CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

No. 10 2013

MINERAL COMPOSITION OF MELAPHYRE ROCKS AND DURABLITY OF A MOTORWAY SURFACE

Tadeusz CHRZAN*, Justyna ZAWORSKA†
University of Zielona Góra, Faculty of Civil and Envirnomental Engeenering
ul. prof. Z. Szafrana 1, 65-615 Zielona Góra, Poland

The article presents the mineral composition of melaphyre and discusses durability of minerals contained in the rock for the impact of weather conditions on stability and strength of mineral rocks. The analysis showed that the tested melafir contained too many minerals not resistant to weathering. This fact had a significant impact on the exploitatnion of the new done motorway surface. The surface layer of the motorway was made between June and November 2001 and at the beginning of 2003 there started its renovation. The resulting rapid wear of the upper surface of the motorway may be explained by an excessive content of minerals that have gone rapid transformations (weathering and oxidation) in the conditions of the top surface layer of the motorway.

Keywords: melaphyre rocks, motorway, surface layer

1. INTRODUCTION

The surface layer of the Konin-Września motorway section was made during the period from July to November 2001. The layer was made from granulated aggregate 0-20 mm in diameter derived from Borówko and Grzędy melaphyre quarry, bounded with modified bituminous mass. The tests of melaphyre aggregates against grade and class requirements had confirmed that those grits were the first class and grade [1,2,3] according to the Polish Standards [11,12, 14].

The binding layer of asphaltic concrete made and tested on samples that were taken from the completed motorway also conformed to the standard requirements according to Polish Standards [4,15,16]. Also, the adhesion of asphalt to the melaphyre grit conformed to the standard [6,13].

* Corresponding author. E-mail: t.chrzan@iis.uz.zgora.pl
† Doctoral student

After the wintertime, in spring 2002, on the surface of the roadway, distinct signs of scaling and weathering were observed on the surface of larger melaphyre grit grains. In August 2002, it was found that the number of weathered grains had increased and some of them lost their compactness and disintegrated [10,7]. Between September and November of 2003, due to the above reason, which threatened the safety of moving vehicles, partial repairs were carried out covering 1600 square meters. The surface of motorway has been excessively worn and looks as if it were used for at least 5 years. In this paper, it is explained why the motorway has been worn so quickly.

2. ANALYSIS OF DECREASE OF ASPHALTIC CONCRETE STRENGTH ON MOTORWAY BINDING LAYER IN RESPECT TO MINERAL COMPOSITION OF ROCKS

2.1. Description of melaphyre deposit

The melaphyre used for road construction come from deposit that was formed from basalt-type volcanic rocks in the Permian period around 350 million years ago. The volcanic rocks created trachyte-basalt, trachyte and tuff-type rocks. The melaphyre deposit is mined in the quarries of Borówno, Grzędy and Rybnica Leśna.

There are two types of trachyte basalts. The first one includes rocks coloured cherry-brown, cherry-brick and grey-violet. They have chaotic structure and aphanitic texture. Cracks are filled with the ferruginous and carbonate substance. The second type is the rock ranging from grey-brown through grey-greenish to nearly black in colour. The structure is aphanitic and the texture is dense. Coursegrained breccia of chaotic texture is also found. Volcanic spalls are cemented with the ferruginous and carbonate binder. The rock spalls are grey-brown and are of various size and aphanitic structure. The sedimentary rocks are cherry-brown in colour and have fine-grained structure with directional texture. They disintegrate into irregular small blocks. Rocks of lava mudstone fraction are found in the deposit which may have been the result of lava flooding during volcano eruption of weathered layers from the previous outflow.

The exploited rock is melaphyre-type aphanite lava ranging from dark grey to black in colour; solid but intensely cracked rock. The cracks make it vulnerable to weathering and 0-10 mm sized rock is dumped as waste [5] in amount of 21% at Borówno quarry, and 15% at Grzędy quarry.

This gives evidence that melaphyre in the Borówno quarry is built from minerals that are subject of stronger weathering than that in the Grzędy quarry. The melaphyre in both quarries is built from minerals that disintegrate under the influence of temperature, air and water.

2.2. Petrographic analysis of melaphyre

The petrographic analysis of Grzędy deposit shows that plagioclases are found in the form of small phenocrysts. Feldspars undergo the process of sericitization and carbonization, and weathering processes lead to kaolinization. The ferruginous substance infiltrates the strips of plagioclases. Dark minerals were completely transformed. They were replaced with hydrated iron oxides accompanied by concentrations of carbonates, and in place of olivine there is a substance that is difficult to identify. Chlorite is rarely found. Pores are refilled with calcite accompanied by ferruginous pigment. In the pores there are concentrations of chalcedony. Concentrations of limonite are often found. Apatite, limonite and magnetite are accessory minerals. Volcanic glass, brown or orange in colour is also found. The rock groundmass consists of heavily carbonatizated glass, perches of plagioclases, ash fraction and iron oxides.

3. MINERALOGICAL TESTS

The testing of samples collected from the Borówno quarry was carried out both on fresh solid, not weathered samples, and on weathered, low-cohesion samples in a laboratory in Austria [9]. The petrographic study determined, as it is specified in the Polish geological documentation of Borówno melaphyre deposit [8] that in the melaphyre there are clay minerals and plagioclases which undergo weathering into quartz and clay minerals.

The contents of plagioclases in both cases were very high in samples from Borówno (58% to 76% according to Austrian study and from 45%, 75% according to the Polish study).

Samples were collected from the Borówno quarry and were designated as:

- BO–2 - brittle grains taken from key aggregate 16/22, brown, able to be ground with fingers,
- BO–3 - sample taken from fresh gram,
- BO–4 - sample able to be ground with fingers,
- BO–5 - sample from 2nd production level,
- BO–6 - sample from 2nd level at the road.

3.1. Clay minerals

Clay minerals is kaolinite ranging from white to red or greenish in colour. It is commonly found as a product of feldspar and aluminosilicates weathering. It becomes plastic under the influence of water.

Clay minerals include kaolinite, which is a product of weathering of feldspars and plagioclases that make up 60% of the deposit illite products of feldspar and kaolin weathering. Commonly found components of clay rocks such as kaolin, clay, silt, and rocks that are formed in sea environment. These minerals are chemically related and do not differ in macroscopic properties. Their colour depend on iron admixture.

Montmorillonites are a dense concentrated wax. Their colour depend on iron admixture and ranges from white to black-brown. They swell when flooded with water. They discolour methylene blue solution. Components of sedimentary rocks and hydrothermal formations of low temperature. Montmorillonites are created as the products of magma glaze weathering in alkaline and heavily salted environment.

3.2. Quartz SiO_2

Rock forming mineral, very durable and weatherproof. It may also be found as tridymite and cristobalite. Its colourless form is called mountain crystal, other forms are yellow, violet, black, pink, green. It does not reduce the strength of grits in the motorway surface. A small content of quartz in the rocks causes that the rocks are not resistant.

3.3. Plagioclases

According to the mineralogical testing of the deposit, there is from 58% to 76% of plagioclases in melaphyre. These minerals are sodium-calcium feldspars, which with increasing calcium content due to the weathering process, disintegrate into kaolin, which is a clay mineral. It may not be ruled out that the weathering process in melaphyre grits, which has begun in the deposit, will continue on the surface of the motorway.

3.4. Carbonates

Carbonate minerals such as calcite, aragonite, dolomite and magnesite are products of hydrothermal formations and are found in melaphyre. They do not undergo oxidation or weathering process. Howeyer, syderyte ($FeCO_3$) is a product of hydrothermal waters, and under the influence of water and oxygen, that is possible on the motorway surface, transforms into iron hydroxides. It can also contains admixtures of clay minerals and calcite. That carbonate mineral may have a great impact on the strength of grits in the motorway surface, assuming goethite's colour.

3.5. Oxides and hydroxides

These kinds of minerals occur in melaphyre with the content ranging from 6 to 39%. They may be iron compounds, which are components of magma rocks. Goethite (FeOOH), a product of iron mineral oxidation, may be also found, which is also a product of low temperature hydrothermal activity. The minerals undergo considerable oxidation during one-year period (visible change in aggregate colour in the storage yard). The impact of their content on grit strength in the motorway surface is difficult to determine. However, the iron oxidation process certainly reduces the strength of rock components in asphaltic concrete.

3.6. Amphiboles

Amphiboles are important rock-forming ribbon silicates and aluminosilicates minerals. Four groups of amphiboles are distinguished: 1) Fe-Mg-Mn, 2) Ca, 3) Na-Ca, and 4) Na. Amphiboles also include the hornblende group usually containing Na, Ca, K, Fe, Si, AI, SiO_2 ranging from light green to dark green in colour, with density 2.9-3.4 Mg/m^3. Hornblende usually occurs in magma rocks of any type from neutral, acid to alkaline.

3.7. Pyroxenes

Pyroxenes belong to aliphatic silicates and aluminosilicates. Group I consists of Mg-Fe, Mn-Mg, Ca, Ca-Na, Na-type pyroxenes. Pyroxenes are an important group of rock forming minerals, which are created at high temperatures and at low water pressure. They are components of magma rocks and metamorphic rocks. They are not resistive to climatic factors, therefore are rarely found in sedimentary rocks. The colour of pyroxenes depends on iron and titanium content. At small content, it ranges from white to greenish, with larger content, it is olive, brown or dark green. Orthorhombic pyroxenes form the isomorphous series from Mg to Fe, with distinguished enstatite, bronzes, hypersthenes, ferrohyperstene, eulite. Monoclinic pyroxenes include four minerals creating a diopsyde-hedenbergite series built from Ca, Mg, Fe, SiO_2. Pyroxene minerals are not weatherproof. It is visible in table 1.

Table 1. Content of minerals in samples taken for the Borówno quarry [9]

	Weathered samples		Fresh samples	
	BO-4	BO-2	BO-3	BO-5
Clay minerals, montmorillonites	60	50	32	13
Qartz	7	3	-	-
Plagioclases	13	45	58	76
Calcite	15	-	-	-
Geothite	5	-	-	-
Amphiboles	-	2	-	-
Pyroxenes	-	-	10	11

Table 1. shows that montmorillonite and quartz are formed from plagioclases. In alkaline environment montmorillonite is formed, and kaolinite is formed in the acidic environment. In the weathering process, iron hydroxides are formed (such as goethite), which is not present in samples taken from the fresh rocks. The study shows that pyroxenes also disintegrate into iron hydroxides and calcite, which were not present in the fresh samples. On the basis of tests and analysis, it may be stated that melaphyre and its minerals, used for the top layer

have undergone oxidation and weathering processes that cause rapid disintegration of melaphyre and compactness of the motorway top layer.

4. SUMMARY AND CONCLUSIONS

The petrographic analysis shows that melaphyre is built from the minerals, which undergo weathering and oxidation under the influence of water, temperature, air and therefore it should not be used for top layers of roads and motorways.

In the melaphyre deposit of Borówno quarry, the intense and developed processes of weathering and oxidation take place, which is obvious, considering 21% of waste being dumped. This 21% of waste confirms the petrographic appearance of the rock in which there are minerals not resistant to weathering and oxidation processes. The rock is not weatherproof, and this is a reason of rapid disintegration of melaphyre grits contained in asphalt. The mineralogical analysis of the rock applied to asphalt mass makes it possible to explain the reason of rapid deterioration of the new motorway surface:

1. Rocks containing more than 45% of minerals that are not resistant to oxidation and weathering processes despite conforming to all standard requirements should not be used for the top layers of motorways.
2. This type of rock includes melaphyre and gabbros.

REFERENCES

1. Bolewski A., Manecki A.: *Mineralogia szczegółowa*, Wydawnictwo PAE, Warszawa 1993.
2. Bolewski A.: *Rozpoznawanie minerałów*, Wydawnictwa Geologiczne, Warszawa 1972.
3. Chrzan T.: *Autostrady i surowce do ich budowy*, Politechnika Wrocławska, Wrocław 1997.
4. Kancler M.: *Operat ewidencyjny zasobów złoża melafiru 'Borówno"* Kopalnia Melafiru „Borów" Wałbrzych, 2002.
5. Kancler M.: *Operat ewidencyjny zasobów złoża melafiru „Grzędy*" Kopalnia Melafiru „Grzędy" Wałbrzych, 2002.
6. Radziszewska-Jagosz E.: *Opracowanie petrograficzne skał ze złoża Grzędy*, Przedsiębiorstwo Geologiczne, Wrocław, 1982.
7. Ruttmar I.: *Degradacja grysów melafirowych na nawierzchni autostrady A-2* Raport nr. O2/A2/EW/SW/IR/05 Instytut Badań Technicznych TPA, Poznań, 2002.
8. Szuszkiewicz K., Król J.: *Dokumentacja geologiczna złoża melafiru Borówno*, Przedsiębiorstwo Geologiczne. Wrocław, 1988.

9. Strasser M.: *Badania petrograficzne melafiru Czarny Bór*, Laboratorium TP, sprawozdanie nr. 5, 7/02,Wiedeń, Austria, 2002.
10. Wysokowski A.: *Orzeczenie o jakości kruszywa.* Instytut Badawczy Dróg i Mostów, Filia Wrocław, 2001.
11. PN-B- 11112: 1996r. Kruszywa łamane do nawierzchni drogowych.
12. PN-B-A 1110 Surowce skalne lite dla produkcji i kruszyw łamanych, stosowanych w budownictwie drogowym.
13. PN-84 / B-067 14 / 22 Oznaczanie przyczepności do bituminów.
14. PN-EN 1097-2 Badanie mechanicznych właściwości kruszyw.
15. PN-S / 96025 Badanie mieszanek mineralnych i betonów asfaltowych.
16. PN-74 / S-96022 Badanie masy z betonu asfaltowego przy układaniu i wykonaniu.

SKŁAD MINERALNY SKAŁ MELAFIROWYCH A TRWAŁOŚĆ AUTOSTRADY

Streszczenie

W artykule poddano analizie skład mineralny melafiru użytego do budowy nawierzchni autostrady oraz omówiono trwałość poszczególnych minerałów pod kątem ich odporności na czynniki atmosferyczne i ogólnej wytrzymałości skały. W wyniku analizy stwierdzono, że zbadany melafir zawierał zbyt dużą ilość minerałów nieodpornych na czynniki atmosferyczne, co miało znaczący wpływ na eksploatację nawierzchni autostrady; powierzchniowa warstwa autostrady powstała pomiędzy czerwcem i listopadem 2001 r., a już na początku 2003 r. przystąpiono do jej remontu. Szybkie zużycie górnej warstwy autostrady wytłumaczono nadmierną zawartością tych minerałów, które pod wpływem czynników atmosferycznych stosunkowo szybko uległy przemianom.