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# The use of non-conventional fillers in asphalt mixtures for wearing course

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**Abstract**

The choice of a filler for the production of asphalt mixtures for road pavements is the synthesis of a careful analysis of various performance aspects. In particular, filler, for its fineness and chemical composition, plays an essential role for obtaining compact and mechanically suitable, but that can ensure the maintenance of these requirements over time, asphalt mixtures. Compared to mineral fillers produced by milling lithic material or by recovering dust from filters of plants intended for the processing and the production of stone aggregates, some fillers derived from the industrial world and also from the related by-products could be usefully considered among those products that a designer can select, for local availability, process economy and improvement of expected performance. Paper presented a comparison between a traditional filler (limestone powder) and two non-conventional fillers (cement and coal combustion fly ash) in order to supply to asphalt mix designers the potential of consider the latter materials, even in mixtures for road surface layers, characterized by high filler content, subjected to road traffic and different environmental conditions.

*Keywords:* Alternative materials, filler, asphalt mixtures, fly ash

## 1. Introduction

In recent years, research in the road paving sector has been strongly oriented towards studying the possibility of combining the supply of large amounts of construction materials with the sustainability of processes. Particular attention has been paid to the reuse of road demolition recycled materials in road pavements, such as reclaimed asphalt pavement (RAP), or to the recycling of waste materials or industrial by-products in different forms (Balaguera et al., 2018; Huang et al., 2007; Silva et al., 2019; Stimilli et al., 2016), and to the reduction of temperatures at which the hot mix asphalts (HMA) are mixed and placed on the road, i.e. warm mix asphalts (WMA) and cold mixtures (Capitão et al., 2012; Mohd Hasan et al., 2017). The dialogue between road construction sector and the industrial world has often focused on reusing and recycling, as partial or total replacement of natural aggregates in road pavement mixes, waste materials or by-products derived from industrial processes, especially those characterized by a consistency in mineral composition and in production quantity, such as for example the steel slags and the construction and demolition materials (C&D) (Herrador et al., 2012; Reposeiras et al., 2018; Skarf et al., 2017; Somasundaram et al., 2015). Although these materials often show excellent mechanical performances, their applications usually come with additional property requirements and technical restriction due to possible leaching of pollutants or to not completely inert behaviour (Autelitano and Giuliani, 2015; Gautam et al., 2018; Mohammadinia et al., 2015; Yang et al., 2018).

In regard to the finest fraction, this research trend has also been well received at an international level. But, alternatives to traditional fillers often find resistance among designers, also properly motivated by the fact that this fraction plays a key role on the one hand on bitumen/coarse aggregate adhesion and therefore on durability, and on the other on obtaining mixtures that can be easily produced in the plant and that allow the formulation of compact and resistant mixtures, especially for the wearing courses.

Paper presents a direct technical comparison between three different fillers, a traditional limestone and two non-conventional fillers, within wearing courses characterized by high content of bituminous mastic, i.e. skid-resistant asphalt mixtures. Specifically, cement represented the first non-conventional albeit expensive alternative, whose excellent function for road use has been confirmed in the sector literature; whereas fly ash derived from a coal thermal power station was the second one. The use of fly ash arose from the need to dispose of large quantities of waste from thermoelectric plant processes that already represent a successfully employed solution in the construction of road embankments and fills or in the production of cements and cement-base mixes.

## 2. Material and methods

Three different skid-resistant asphalt mixtures, each containing different types of finest fraction (particle sizes smaller than 0.075 mm) were designed and analyzed. Starting from the reference mix (M1_L), characterized by limestone filler, the other two were prepared replacing the filler with Portland limestone cement CEM II/B-LL strength class 32.5 R (M2_C) and coal combustion fly ash (M3_FA). Chemical composition of combustion fly ash is reported in Table 1.

Table 1 - Chemical composition of coal combustion fly ash.

| | $SiO_2$ | $Al_2O_3$ | CaO | $Fe_2O_3$ | MgO | $Na_2O$ | $K_2O$ | $TiO_2$ | $P_2O_3$ | $SO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Fly ash | 43.5 | 23.7 | 14.4 | 8.2 | 2.7 | 1.8 | 1.4 | 0.9 | 0.4 | 2.3 |

The mixtures were composed of 37% basaltic grit (6/12 mm), 27% dolomite grit (3/5 mm), 27% limestone sand (0/4 mm) and 7% finest fraction. Physical parameters of natural aggregates are shown in Table 2.

Table 2 - Physical properties of selected coarser aggregates.

| *Parameter* | *Standard EN* | *Basalt aggregate* | *Dolomite aggregate* | *Limestone sand* |
|---|---|---|---|---|
| Nominal size [mm] | - | 6-12 | 3-5 | 0-4 |
| Sand equivalent test (%) | EN 933-8 | - | - | 82 |
| Los Angeles coefficient (%) | EN 1097-2 | 14 | 13 | - |
| Density (kg/m$^3$) | EN 1097-6 | 2.76 | 2.76 | 2.65 |

As far as the binder is concerned, a 50/70 bitumen modified with elastomeric thermoplastic polymers was used. The skid-resistant asphalt mixtures were combined in accordance to the aggregate grading curve suggested by Italian government-owned road company corporation (ANAS) specifications (Tab. 3).

Table 3 - Grading curve of anti-skid asphalt mixtures

| Sieve [mm] | Cumulative passing [%] | |
|---|---|---|
| | Italian specification | Selected mixture |
| 15 | 100 | 100 |
| 10 | 85-100 | 85 |
| 5 | 30-45 | 37 |
| 2 | 20-30 | 26 |
| 0,425 | 10-20 | 16 |
| 0,18 | 9-18 | 13 |
| 0,075 | 8-13 | 7 |

Cylindrical specimens (Ø = 100 mm; h = 64 mm) were prepared with 4.6% of asphalt content by weight of the mixture at 165 °C and compacted using a Marshall hammer (EN 12697-30) with 75 blows/side at 155 °C. Specifically, five specimens for each mixture were prepared.

The experimental testing program, aimed at evaluating the possibility of using different types of fillers in skid-resistant asphalt mixtures, provided for a preliminary determination of the bulk density, by dimension (A) and sealed specimen (B) methods (EN 12687-6), of the samples on which some tests were subsequently conducted to check the acceptance requirements. On the one hand, stability and creep were evaluated using the Marshall test (EN 12697-34), i.e. conventional measurements of the resistance of the mixture to load-induced deformation. On the other hand, the performance of the surface texture and slip/skid resistance were analysed using the volumetric sand patch method (ISO/DIS 13473-1) and the British pendulum tester (EN 13036-4) respectively.

Preliminarily, some significant physical parameters of fillers (fineness modulus - FM, void volume in a dry-compacted mineral filler or Rigden voids - RV and the median diameter - $D_{50\%}$) and the interactions between fillers and bitumen (stiffening rate and stripping) were evaluated. Stiffening rate was determined as percentage variation between the softening point, using Ring & Bell test (EN 1427), of the filler-bitumen mastic (F/B=1 by weight) and the only-bitumen. The same amount of each filler was mixed with basalt aggregate (6/10) and bitumen to estimate the stripping through the Ancona Stripping Test (AST) or boiling water stripping test (Bocci and Colagrande, 1993).

## 3. Results

Firstly, physical parameters of fillers, their stiffening rate and susceptibility to stripping were reported in Table 4.

Table 4 - Physical properties, stiffening rate and susceptibility to stripping of selected fillers

| *Parameter* | *Limestone* | *Cement* | *Fly ash* |
|---|---|---|---|
| Fineness modulus [-] | 3.84 | 4.38 | 3.92 |
| Ridgen voids [%] | 38.05 | 45.79 | 39.08 |
| Median diameter [mm] | 11.95 | 17.97 | 15.87 |
| Stiffening rate [°C] | 8.75 | 7.75 | 9.25 |
| Stripped aggregate surface [%] | 46.2 | 20.8 | 22.0 |

The comparative analysis of the experimental results, in relation to the mechanical characterization tests, shows that there was a substantial equivalence between the Marshall values between the reference mixture (M1_L) and the skid-resistant mixture prepared with fly ash (M3_FA) (Tab. 5). The skid-resistant mixture with cement (M2_C) provided instead lower stability values, at the limit with the specification values (S ≥ 10.79 kN and MQ ≥ 2.95 kN/mm). The different response to the Marshall test of compared to the others was moreover consistent with the porosity results. For M2_C a porosity of about half a percentage unit more than other mixtures was registered.

Table 5 - Skid-resistance asphalt mixtures' properties

| *Mixture* | *Bulk density* | | *Porosity* | *Marshall* | | | *BPN* | *HS* |
|---|---|---|---|---|---|---|---|---|
| | *(A)* | *(B)* | | *Stability S* | *Flow F* | *Quotient MQ=S/F* | | |
| | *[kg/m3]* | *[kg/m3]* | *[%]* | *[kN]* | *[mm]* | *[kN/mm]* | *[-]* | *[mm]* |
| M1_F | 2.35 | 2.35 | 6.09 | 12.00 | 3.83 | 3.13 | 65 | 1.03 |
| M2_C | 2.36 | 2.35 | 6.73 | 10.78 | 3.75 | 2.87 | 64 | 1.08 |
| M3_FA | 2.32 | 2.33 | 6.21 | 11.88 | 3.80 | 3.12 | 63 | 1.06 |

The results of surface texture and slip/skid resistance performances deserve a careful examination: the HS value was about 1.03-1.08 representing a "coarse" macro-textures whereas BPN of 63-65 exceeds the values imposed by technical specifications, for which the skid resistance must have a BPN value > 50. It is appropriate to highlight that the skid resistance is mostly influenced by the coarser aggregate and the mineralogical composition of filler did not significantly affect this parameter.

## 4. Conclusions

The experimental investigation carried out on different mixtures showed the influence of different fillers on both mechanical and physical characteristics of HMA. In particular, the use of fly ash as filler replacement in skid-resistant mixtures an additive represents an interesting opportunity, also from an economic standpoint. This material could also be mixed in the appropriate proportions to the traditional limestone sand, wherever it should be partially or totally lacking in finer fraction. It seems evident the influence that coarser aggregates have on the surface characteristics of road pavements and that filler did not involve any noticeable variation. The use of alternative or non-conventional fillers such as fly ash, without prejudice to the necessary and specific process of management, storage and introduction into the HMA production plant, leads to performances that are completely comparable with those of other fillers of proven success and can be considered, after further pre-qualification and environmental assessment, as a solution that can be adopted for the most noble layers of road pavements.

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