Changes of physical properties of asphalt aggregates by heat. A laboratory study.

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Asphalt mixtures can meet with several different temperatures during their life cycle. The effects of high temperatures on asphalt aggregates have not been examined in detailes yet. Two temperatures were choosen (240 °C and 480 °C) to be examined. Aggregates meet with 240 °C temperature in case of mastix asphalt, and 480 °C temperature during asphalt binder analysis. High temperatures cause changes in the physical properties of aggregates that are commonly used in asphalt mixtures. To asses these changes 11/16 mm fractions of three different types (andesite, basalt and dolomite) of Hungarian aggregates were tested in the laboratory by submitting the samples to heating at 240 °C and at 480 °C. The loss of masses, and particle size distributions coloures and colour differences were recorded and compared. The physical parameters have shown that aggregates behave differently after burning on different temperatures and uniform trends could not be discovered between the type of aggregate, the mechanical properties and thermophysical behaviour of aggregates.

Keywords: high temperature, asphalt aggregates, physical properties, thermophysical behaviour

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1. Introduction

Asphalt is defined as a mixture of inert mineral matter, such as aggregate, mineral filler and bituminous binder in predeterminated portions.

Aggregates have been used as pavement materials since prehistoric time. Aggregates of asphalt mixtures can be different depending on the location of the constructed road.

Thermal behaviour of aphalt mixtures have been examined previously [6] [8], but the thermal behaviour of aggregates themselves, especially the effect of high temperature on asphalt aggregates has not been examined in details yet.

Two temperatures were choosen (240 °C and 480 °C) to be examined. Aggregates meet with 240 °C temperature in case of mastix asphalt, and 480 °C temperature in the quality control practice, in case of asphalt binder analysis (but fire hazards can also cause high temperatures). Very few attempts have been made to understand how these stones behave under different temperatures, especially under high temperatures.

My aim was to collect more knowledge from the behaviour of Hungarian asphalt aggregates.

2. Experimental methods

The effect of heat was studied on three Hungarian stone types. 11/16 mm fractions were examined. 10 × 1000 g portions were prepaired from each rock type for burning. Test portions in steel basket were placed in the furnace. The portions were heated in a special oven (ABA/75 Carbolite Asphalt Binder Analyser) at 240 °C and at 480 °C while mass loss was recorded until the mass become constant. The ignition furnace consists of a combustion chamber with an integral balance located below. The balance contains software to monitor the rate of mass loss during the test. Once the sample has reached a predetermined constant mass point the test is automatically stopped.

After heating the portions were cooled down on 22 °C to become ready for sieving. In each case sieving took for half an hour (hole sizes of sieves were the followings: 0 mm, 0,063 mm, 0,125 mm, 0,250 mm, 1 mm, 2 mm, 4 mm, 5,6 mm, 8 mm, 11,2 mm). The particle size distribution of the burned portions was measured after sieving. After the end of the examination 2×3×10 particle size distribution and mass loss data were available for the analysis.

Photographs were also made before and after heating.

2.1. Description of stones

Asphalt aggregates are those materials used in asphalt pavements. Three Hungarian aggregate types correspond to the most widely used pavement stones in this country were choosen to be tested under different circumstances. The most important parameters of studied aggregates are given in Table 1.

Nr.	Origin	Type	Colour at 22 °C	Typical Minerals	Bulk Density [kg/m³]	Los Angeles [m%]
1.	Tállya	Andesite	Greyish black	Plagioclase, Amfibole, Piroxene, Biotite	2650	19,07
2.	Uzsa	Basalt	Greyish black	Plagioclase, Piroxen, Olivine	2750	13,23
3.	Iszkaszent-györgy	Dolomite	Jonquil	Dolomite	2750	17,70

Table 1. Most important parameters of examined aggregates
1. táblázat A vizsgált kőzetek legfontosabb tulajdonságai

Hungary is rich in dolomite, but the effusive rock sources of the country are limited (especially basalt) so the knowledge of the mechanical and thermal behaviour of different aggregates is fundamental for the pavement design and for mining. As Hungary has dolomite resources in a high ammount some researchers started to go on to discover whether asphalts with dolomite aggregates can reach the same quality as other mixtures, or could they be used somehow as pavement material.

This laboratory testing can provide valuable information on thermal behaviour of aggregates.

3. Results

Three types of changes in physical properties have been observed, and evaluated after testing:

- changes in particle size distribution,
- changes of mass and
- colour changes.

3.1. Changes in particle size distribution

According to the laboratory tests after burning the speciments on 240 °C and on 480 °C notable changes have been appeared in the particle size distribution of the stones. Small pieces broke down from the 11/16 mm fractions as the result of heating. In Fig. 1–5. particle size distributions of the examined rocks are represented (the end of the diagrams of particle size distributions has been cut off as the percentage passing reaches 100% above 11,2 mm in each case). Particle size distributions were compared after heating at different temperatures in case of each type of stones, and the particle size distributions of the different type of stones were also compared with each other.

After heating at 240 °C weathering of Tállya andesite varied between 0,08–1,15%. This is less than the weathering of this type of stone after heating at 480 °C where the minimum was 0,35% and the maximum 1,77%. The average of weathering after heating at 240 °C was 0,60%, while after heating at 480 °C it was 1,27%. Deviation of the measured values was 0,36% (240 °C) and 0,45% (480 °C).

In case of Iszkaszentgyörgy dolomite results were different. After heating at 240 °C weathering of Iszkaszentgyörgy dolomite varied between 0,99–2,70%. Average of the results was 1,58% and the deviaton was 0,64%. Weathering of Iszkaszentgyörgy dolomite reached 0,59–1,39% after heating at 480 °C. Average of the results was 0,95%. Deviation of the values was 0,30%. What is interesting in these results is the opposite relation. While the temperature increased weathering decreased.

The same happened in case of Uzsa basalt where the results of weathering varied between 0,51–2,78% after heating at 240 °C. Average was 1,34% and deviation 0,75%. After heating at 480 °C 0,32–2,23% of weathering was measured. Average of particle size distributions was 1,63% while deviation was 0,62%.

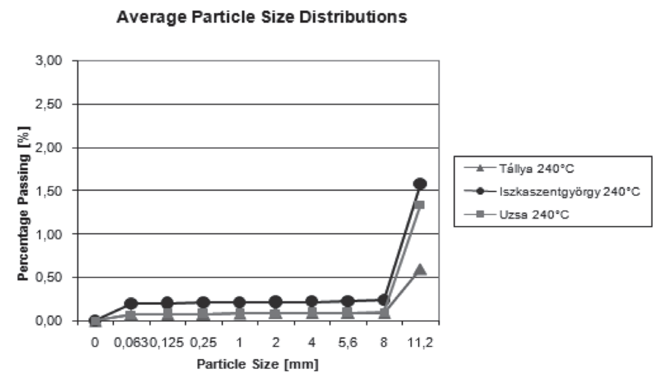

Fig. 1. *Average particle size distributions of aggregates after heating 11/16 mm fractions at 240 °C*
1. ábra *A vizsgált kőzetek szemmegoszlás átlagai 240 °C-on történő égetést követően*

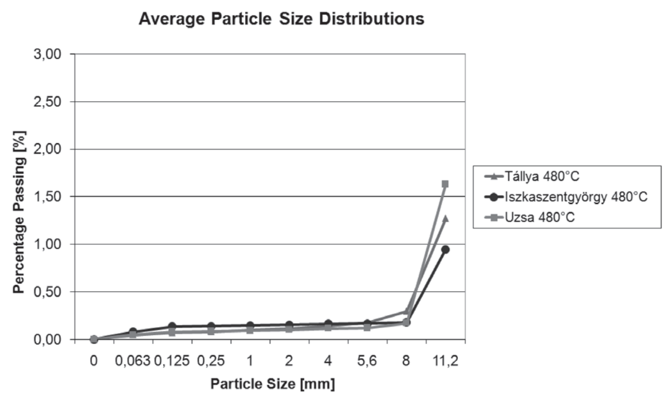

Fig. 2. *Average particle size distributions of aggregates after heating 11/16 mm fractions at 480 °C*
2. ábra *A vizsgált kőzetek szemmegoszlás átlagai 480 °C-on történő égetést követően*

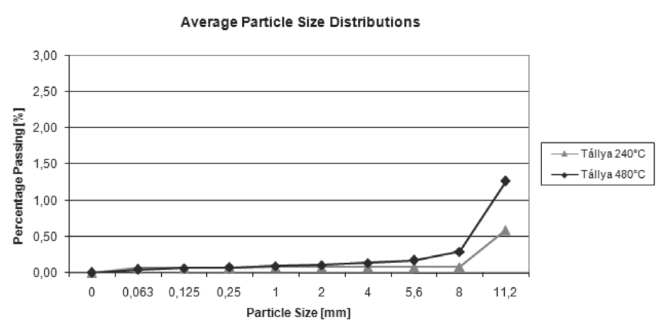

Fig. 3. *Average particle size distributions of Tállya andesite after heating 11/16 mm fractions at 240 °C and 480 °C*
3. ábra *A tállyai andezit szemmegoszlás átlagai 240 °C-on, valamint 480 °C-on történő égetést követően*

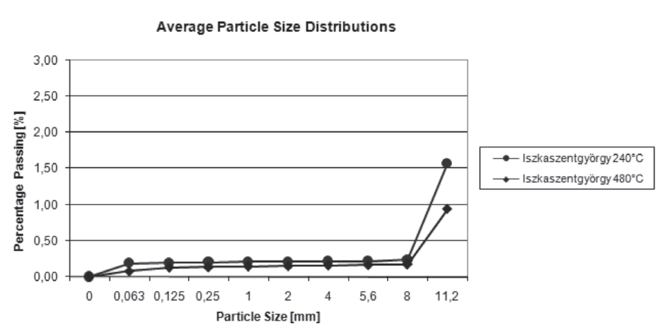

Fig. 4. *Average particle size distributions of Iszkaszentgyörgy dolomite after heating 11/16 mm fractions at 240 °C and 480 °C*
4. ábra *Az iszkaszentgyörgyi dolomit szemmegoszlás átlagai 240 °C-on, valamint 480 °C-on történő égetést követően*

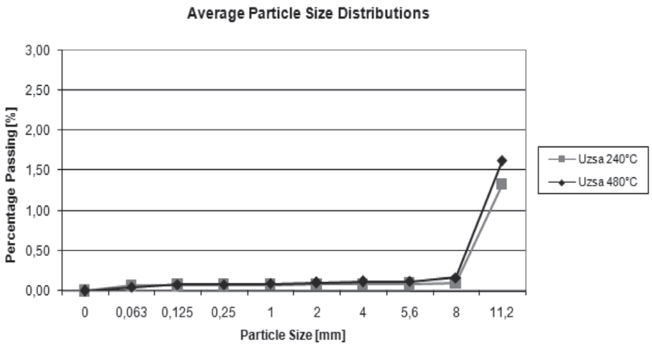

Fig. 5. Average particle size distributions of Uzsa basalt after heating 11/16 mm fractions at 240 °C and 480 °C
5. ábra Az uzsai bazalt szemmegoszlás átlagai 240 °C-on valamint, 480 °C-on történő égetést követően

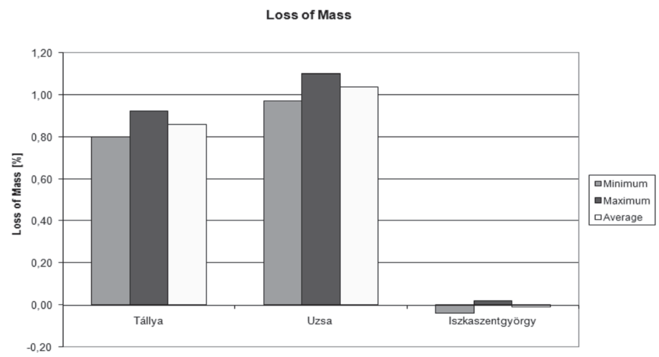

Fig. 6. Mass losses of aggregates after heating at 480 °C
6. ábra A vizsgált kőzetek 480 °C-on történő égetés hatására bekövetkező tömegvesztesége

3.2. Loss in mass

The laboratory test has shown that the examined stones change their mass during burning on 480 °C but loss in mass has not been appeared at 240 °C (Fig. 6. and Table 2.). In case of Tállya andesite the minimum of mass loss was 0,80% and the maximum 0,92%. In case of Uzsa basalt this rate was higher. The biggest mass loss was measured in case of this type of stone. The maximum was 1,10% and the minimum was 0,97% which is higher than the maximum of Tállya andesite. According to the experiment mass loss in case of dolomite has not been measured. On the contrary although in a very little rate (0,01%) but mass of dolomite has decreased after heating.

3.3. Colour changes

An additional result of the laboratory tests was the colour change of aggregates (Table 3.). After heating at 240 °C colour changes of stones were not observable but some of the aggregates show very distinct colour changes after heating at 480 °C which was visible to the naked eye. At room temperature the colour of dolomite is yellowish (jonquil) but after heating at 480 °C this colour turned to pinkish. Andesite and basalt has greyish black colour at 22 °C but this colour also transforms to reddish or to brownish. For the question of colour changes has mineralogical answers.

4. Discussion

240 °C and 480 °C temperatures although in different quantities but in both cases cause changes in the original particle size distributions of the stones because of weathering.

There is no relation between the ammount of weathering and the type of aggregate.

According to the comparison of particle size distributions with the Los Angeles values relation could not be discovered beween the mechanical and the thermophysical behavour of the stones.

It was expected that weathering of dolomite is more than the weathering of effusive rocks as they known as less lasting stones, but trend could not be discovered.

In these experiments not only thermal breaks has been documented but also changes in mass of aggregates. 240 °C temperature has not caused chanes in the original mass of samples. But after heating at 480 °C mass losses were recorded for effusive rocks, and constant mass, or mass growing for dolomite. This suggest that the sedimentary rocks can absorb air moisture during heating, while in effusive rocks organic parts, or minerals burn out.

Higher temperature caused higher weathering in case of andesite rocks, but dolomite and basalt had less weathering in case of 480 °C. The reason of this could be the cohesion of grains. These experiments have shown that type of aggregates do not necessarily show a uniform behaviour.

Origin	Type	Number of samples [pieces]	Mass Loss [m%] at 240 °C	Mass Loss [m%] at 480 °C			
				Average	Deviation	Minimum	Maximum
Tállya	Andesite	2×10	0	0,86	0,04	0,80	0,92
Uzsa	Basalt	2×10	0	1,04	0,04	0,97	1,10
Iszkaszentgyörgy	Dolomite	2×10	0	-0,01	0,02	-0,04	0,02

Table 2. Mass losses of aggregates
2. táblázat Kővázak égetés hatására bekövetkező tömegvesztesége

Origin	Type	Colour at		
		22 °C	240 °C	480 °C
Tállya	andesite	greyish black	greyish black	reddish grey
Uzsa	basalt	greyish black	greyish black	brownish
Iszkaszentgyörgy	dolomite	jonquil	jonquil	pinkish

Table 3. Colour changes of aggregates after heating at 240 °C and 480 °C
3. táblázat A vizsgált kőzetek 240 °C és 480 °C hatására bekövetkező makroszkópos színváltozása

During these examinations macroscopic colour changes were also documented. After heating at 240 °C macroscopic colour changes have not been discovered. Changes were observed both on effusive and sedimentary rocks after heating at 480 °C. It depends on the mineralogical contents of the stones whether their original colours change during heating. The most common was the transformation of the original colour to reddish, which is the result of the transformation of ferro-oxids, but the transformation of mangan and organic parts can cause colour changes too [3].

When iron is present as ferri-oxy-hydroxid (goethite) it often transforms to ferro-oxid (hematite), while the water dissapears. Changes start at 200–300 °C [2] [3]. Transformation of organic parts to carbon starts at arround 500 °C [2] [3].

5. Conclusions

The most important establishments in relation with the thermophysical behaviour of aggregates are the followings:

1. High temperature (480 °C) causes minearlogical and physical changes in the asphalt aggregates.
2. 240 °C temperature does not have significant influence on the mass losses and the mineralogical changes of asphalt aggregates.
3. Weathering of aggregates was observed in case of both temperatures. In case of 240 °C weathering of stones was less than 1,10%. Heating rocks at 480 °C causes less than 3% weathering in case of 11/16 mm fractions of examined aggregates.
4. Higher temperature caused higher weathering in case of andesite rocks, but dolomite and basalt had less weathering after submitting to 480 °C.
5. Effusive rocks have mass losses during heating at 480 °C, because organic or mineral parts burn out, while near the same circumstances mass of dolomite stayes constant.
6. It can not be stated that effusive rocks have better quality than the sedimentary rocks, at least according to their thermophysical behaviour.
7. There is no relation between the Los Angeles values and the thermophysical behaviour of aggregates.
8. Indirectly lasting of pavements depends also on the thermophysical properties of aggregates, not only on the mechanical properties.
9. Colour changes were observed as additional results of the analysis. The aggregates have changed their colours after burning at 480 °C. Heating of stones at 240 °C has not caused macroscopic changes in the original colour of the samples.

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Az aszfaltkeverékek jellemző kővázainak égetés hatására bekövetkező fizikai változásai

Az útépítés aszfaltkeverékeit különböző nagyságú hőmérsékletek érik a gyártás, illetve a minőségellenőrzés során. Az öntött aszfalt hőmérséklete eléri a 220–240 °C-ot, míg a minőségellenőrző vizsgálatok közül a bitumentartalom égetéssel történő meghatározását 480–540 °C magas hőmérsékleten végzik. Az aszfaltkeverékeket alkotó kővázak fizikai tulajdonságaiban magas hőmérséklet hatására bekövetkező változások mélyreható vizsgálatára korábban nem került sor. Jelen kísérlet sorozat három különböző kőzet típus (andezit, bazalt, dolomit) meghatározott frakciójának (11/16 mm) két különböző hőmérsékleten (240 °C-on és 480 °C-on) való viselkedését követi szemmel. A laborvizsgálat során az ásványi vázak eredeti tömegében bekövetkező változások, az eredeti frakció szemmegoszlás változása, valamint a kőzetek makroszkopikus színváltozása került dokumentálásra. Az ásványi vázak az égetés során egészen eltérő viselkedést mutattak, így a kővázak termofizikai viselkedése és mechanikai viselkedése között határozott összefüggésekre nem lehetett következtetni.

Kulcsszavak: magas hőmérséklet, aszfalt, kőváz, fizikai tulajdonságok