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Some engineering geological problems encountered during the construction of the rock-fill dam Turček

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Abstract: The geological structure of Central Slovak Neovolcanites is very complicated. In spite of the similarity of petrographic composition of here occurring rocks, a characteristic feature of the geological structure is a considerable heterogeneity of physical conditions in rock massifs, caused by their petrogenetic and tectonic evolution. Due to this fact, all engineering activities in the above mentioned environment are connected with a number of problems and complications (different bearing value, permeability and rock material quality of various parts of rock massif). The heterogeneity of the rock environment affects especially adversely the prospects of finding a sufficient quantity of ballast, with a quality corresponding to requirements on material for rock-fill dams. The paper presents some results from geological-petrographical and, subsequently, engineering geological investigations of the andesite rock mass aimed at choice of suitable quality and quantity of the rock material for the dam of the water reservoir Turček.

Key words: andesites, physical and mechanical properties, ballast for dam, loosing of massif, discontinuity

Introduction

Any technical activity in an exceptionally heterogeneous rock environment of an autometamorphically altered andesite massif brings about a number of engineering geological problems. The range of this problems is extended and their gravity increased proportionally with the complexity of the designed technical work. Hydrotechnical constructions, consisting of a series of objects of different type and with different requirements, belong generally to the most complex technical works, having high demands on the quality of rock mass in which they should be realised, as well as on the quality of rock material, used in their construction.

The above facts were to a great extent manifested also during the investigation and the construction of the dam Turček, situated into a rock massif of autometamorphically altered andesites. Engineering geological investigation showed several controversial problems connected with the construction of the 59 m high and on the crest 285 m long-fill dam, (problems of loading capacity and impermeability of the dam underlier, problems of obtaining the required quality and quantity of rock material for the dam body etc.), as well as with the creation and operation of the reservoir itself (problems of impermeability of the bottom and slopes of the reservoir, problems of changes of reservoir banks in the selected regime of operation, prognosis of its siltation etc.). Several problems originated or were aggravated only during the construction of the water reservoir. From the indicated wide range of engineering geological problems, we shall deal with two selected groups of problems, in the solution of which the authors of the contribution were involved. They are the evaluation of quality of rock material used for the earth dam body and problems of obtaining the necessary quantity of material based on a study of massif loosening in the area of the material quarry.

Solving of the above problems was based on the results of petrographic study of the rocks, followed by their engineering geological evaluation.

Geological and engineering geological characterisation of the rock mass

The water reservoir Turček is located in Central Slovakia, east of the village Dolný Turček in Kremnické vrchy Mts. (Fig. 1). Geographically the territory belongs to the region of neovolcanites, the area of volcanic highlands.

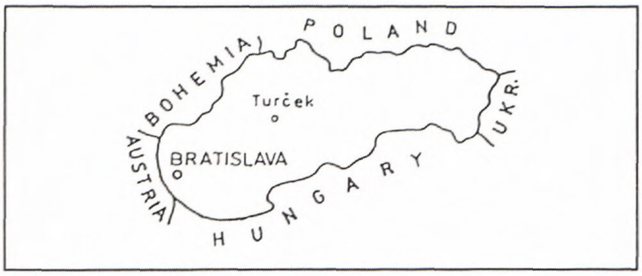

Fig. 1 Location map

The area of interest, a quarry for ballast used for the dam, occurs NE of the dam profile, partly in the area of the future reservoir. It is formed of an andesite body in the area of the elevation point Špicatá (898 m a.s.l.).

This is a considerably inhomogeneous rock environment, due to the formation mechanism of extrusive bodies, accompanying alterations of the material and tectonic activity. Simultaneously with the formation of the rock body, autometamorphic processes took place in some of its parts, especially basal ones, which, along with other factors, caused deterioration of the rock material quality. In some places there are even layers of extrusive breccias.

Detailed mapping aimed at determination of geological structure of the andesite body and distinguishing the most favourable lithologic type for use in the dam, complemented by sample collection for mineralogical, petrographic as well as engineering geologic analyses, was carried out on about 4 km^2 on the scale 1 : 2 500 (Stolár et al., 1994, Fig.2).

Geological-tectonic structure of the territory

Geological structure of the territory is formed of the Kremnické vrchy Mts. volcanic rock complex. The territory is built of three volcanic formations. The formations are covered by Quaternary fluvial and debris sediments.

The majority of the territory studied is built of the Kremnický štít Formation. From its underlier emerges the Turček Formation, covered by the Vlčí vrch Formation.

The Turček Formation is represented by denuded relics of a stratovolcano with pyroxene and basaltoid andesites, developed in the environment of the Kremnica graben. The Kremnický štít Formation, represented by amphibole-pyroxene andesites, formed successively above the previous one. The Turček and the Kremnický štít Formations are both severely tectonically affected.

The youngest volcanic formation on the territory under study is the Vlčí vrch Formation. The formation represents relics of a small basaltoid andesite stratovolcano, covering a rugged relief, formed on older rocks of the above formations. The formation is considerably eroded. The age of the described rock units is Badenian-Pannonian.

Above the volcanic formations, recent and subrecent sediments have been formed during the Quaternary, especially slope debris and alluvial ones. They are represented by bouldery sandy gravels, loamy-stony sediments and bouldery debris.

Lithologic characterisation of volcanic formations

Turček Formation

The formation occurs on the surface in a narrow belt at the elev. p. 720 m a.s.l. (Fig. 2). It is a lava flow of basaltoid andesite and pyroclastic rocks. The lava flow has a thickness of about three meters. The flow consists of bedded or irregularly cracked massive andesite, dark-grey to black in colour. The andesite is glassy. In the upper part, the flow passes into lava breccia. Pyroclastic rocks consist of dark, glassy andesite with fragment size of 5 to 50 cm (the proportion of which in the rock is 30 to 60 %). The fragments and blocks in the breccia have angular form. Between them, there is a groundmass consisting of a tuff-pumice substance.

Kremnický štít Formation

The formation occurs in the studied territory above all in the surroundings of the elev. p. 898 m a.s.l. Špicatá and elev. p. 855 m a.s.l., as well as on both sides of the brook Turiec (Fig. 2). Geological mapping revealed that the formation is represented by an extrusive body of dome flow type. This means that the extrusion passes in the upper part into a thick lava flow, tilting over towards the east and the west. The body displays tabular, sheet or block jointing. During the formation of the body, its different parts developed irregularly. This caused the formation of different structural and textural characteristics and lithologic phenomena.

Vlčí vrch Formation

The formation is represented by lava flows in the area of Šajba (Fig. 2). The lava flows are formed of massive lava in central parts and lava breccia in the basal and upper part. Their thickness reaches about 20 to 30 m. Jointing of the rock is tabular or blockwise. Lava breccias are characterised by caked porous to slaggy fragments 5 to 50 cm in size. The colour of the breccias is red to black. Groundmass of the breccia is detritic or it is completely missing.

Lava flows are formed of dark basaltoid andesite. From petrographic viewpoint the rock is ba-

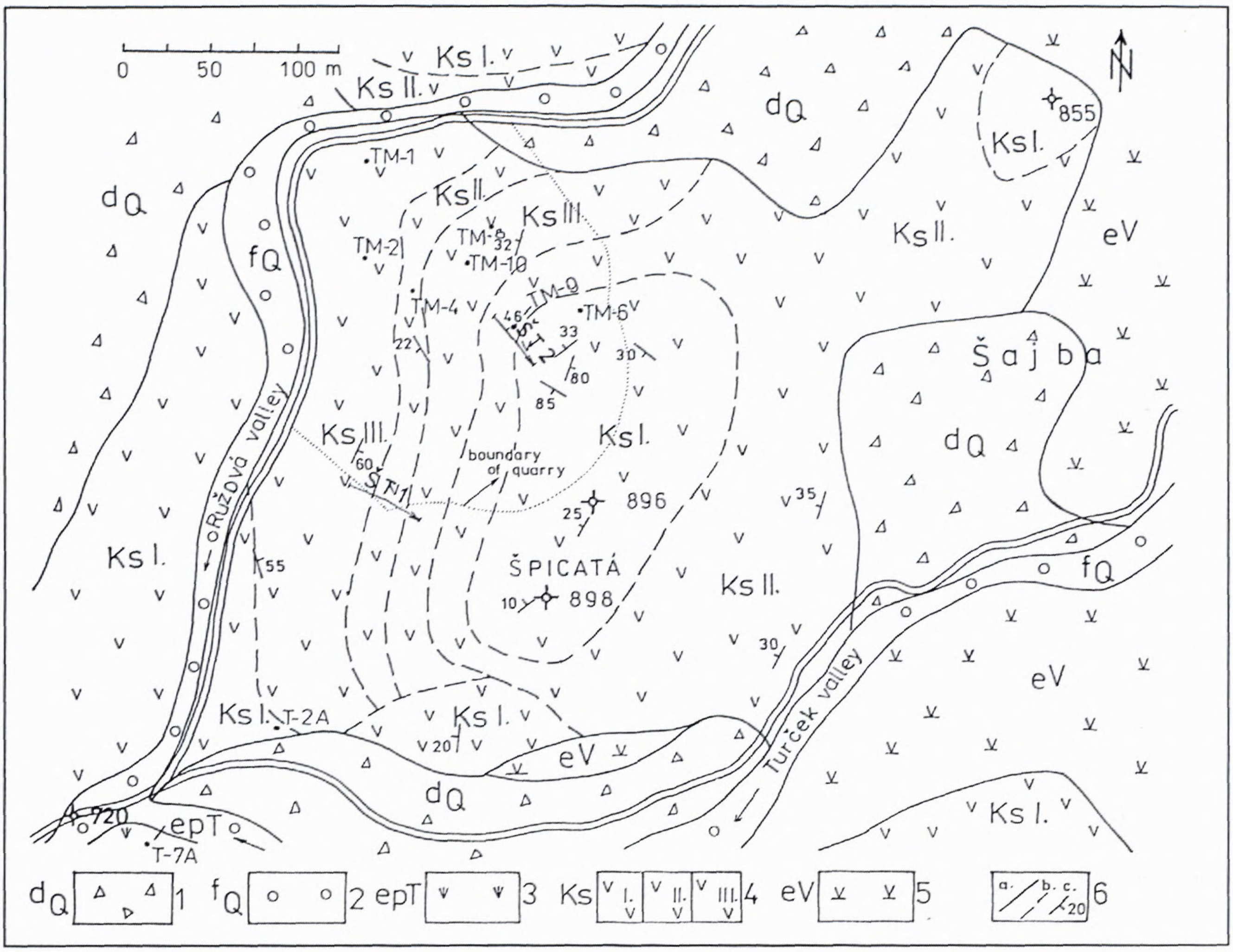

Fig.2 Geological map of the wider surroundings of the quarry of material for the dam Turček
1-deluvial loamy-stony debris, 2 - alluvial, predominantly gravelly sediments, 3 - the Turček Formation - lava flows and basaltoid andesite pyroclastics, 4 - the Kremnický štít Formation - amphibole-pyroxene andesite extrusive body: I, II, III - distinguished technologic types, 5- the Vlčí vrch Formation - lava flows of basaltoid andesites, 6 - others: a-geological boundaries, b - boundaries of distinguished technologic types, c - mode of deposition..

saltoid andesite with phenocrysts of hyperstene, augite and plagioclases. The groundmass is hyaline, composed of plagioclases and pyroxenes.

Engineering geologic characterisation of the rocks

Material quarry occurs in the rock environment of the Kremnický štít Formation (Fig. 2).

From petrographic viewpoint the volcanic body of the Kremnický štít is built of amphibole-pyroxene andesite with sporadic occurrence of biotite. Within this petrographically quasi-homogeneous rock massif we distinguished on the basis of a detailed mapping and petrographic analyses three rock types, differing significantly in their properties. Their areal extent is shown in the geological map (Fig. 2).

They are the following rock types:

Type I - fresh, unaltered andesite
Type II - transitional
Type III - porous.

Type I is represented by massive, dark-grey amphibole-pyroxene andesite, fresh, partly altered. The andesite is composed of plagioclases, pyroxenes, amphiboles and biotites. The groundmass is hyalopilitic - pilotaxic with sporadic presence of felsitic matrix (samples TM-1, TM-6, TM-9, Tab. 1). Dark minerals are relatively fresh. Amphiboles have opaquised margins.

Tab. 1 Modal composition of samples (%).

	TM - 1	TM - 2	TM - 4	TM - 6	TM - 8	TM - 9	TM - 10	T - 2A	T - 7A
plag.	25.00	18.33	20.52	25.98	15.15	21.56	21.73	18.57	32.97
px-hy	0.88		1.30	0.69	0.39	0.86	2.34	1.52	0.72
amph	5.59	2.87	8.86	8.63	2.52	12.02	5.85	7.36	1.62
bt	0.78							0.47	
dk.min.	0.49	2.18			3.69				1.26
aggr.	0.79			0.98		1.81	0.49		
mt-type1	66.47	18.84	50.40	56.67	43.10	56.40	20.37	66.82	40.00
mt-type2		57.78	18.92	7.05	35.15	7.35	41.13	5.26	23.43
pores							8.09		
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Explanations :
plag. = plagioclase,
px - hy = pyroxene - hypersthene,
amph = amphibole,
bt = biotite,
dk. min. = dark minerals,
aggr. = aggregates,
mt-type1 = groundmass hyalopilitic-pilotaxic,
mt-type2 = groundmass felsitic

Tab. 2: Principal distinguishing petrographic characteristics of the andesite types at the locality Turček

	Groundmass	Porosity	Colour	Opacitisation
type I	hyalopilitic-pilotaxitic	-	dark grey	margins
type II	hyalopilitic-pilotaxic felsitic	low	grey brown light brown	margins + sporadically areal
type III	felsitic hyalopilitic-pilotaxic	high	light, light-pinkish	margins and areally

Type II is represented by slightly porous, greyish-brown to light-brown amphibole-pyroxene andesite, slightly altered. The andesite is composed of plagioclases, pyroxenes and amphiboles. The groundmass is variable: hyalopilitic-pilotaxic and felsitic, hyalopilitic-pilotaxic predominating over the felsitic (see Tab. 1, samples TM-4 and TM-8).

Type III is represented by porous, light-coloured and light-pink amphibole-pyroxene andesite, strongly altered. It is composed of plagioclases, pyroxenes and amphiboles. The groundmass is felsitic and hyalopilitic-pilotaxic, felsitic groundmass being predominant (see modal composition in samples TM-2 and TM-10, Tab. 1). Dark minerals are areally strongly opaquised (Tab. 2).

The above distinguishing of three basic rock types conforms to engineering geological assessment of the rocks used as material for the dam. From engineering geological viewpoint, the type I rocks have high strength, rocks of the type II high to medium and the rock type III is classified among rocks with medium to low strength.

When describing the rock massif from engineering geological viewpoint, type I andesite may be characterised by tabular, less frequently banket bedding, which, together with irregular, vertical discontinuities, causes tabular jointing and blockiness of the rock, the blocks being of medium size. The blocks and fragments are characterised by sharp edges.

The massif with occurrences of type II and III rocks is usually characterised by irregular discontinuities, without significant ordering into systems, resulting in predominantly polyhedral blockiness, with blocks of small to medium size.

Engineering geological assessment of the rock material and massif in the area of material quarry

As already mentioned in the introduction, from the wide range of engineering geological problems connected with the construction of the water reservoir Turček, we aimed our attention at specific problems of assessing the quality of rock material for the dam and evaluating of massif loosening in the quarry. We base this on the conclusions of basic geologic mapping and petrographic analyses.

Assessment of the quality of rock material used in the rock-fill dam body

The considerably variable character of the amphibole-pyroxene andesite corresponding to various grades of its autometamorphic alteration is reflected quantitatively also in the values of characteristics describing physical state of the rock. They are above all the values of some physical and mechanical rock material properties (above all density, porosity, absorption capacity, uniaxial compressive strength and several others). Marked differences in these properties in different rock types have been pointed out already by authors of previous engineering geological investigations in the area of designed water reservoir, when analysing the possibilities of using the rock ballast as construction material. JADROŇ (1971) distinguished in the wider area of the water reservoir three andesite types (I - pyroxene-biotite-amphibole andesite, medium to high-metamorphosed, II - pyroxene-biotite-amphibole andesite, low-metamorphosed, and III - andesite agglomerate) and he presented the ranges of selected rock material properties from the viewpoint of its use as construction rock ballast. DOMANICKÝ (1988), on the basis of investigations of the territory with material for the rock-fill dam Turček, distinguished three types of construction ballast (I - dark grey amphibole-pyroxene andesite, unaltered, II - pinkish-red autometamorphically altered amphibole-pyroxene andesite, and III - tuff-breccia) characterised by selected physical and mechanical properties.

Assumptions of strong heterogeneity of the massif in the area of construction ballast deposit were confirmed after the opening of the quarry in the year 1993. In the highest part of the massif (below the elevation points Špicatá and 896 m a.s.l.), in the area of benches 1 and 2, partly also 3, there was relatively fresh, dark-grey andesite . Starting with bench 3, the character of rock material significantly deteriorated - in the area of benches 4, 5 and 6 predominated andesite of various alteration grade, porous, predominantly grey-brown in colour. From bench 5 and, above all, at bench 6, layers of porous, light-pink andesite, frequently totally disintegrated, of sandy character, occur significantly. At the foot of the slope, at bench 7, a body of relatively fresh, dark-grey andesite was exposed. The alternation of different andesite types from level 3 to the foot of the slope is very irregular.

The character of rock material in the quarry has been evaluated from the viewpoint of possible use as construction material for the rock-fill dam body independently by workers of the Dionýz Štúr Institute of Geology Bratislava (GÚDŠ) and Faculty of Natural Sciences, Comenius University (PriF UK), Bratislava. On the basis of field inspection and mapping of the exposed quarry area they came in both cases to the same conclusion regarding the classification of rock material in 3 basic technologic types, differing significantly in their physical state. Each of the distinguished types has been characterised by physical and mechanical properties, important from the viewpoint of its use as material for the rock-fill dam. The determined values of properties of basic three technologic andesite types occurring in the area of material quarry are summarised in Tab. 3.

From the comparison of the results of petrographic analyses (Tab. 1, 2) and physical parameter values (Tab. 3), a relationship between the mineral composition and properties of the distinguished three rock types may be inferred. Absorption capacity belonging to basic characteristics of physical state of rock material was determined (results of GÚDŠ) under specific conditions by permanent boiling of the samples during 3 hours, determining thus the active porosity values. The determined values (Tab. 3) correlate well with values of porosity, indicating good communication of the

Tab.3 Physical and mechanical properties of the three technologic types of andesite

Authors	Dionýz Štúr Instute of Geology			Faculty of Natural Sciences		
Properties	I	II	III	I	II	III
specific density ρ_s [kg.m^{-3}]	2664 (3)	2663 (2)	2633 (2)	2680-2700 2690 (3)	2670-2680 2670 (3)	2660-2680 2670 (3)
bulk density ρd[kg.m^{-3}]	2381 (3)	2228 (2)	2003 (2)	2450-2580 2518 (11)	2080-2490 2397 (27)	1900-2370 2195 (26)
porosity n [%]	10,63 (3)	16,28 (2)	23,93 (2)	6,4	10,3	17,8
saturation N [%]	4,01 (3)	6,46 (2)	11,22 (2)	0,85-1,59 1,19 (11)	0,86-6,76 2,56 (26)	1,67-12,4 5,48 (26)
Na_2SO_4 [%] 10 cycles				0,9-2,75 1,57 (5)	16,77-100,0 86,53 (20)	19,63-100,0 86,76 (18)
point load $Is_{(50)}$ MPa				1,64-6,31 3,98 (23)	0,8-5,48 2,64 (37)	0,65-2,51 1,53 (37)

Explanations
$x_{min,} - x_{max}$,
x_{aver} *(frequency)*

Tab.4: Required properties of rock material for rock-fill dams

Authors	Properties of rock material			
	ρ_d [kg.m^{-3}]	N [%]	Na_2SO_4 [%]*	σ_c[MPa]
ESMIOL (1968)	2750		5	
Rip-rap comm. USBR (1970)	2500		10	
ONDRÁŠIK (1976)	> 2500	> 1,8	5 - 10	
MENCL (1966)				70

**The test with 5 cycles*

pores. In the case of gradual frost penetration into type I andesite, we may expect equalisation of pressure due to ice crystallisation. Andesites of the type I are fresh, or only partly altered, porosity of the above rocks is syngenetic. Andesites of the types II and III are also characterised by predominantly syngenetic porosity, however, reaching considerably higher values. At the same time it is important to know that autometamorphic alteration processes did not lead to the formation of a significant proportion of clayey minerals (up to 1%). According to ČABALOVÁ (1978) and other authors, the presence of clayey minerals has negative effects on the resistance of altered volcanic rocks to weathering.

When comparing the rock material characteristics with criteria required by various authors for rock dams (Tab. 4), we come to the conclusion that material of the types II and III is for this use unsuitable. Subsequently to these findings, the project of dam body construction has been adjusted. The surface of the more requiring water-front side is constructed of imported granitoid rocks. The surface parts of the crest of dam as well as its air-exposed side are built of highest-quality technologic andesite (type I). The dam body itself is zoned, with various per cent proportion of technologic andesite of the types II and III in the zones. The qualitatively most unsuit-

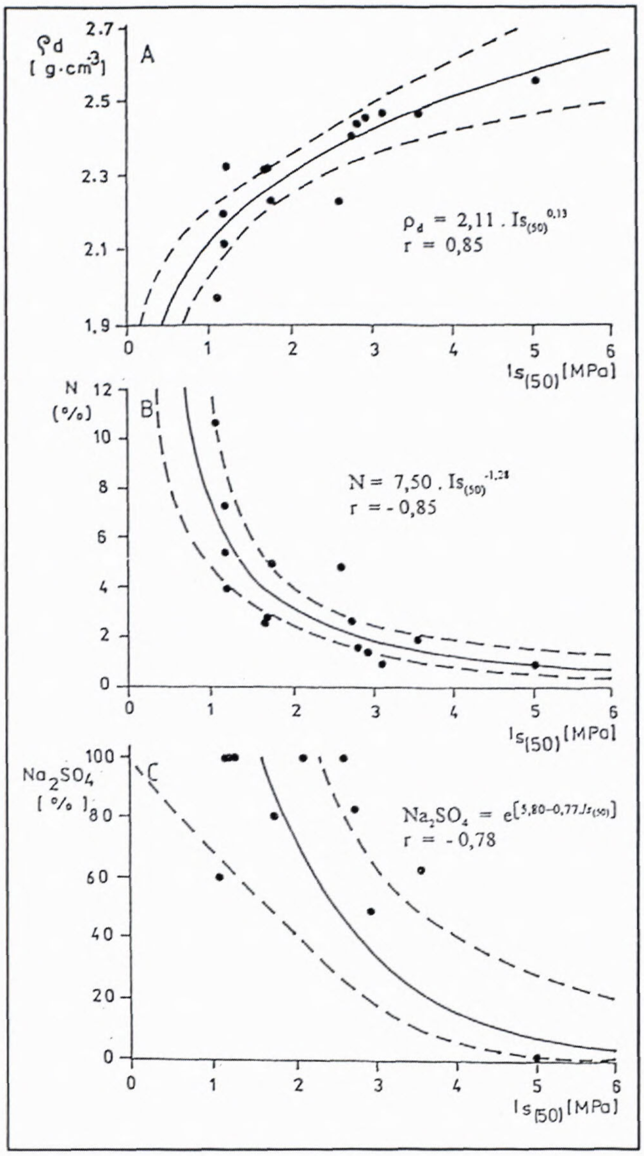

Fig. 3 Correlation between the strength index at point load $I_{s(50)}$ and bulk density ρ_d (A), absorption capacity N(B) and resistance to weathering in Na_2SO_4 solution (C). Dashed lines are restricting a reliability zone along the regression line with the probability of 95% (after HYÁNKOVÁ, SZABO, WAGNER, 1994). Each correlation is provided with a relationship corresponding to the highest value of the correlation coefficient r.

able material (andesite II : III ratio 5 : 5 to 3 : 7) occurs in the core of the dam body.

At mining of the rock ballast it is unavoidable to asses the qualitative classification of different charges (blasted rock) according to distinguished technologic types and to place them according to this into corresponding zones of the dam body. Physical state of the rocks is most accurately characterised by physical properties (density, porosity, absorption capacity), or by the results of special technologic tests (e.g. resistance against weathering tested by sodium sulphate). Their determination is however time-consuming and during mining practically not applicable. Therefore, such properties of rocks have been looked for, the determination of which is rapid and easy and the results of which are well correlable with the values of properties characterising the physical state of rocks.

The in such cases frequently used determination of rebound hardness using Schmidt´s hammer did not prove to be applicable in the very heterogeneous environment of altered andesites. Considerably more reliable results have been obtained by point load test. The test was carried out on samples of various technologic types of andesite, on which there were simultaneously determined physical properties. The obtained results show high correlation between point load strength, bulk density, absorption capacity and partly also resistance against weathering (saturation with sodium sulphate solution, Fig. 3). The figure shows only average values from the set of determinations, as well as point load tests. From thus deduced relationships, we can determine limit values of strength at point load, corresponding to required criteria of rock material physical properties. For example, if, for rocks used into surface parts of dam crest and its air-exposed side, we require volume bulk density of minimum 2500 kgm^{-3}, absorption capacity of approx. 1.3 % and sufficient weathering resistance, then these parameters are secured by strength at point load of above 4 MPa. Point load test may be carried out on irregular, unprepared samples (rock fragments, lumps), quickly, in great quantity, directly in the quarry. Its use makes the decisions on classification of mined parts of the quarry into required technologic rocks groups more objective and, at the same time, the test may be used also as a controlling and verifying method for the assessment of the quality of mined ballast, as well as of rock ballast incorporated into the dam body.

Calculation of rock massif loosening

Another separate problem which we attempted to solve was the assessment of rock massif loosening in the area of the exploited quarry. This problem has a practical meaning in connection with correct determination of the necessary quantity (volume) of material for the dam. High loosening of the rock massif requires mining of considerably larger quantity of material from the quarry, leading at volumes of matter necessary for the earth dam to serious economic effects.

The evaluation of the loosening of the massif is based on detailed documentation of joint parameters (above all orientation, mutual distances, width and filling). In the case of the evaluation of rock massif loosening in the area of material quarry for the dam of the water reservoir Turček, this was based on detailed documentation of discontinuities in survey galleries ŠT-1 and ŠT-2 (Fig.2). Only open discontinuities were taken into consideration. Their parameters were evaluated in accordance with the methodical manual (ONDRÁŠIK et al., 1983). In all, 296 discontinuities were selected in the gallery ŠT-1 and 95 discontinuities in ŠT-2, i.e. totally 391 discontinuities. For the calculation of loosing we used the software "PUKLINA" of the Department of Engineering Geology, Comenius University, Bratislava.

Adit ŠT - 1

The length of the gallery ŠT-1 is 90 m. The adit was in its whole length tunnelled through pink, red-brown, autometamorphically altered amphibole-pyroxene andesite (DOMANICKÝ, 1988) of the type II.

For the calculation of loosening, from available data, 296 discontinuities were taken into consideration. On the basis of evaluation of their spatial position, 9 fracture systems were distinguished.

The software PUKLINA is using the formula for the calculation of rock massif loosening (I_{rm}) according to ONDRÁŠIK et al., (1983):

$$I_{rm} = \sum I_{rmi} = \sum_{i=1}^{n} \frac{\delta a_i}{a_i + \delta a_i} .100\% \qquad (1)$$

where δa_i - is average discontinuity width in the system i,

a_i - is average distance between discontinuities of the system i,

n - is the number of discontinuity systems in a given massif volume.

For andesite of the type II in the gallery ŠT-1, the value of loosening index I_{rm} = 9.8 %.

Gallery ŠT-2

The gallery ŠT-2 had a total length of 58.8 m. According to DOMANICKÝ (1988), it cut across two andesite types:

1 - amphibole-pyroxene, dark-grey unaltered andesite (type I)

2 - pink, red-brown, autometamorphically altered amphibole-pyroxene andesite (type II)

Both types are alternating along the gallery, forming separate sections - three sections with a total length of 30.6 m (sections A, B, C) in the rock type I and two sections with a total length of 24.8 m (sections D and E) in the rock type II. The adit mouth section has not been evaluated.

The following values of loosening index I_{rm} (%) have been calculated according to the formula (1) for different sections:

A 1.9 , B 3.6, C 5.9, D 17.3, E 7.6

Average values of I_{rm} for different andesite types in the gallery ŠT-2 and general I_{rm} of the rock massif along the course of the gallery has been calculated according to the formula for the calculation of weighted arithmetic mean:

$$I_{rm} = \frac{\sum_{i=1}^{k} I_{rmi}.n_i}{\sum_{i=1}^{k} n_i} \qquad (2)$$

where I_{rmi} - is loosening index for section i of the gallery,

n - is the number of discontinuities in the section i of the gallery,

k - is the number of sections in the gallery.

For andesite of the type I, average value of the loosening index I_{rm} = 3.78 %.

For andesite of the type II in the gallery ŠT-2, average derived loosening index value I_{rm} = 12.2 %.

For andesite of the type II in both galleries, average value of loosening index calculated using the formula (2) is I_{rm} = 10.2%.

The above relatively very high values of massif loosening may be partly reduced if we take into consideration the average per cent filling of discontinuities.

Conclusion

On the basis of petrographic and engineering geologic analyses and evaluation it may be stated that the andesite body from which rock ballast for the construction of the water reservoir dam Turček is mined is characterised by marked inhomogeneity. The formation of the body by extrusion with gradual pushing of the material from the vent led to the formation of zones and layers of andesite, which differ considerably in their petrographic composition and above all development of groundmass. The variability of petrographic composition is reflected also in the variability of quality indicators of rock ballast. The qualitatively different zones are however not sharply restricted and transitions between them may be characterised as gradual, or the petrographic types are mutually mixing and alternating. The transition of the extrusive body into a "dome flow" body type in the upper part of the extrusion, with north- and south-dipping lava flows caused the formation of another rock type, with different petrographic development and thus different, more favourable quality parameters. To the contrary, the result of autometamorphic processes in the lower part of the extrusive body is alteration of minerals, causing unfavourable quality parameters of the rocks. Tectonic activity led to the formation of disintegration structures in the body.

From the viewpoint of the use of the rock ballast in the rock-fill dam of the water reservoir, as favourable may be regarded only the minimum occurrence of clayey minerals, representing the products of alteration processes. Petrographic analysis did not reveal propylitisation of the rocks. The relatively low values of absorption capacity and active porosity allow to assume considerable resistance of type I amphibole-pyroxene andesite to weathering factors. These indicators, as well as higher alteration grade are unfavourable at andesites of the type II and III. A practical result of these findings is the fact that the above technologic rock types are to be used only in those parts of the dam body where they shall not be exposed to weathering.

Calculations have shown also relatively high loosening of the rock massif in the area of the material quarry. The loosening values are significantly hogher in andesites of the technologic types II and III.

The investigations have shown the usefulness of mutually connected petrographic and engineering geological methods of rock environment evaluation, allowing to design optimum methods for solving practical problems of the construction large technical works.

References

ČABALOVÁ D., 1978: Vplyv pórovitosti na technické vlastnosti niektorých slovenských vulkanitov. Výsk. správa SVŠT, Bratislava.

DOMANICKÝ A., 1988: Turček - stavebný kameň. Správa s výpočtom zásob. Archív Geofondu.

ESMIOL E.E., 1968: Rock as a upstream slope protection for earth dams - 149 case histories. Dam Branch rep. no. DD-3, Bureau of Reclamation. Denver, Colorado.

HYÁNKOVÁ A., WAGNER P., 1994: VN Turček - 1. stavba, DVP č. 2, SO Hrádza, doplnok vykonávacieho projektu, Archív Katedry inžinierskej geológie, Bratislava.

HYÁNKOVÁ A., SZABO Š., WAGNER P., 1994: Point load test - vhodná metóda na určenie pevnostných charakteristík i fyzického stavu horninového materiálu. In. zb. Výsledky, problémy a perspektívy inžinierskej geológie v Slovenskej republike. SAIG, Bratislava.

JADROŇ D., 1971: Turček na Turci - stavebné materiály. IGHP Žilina. Archív Geofondu.

MENCL V., 1966: Mechanika zemín a skalných hornin. ČSAV, Praha.

ONDRÁŠIK R., HOLZER R., WAGNER P., INGR M., 1983: Inžinierskogeologické hodnotenie diskontinuít horninových masívov. Metodická príručka. IGHP Žilina.

ONDRÁŠIK R., NEŠVARA J., 1976: Poruchy ochrannej vrstvy z netriedeného kameňa hrádzí Podvihorlatskej nádrže. Acta geologica et geograph. UC, Geologica, Nr. 29, Bratislava.

STOLÁR M., LIŠČÁK P. ŠIMON L, MACINSKÁ M., LEXA J., 1994: Petrografické posúdenie lomového kameňa pre vodné dielo Turček. Archív GÚDŠ Bratislava.