cutters, must be included into the unit prices. Additional excavation with the objective of achieving a larger cross-section for accepting expected displacements must be laid down by the client and therefore be paid for.

Support

Segment lining must be put out to tender per linear meter of tunnel, if necessary, broken down by type of segment.

The amounts of mortar necessary for filling the system immanent annular gap can be included in the price of excavation. Alternatively a separate item may be provided. Separate compensation is paid for additional amounts required for improving the rock mass or for filling any over-excavation.

Hindrances, difficulties and additional measures

Hindrances due to water inflow are regulated per linear meter and per tunnel section and broken down by the amount of water encountered.

Rules must be provided for taking into account other difficulties such as difficult boring, high wear, mixed face conditions, occurring of blocks, which cover the reduction in performance and the increased costs for material and equipment.

Special items must be provided for additional measures such as special treatment of the ground.

Special measures and reconnaissance

Information must be provided on the purpose, the type, the time and the place of the measure, on any necessary suitability and quality examinations and – in accordance with the comprehensive principle of the refunding of time-dependent costs – on the effects on the construction time (time extension).

Conclusion

Part 2 of the new ÖNORM for TBM excavation is based on the standard for conventional excavation. A new approach is taken, however, in major points. The novelties concern in particular the definition of excavation classes and the formulation of rules for measuring and compensation for excavation, support hindrances and difficulties, additional and special measures.

It is expected that the work on part 2 of the new standard will be completed by the end of 2003 and it can be applied for the first time to one of the railway tunnels planned in Austria over the next few years.

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