Buletinul Ştiinţific al Universităţii „POLITEHNICA" din Timişoara

Seria HIDROTEHNICA
TRANSACTIONS on HYDROTECHNICS

Tom 57(71), Fascicola 2, 2012

# Case study concerning pollution mitigation by using industrial wastes in asphalt mixtures

Marc Paul[1] Costescu Ciprian[1]

**Abstract: Considering the shortage of raw materials, the idea of creating techniques and technologies to determine radical changes in the methods of industrial production, by using as fully as possible the secondary resources, thus increasing the recirculation degree and successive using of resources by adopting the so-called no waste technologies is increasingly developing. The fact that the ashes from the CET units representing at the moment and for the future the main industrial waste which, due to their chemical composition and hydraulic properties, makes them sources of new raw materials to be valorized in different fields. This paper aims at showing the impact of the use of flying ashes from the CET Timisoara South upon the physical-mechanical characteristics of asphalt concretes.**
**Keywords: asphalt concrete / flying ash / physical-mechanical characteristics**

## 1. INTRODUCTION

The ashes from the CET units (Electric Heating Plants) represent at present and for the future the main industrial waste which, due to its chemical composition and hydraulic properties, can be used as new raw materials usable in different fields. As far as the sterile storage at the CET South unit, it is situated next to the town of Utvin several kilometers from Timisoara. The storage lays on a surface of 50 ha and gathers about 45 t of ash per day during the cold season. Following a research concerning the impact of this sterile storage upon the environment, it was concluded that, in the south-west of the city of Timisoara, the air, water and soil are polluted. This conclusion triggered the study concerning the use of the flying ash resulting from the CET South unit in the manufacturing of asphalt mixtures.

The idea of using the flying ash instead of filler in the asphalt mixes is not a new concept. Its use in asphalt mixes was investigated by several scientists and the conclusions of their research can be summarized as follows:

– **Warden** et al. (1952) stated that the ash is an adequate filling material for the asphalt mixes, its introduction resulting in a better stability and a higher resistance to humidity and flexibility [3].

– **Zimmer** (1970) analyzed the impact of the carbon content of the ash. His results showed that the samples with ash in their composition present a higher stability after water immersion [4].

– **Henning** (1974) researched the impact of the class C ash upon the characteristics of the asphalt concretes. His conclusion was that adding 4 % ash in the composition of the macadam results in a higher stability with a lower void content. Henning also stated, like his predecessor researchers, that the use of ashes leads to a higher stability after immersing the sample into water.

The analysis of these aspects from different points of view, such as economic and environmental, resulted in several experiments concerning the possibility of totally or partially replacing the filler with flying ashes in the composition of the asphalt mixtures.

## 2. CHARACTERISTICS OF COMPOSITE MATERIALS IN ASPHALT MIXES

The **aggregates** play an important role in the performances of the asphalt structures to which they contribute in a proportion of 85 – 90 % of the mixture weight and represent 75 -80 % of its volume. Therefore, knowing the properties of the aggregates is crucial in designing high quality asphalt mixtures. The aggregates used in manufacturing the samples within the laboratory of the Department for overland Communication Ways, Foundations and Surveying come from the Lucareţ quarry in the Timiş County. Their physical-mechanical characteristics and grading are in compliance with the standards in force.

The **filler** used in manufacturing the samples of asphalt mixture in the laboratory was produced by HOLCIM ROMANIA and it also is compliance with all the conditions of the standards in force.

The **flying ash** used for this research was subjected to physical-mechanical tests taking into consideration several studies realized by the research team of the Department for Civil and Industrial Engineering within the Faculty for Civil Engineering of Timisoara [1]. Thus, table 1 presents the chemical analysis of the ashes coming from some CET Units in Romania, and table 2 shows the densities and specific surface of the same flying ashes.

[1]"Politehnica" University of Timisoara, Department of Land Communication Ways, Foundations and Survey, Ioan Curea Str., No. 2A, 300224 Timisoara, Romania, paul_marc22@yahoo.com ; ciprian.costescu@ct.upt.ro

Table 1. Chemical analysis

| Source of ash C.T.E. | Chemical composition (average values), % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $SO_3$ | $Na_2O$ | $K_2O$ | MgO |
| Timişoara | 49.07 | 25.52 | - | 1.15 | - | 0.26 | 1.90 | 1.01 |
| Timişoara * | 43.51 | 28.10 | 9.28 | 12.85 | - | - | - | 2.26 |
| Arad | 51.30 | 19.20 | - | 4.25 | - | 0.45 | 1.57 | 1.91 |
| Deva | 47.33 | 24.34 | - | 5.85 | 2.75 | 0.58 | 1.97 | 2.73 |
| Craiova | 49.20 | 22.80 | 7.82 | 8.80 | 1.44 | 0.51 | 1.70 | 2.41 |
| * Tests realized by the CCIA research team | | | | | | | | |

Table 2. Density and specific surface

| Source of ash C.T.E. | Physical characteristics (average values), % | | | |
|---|---|---|---|---|
| | Real density [$Kg/m^3$] | Loose density [$Kg/m^3$] | Packed density [$Kg/m^3$] | Specific surface [$cm^2/g$] |
| Timişoara * | 2333 | 566 | 775 | 3800 |
| Arad | 2378 | 1042 | 1321 | 2238 |
| Deva | 2280 | 579 | 832 | 2649 |
| Craiova | 2370 | 617 | 822 | 1224 |
| * Tests realized by the CCIA research team | | | | |

The tests performed showed, as specified in the scientific literature, that for the flying ashes in our country, the prevailing components are: $SiO_2$, $Al_2O_3$ and $Fe_2O_3$, in proportion of 80.89 %, which overrides 70 %, fact that certifies the possibility of forming the vitreous phases, as well as the silicates, aluminates of Ca, etc. with favorable impact upon the hydraulic capacity.

The researched ash ranges in the class of aluminum-siliceous ashes, as most of the ashes in our country.

The **bitumen** used during the laboratory tests is a D 50/70 bitumen supplied by S.C. CONFORT S.A. and is complying with the Indicative AND 537 – 2003 from the point of view of the main characteristics.

## 3. DETERMINATION OF ASPHALT MIXTURE DOSAGES TOTALLY OR PARTIALLY REPLACING THE FILLER WITH FLYING ASH

After all the materials entering in the composition of the asphalt mixture have been analyzed, the decision was made to research the impact of replacing the filler with flying ashes. This replacement was realized in different percentages for the following types of mixture:

- asphalt concrete B.A.16 used in wearing courses;
- open asphalt concrete B.A.D.25 used in binder courses.

Therefore, according to the ash contents determined for each type of asphalt mixture, the final dosages were realized according to tables 3 and 4, and the samples were manufactured for each test.

Due to the fact that the ash used in the asphalt mixes has a packed density ρ=775 kg/m$^3$, it presents a lower participation in the mix than the percentages determined in the initial stage, because it's higher volume of fines.

From the point of view of classifying these mixes in the grading areas stipulated by the Romanian standard SR 174 – 1/2009, they range as presented in Fig. 1 and Fig. 2 respectively.

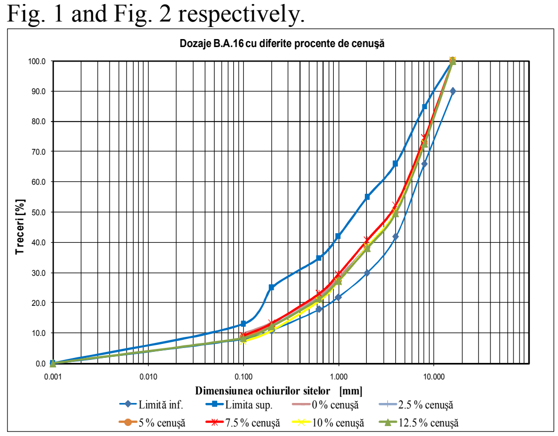



Figure 1. Grading curves determined for B.A.16 asphalt mixture

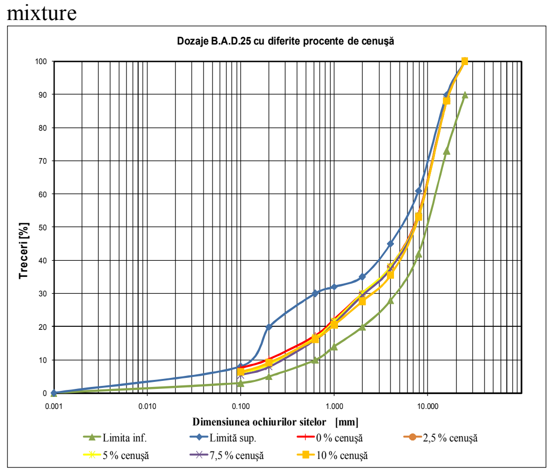



Figure 2. Grading curves determined for B.A.D.25 asphalt mixture

Table 3. B.A.16 final dosages

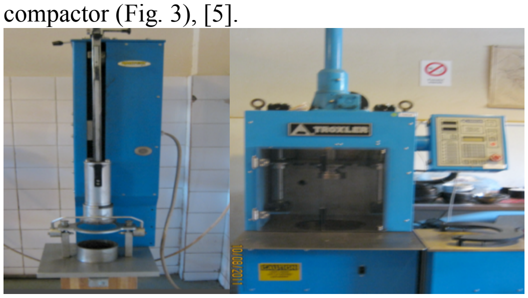
| Elements of the mixture | Ash content (%) | | | | | |
|---|---|---|---|---|---|---|
| | Dosage 1 | Dosage 2 | Dosage 3 | Dosage 4 | Dosage 5 | Dosage 6 |
| | 0 % | 2.5 % | 5.0 % | 7.5 % | 10.0 % | 12.5 % |
| grading 8/16 | 25.80 | 25.70 | 25.10 | 25.90 | 25.20 | 25.10 |
| grading 4/8 | 29.60 | 29.20 | 29.80 | 28.20 | 28.50 | 29.10 |
| grading 0/4 | 24.30 | 25.70 | 25.50 | 26.30 | 26.70 | 25.10 |
| natural sand | 6.20 | 6.20 | 6.10 | 6.80 | 6.50 | 5.60 |
| ash | 0.00 | 1.70 | 3.30 | 4.90 | 6.50 | 8.10 |
| filler | 9.50 | 6.70 | 4.70 | 1.90 | 0.00 | 0.00 |
| bitumen | 4.60 | 4.90 | 5.40 | 6.00 | 6.50 | 7.00 |

Table 4. B.A.D.25 final dosages

| Elements of the mixture | Ash content (%) | | | | |
|---|---|---|---|---|---|
| | Dosage 1 | Dosage 2 | Dosage 3 | Dosage 4 | Dosage 5 |
| | 0 % | 2.5 % | 5.0 % | 7.5 % | 10.0 % |
| sort 16/25 | 22.10 | 22.50 | 22.00 | 21.80 | 22.20 |
| grading 8/16 | 22.60 | 22.70 | 22.90 | 23.30 | 22.70 |
| grading 4/8 | 20.20 | 19.20 | 19.20 | 19.30 | 21.80 |
| grading 0/4 | 16.30 | 17.30 | 17.20 | 17.10 | 14.20 |
| natural sand | 7.70 | 8.60 | 8.60 | 8.50 | 7.10 |
| ash | 0.00 | 1.70 | 3.20 | 4.90 | 6.60 |
| filler | 7.20 | 3.80 | 2.40 | 0.00 | 0.00 |
| bitumen | 4.00 | 4.10 | 4.50 | 5.00 | 5.40 |

## 4. MANUFACTURING OF CYLINDRICAL SAMPLES IN LABORATORY

The cylindrical samples used in the research are Marshall cylinders realized with the help of the Marshall hammer by applying 50 blows on each side and cylinders manufactured with the gyratory compactor (Fig. 3), [5].



a) Marshall hammer b) Gyratory compactor

Figure 3. Equipment used in manufacturing the samples

## 5. EXPERIMENTAL RESEARCH CONCERNING THE PHYSICAL-MECHANICAL CHARACTERISTICS OF ASPHALT MIXTURES WITH FLYING ASH

Thus, following several attempts to determine the bitumen content, taking into account the slightly more absorbing property of the ash, 0.20 % … 0.30 % higher than the filler's, dosages were determined as shown in table 3 and 4 respectively, dosages for which the physical-mechanical characteristics were determined. Table 5 presents the results of the ordinary tests performed for the asphalt concretes B.A.16 and B.A.D.25.

The quality of the designed asphalt concretes was checked by comparing their values with those stipulated by the Romanian standard SR 174-1/2009 for the B.A.16 and B.A.D.25 concretes. The results obtained for the realized dosages are in compliance with the regulations.

If we considered the realized mixtures just from the point of view of the bitumen content and the filler used as filling material, the normal thing to happen would be the decrease of the Marshall stability of the respective dosages, and the flow index and the density to increase. As far as the use of flying ashes in the asphalt mixes instead of the filler, it is worth noticing from fig. 4 – 7 that this presents a reversed impact, but favorable for the mechanical characteristics. Practically, the Marshall stability increases and the flow index decreases, even for a higher bitumen content. The density decreases proportional to the content of ash used in the mix but not under the value stipulated by the standard. This is happening due to the lower density of the ash as compared to the filler.

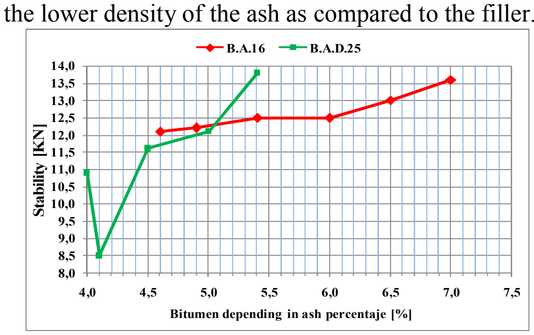



Figure 4. Marshall stability depending on the bitumen and ash contents for B.A.16 and B.A.D.25 mixtures

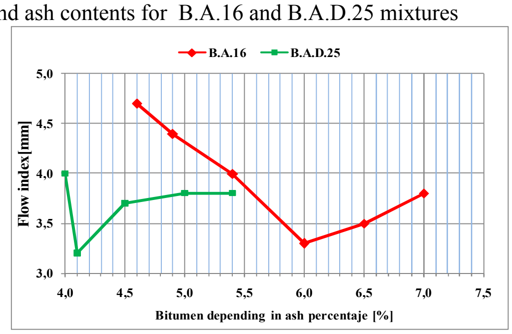



Figure 5. Marshall flow index depending on the bitumen and ash contents for B.A.16 and B.A.D.25 mixtures

Table 5. Physical-mechanical characteristics for a low bitumen content

| | Bitumen (%) | Ash (%) | Corrected stability KN | Flow index mm | Ratio S/I, KN/mm | Density Kg/m$^3$ | Water absorption (%) | Va (%) | VMA (%) | VFA (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| B.A.16 | 4.6 % | 0 % | 12.10 | 4.70 | 2.57 | 2450 | 1.80 | 1.38 | 16.53 | 91.66 |
| | 4.9 % | 2.5 % | 12.20 | 4.40 | 2.77 | 2420 | 3.25 | 3.26 | 17.81 | 81.70 |
| | 5.4 % | 5.0 % | 12.50 | 4.00 | 3.13 | 2400 | 2.20 | 3.75 | 18.91 | 80.19 |
| | 6.0 % | 7.5 % | 12.50 | 3.30 | 3.79 | 2350 | 1.90 | 6.28 | 21.11 | 70.24 |
| | 6.5 % | 10.0 % | 13.00 | 3.50 | 3.71 | 2300 | 2.75 | 8.01 | 23.20 | 65.47 |
| | 7.0 % | 12.5 % | 13.60 | 3.80 | 3.58 | 2290 | 2.55 | 6.97 | 23.94 | 70.90 |
| B.A.D.25 | 4.0 % | 0 % | 10.90 | 4.00 | 2.73 | 2400 | 3.70 | 5.60 | 17.71 | 68.39 |
| | 4.1 % | 2.5 % | 8.50 | 3.20 | 2.66 | 2360 | 3.50 | 8.05 | 19.17 | 58.02 |
| | 4.5 % | 5.0 % | 11.60 | 3.70 | 3.14 | 2330 | 3.95 | 9.14 | 20.53 | 55.49 |
| | 5.0 % | 7.5 % | 12.10 | 3.80 | 3.18 | 2330 | 3.20 | 8.96 | 20.95 | 57.23 |
| | 5.4 % | 10.0 % | 13.80 | 3.80 | 3.63 | 2330 | 4.00 | 7.55 | 21.28 | 64.53 |

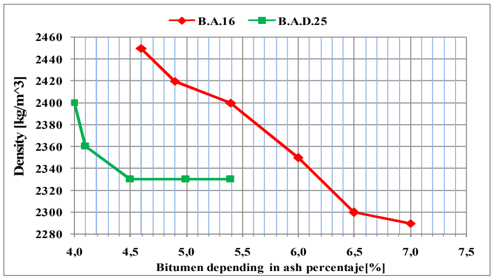



Figure 6. Density of Marshall samples depending on the bitumen and ash contents for B.A.16 and B.A.D.25 mixtures

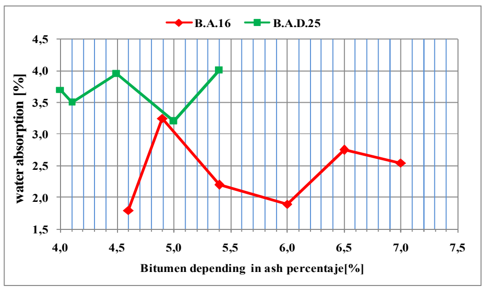



Figure 7. Water absorption depending on the bitumen and ash contents for B.A.16 and B.A.D.25 mixtures

Concerning the water absorption for the realized mixes (Fig. 7), a fluctuation can be noticed depending on the ash content. Although it would seem normal for the water absorption to decrease with the decrease of the density and the bitumen content, in this case, due to the ash in the mix, the density of the mixture decreases and the water absorption for more significant ash contents in the B.A.16 and B.A.D.25 asphalt concretes present a slight increase.

## 5. CONCLUSIONS

The physical-mechanical characteristics, determined through ordinary tests according to STAS 174-1/2009, present a good evolution of the asphalt mixtures depending on the ash content in the mix, the following conclusions being formulated:

- the Marshall stability is higher than the stability obtained on the mixture with filler in its composition;
- lower flow index; as the ash content increases the flow index decreases;
- lower dry density (due to the low density of the ash as compared to the filler's), but complying with the STAS, irrespective of the ash content determined in the mass of the asphalt mixture;
- higher voids due to the low density, but within the limits stipulated by the STAS, even when the bitumen content is higher;
- water absorption within the accepted limits, even for higher voids. This characteristic is due to the fact that the ash is hydrophobic.

The use of flying ashes in the asphalt mixes presents a series of advantages, among which:

- preservation of the environment, since the flying ashes represent a strongly impacting industrial waste due to its large quantities for whose storing large areas of land are taken out of the agricultural circuit;
- in the asphalt mixes, the ashes help to reduce the quantity of asphalt mixtures to ensure the thickness required for the layer. This aspect is linked to the lower density of the ash as compared to the filler's;
- lower costs of the asphalt mixture with ash, due to the fact that the ashes are wastes that cannot be valorized otherwise.

## REFERENCES


[1] *Badea, C.* – Contributions concerning the use of reusable wastes to produce new types of construction materials, Ph.D. Thesis, Timişoara, 2004.

[2] *Sergan, T.* – Mechanical evaluation of asphalt-aggregate mixtures prepared with fly ash a filler replacement. Faculty of Engineering and Architecture, Iki Eylul Campus, Anadolu University, Turkey, 2008.

[3] *Zimmer, F.V.* – Fly ash as bituminous filler. In Proceedings of the 2nd Ash Utilization Symposium Pittsburgh, Pa. 10-11, March 1970, United States.

[4] *Warden, W.B., Hudson, S.B. and Howell, H.C.* – Evaluation of mineral filler in terms of practical pavements performance. Proceedings of the Association of Asphalt Paving Technologists 101 – 110, 1952.

[5] *** - *SR EN 12697-30.* –Asphalt mixtures. Testing methods for hot asphalt mixtures. Chapter 30: Manufacturing of samples with the impact compactor.