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THE USE OF CRUSHED RUBBER IN ASPHALT MIXTURES OF ROAD PAVEMENTS

The presented article gives a brief overview on the possible use of crushed rubber from waste tires in asphalt mixtures. Advantages, disadvantages and difficulties of its use in road construction are also discussed. The results of sieve analysis and thermal analysis obtained on the samples prepared from waste rubber are discussed. The use of recycled tire rubber in road construction can contribute significantly to the reduction of environmental load.

Key words: ground tire rubber, hot mix asphalt, sieve analysis, thermal analysis.

Коротко описано можливості застосування подрібненої гуми зі зношених автошин в сфальтобетонних сумішах. Обговорено переваги, недоліки і труднощі її використання в дорожньому будівництві, результати гранулометричного складу і термічного аналізу зразків гуми, виготовленої з автошин, що були у вжитку. Використання гуми з автошин у дорожньому будівництві може зробити значний внесок у зниження навантаження на навколишнє середовище.

Ключові слова: гранулована гума з автошин, гарячі асфальтні суміші, гранулометрія, термічний аналіз.

Introduction

Waste tire rubber is an important source of secondary raw materials. All countries with developed road network have problems with waste tires. That is why in recent years a lot of effort in research has been devoted to the development of new effective methods for the recovery of waste tires or their disposal. Waste tires are the tires that completed their service life and they come mostly from passenger cars and trucks. The laws and regulations concerning the use of tires are very strict and this results in a large number of tires for disposal. It is estimated that worldwide over 1 billion tires complete their service life annually and become waste tires **Ошибка! Источник ссылки не найден.**.

Processing and properties of waste rubber

The Recycling Fund of Slovak Republic was financially involved in building a comprehensive nationwide waste collection system and processing of waste tires. The financial means were provided to build a technological line in Kechnec which belongs to the V.O.D.S. a.s. company. This company processes waste tires. Granulated rubber of various fractions is a major product of the processing of waste tires. Recycled rubber is widely used, e.g., in ground rubber modified asphalt, concrete filler, noise barriers, the construction layers of roads, rail crossings, car parks, coatings and paints, shoe soles, rubber tiles for playgrounds, roofing shingles, shock absorbers and filling material for artificial lawns, running tracks independent of the weather, tennis courts, fitness centers 0.

Processing method

Waste tires require processing prior further utilization. The method of the waste rubber processing significantly affects the reaction of the rubber with asphalt and the resultant properties of the asphalt-rubber binder. Rubber mixtures are relatively complex systems. Tire rubber includes an extensive range of different raw materials and components, mostly petroleum-based products. It consists of elastomeric matrix containing different types of natural and synthetic rubbers, which limit the future quality and properties of rubber products. If the tire cannot be used longer in its original form, then it can be used to manufacture new products.

There are two main methods of tire processing 0:

- shredding and grinding of the tire at ambient temperature, ambient ground rubber is obtained by this process
- grinding of the tire rubber below the ambient temperature (liquid nitrogen is usually used for cooling), cryogenically ground rubber is obtained by this process

The tires coarsely shred into particles with size of 300 mm (called big pieces), or small pieces with size of 10 – 300 mm are used in embankments, in layers of anti-vibration and drainage structures. The whole tires are often used in supporting walls.

Ground (0.15 – 16 mm) and crushed rubber (0.063 – 6 mm) is obtained by shredding and grinding of small pieces. Then the material undergoes the process of magnetic separation in order to remove steel reinforcement which is the skeleton of a tire, the fibers are blown away. The resulting product is rubber granulate which can be used in asphalt mixtures 0

Characteristics of recycled rubber

The main physical characteristics of recycled rubber are low density and elasticity. Tires are produced from the mixture of natural and synthetic rubber, filler such as soot, sulphur, polymers, oils, wax, pigments, and steel and polymer fibres. The chemical properties of recycled tire rubber which are essential for its use in structural engineering are usually related to the rubber chemical composition. The reactivity of rubber is also important since it is directly related to its potential impact on environment.

The pieces of tires are not reactive in ambient environmental conditions since they are a mixture of natural and synthetic rubber. When ground rubber is used as a modifier for asphalt binder, under specific conditions the reaction between rubber and the asphalt binder can take place. The preparation therefore requires exact temperature, time and type of mixing granulated rubber and asphalt binder. The size and texture of recycled material during the reaction affects the rate of reaction. During the reaction rubber particles become soft. The resulting product of the reaction is modified binder.

Two major processes are used for the incorporation of ground tire rubber in hot mix asphalt (HMA):

- the dry process, called rubber modified mixes, in which rubber amounting to about 3 to 5 % of the aggregate weight is added before the asphalt is introduced and mixing occurs
- the wet process, called asphalt-rubber, in which 18-26% tire rubber is reacted with asphalt at elevated temperatures (190 -218 °C) for one to two hours to produce a material suitable for use as a binder in HMA construction.

Principal differences between these processes include size of rubber (much coarser rubber is used in dry process than in wet process), amount of rubber (the dry process uses 2 to 4 times as much as the wet process), function of rubber (in the dry process the rubber acts more like an aggregate but in the wet process it acts more like the binder), and ease of incorporation into the mix (in the dry process no special equipment is required while in the wet process special mixing chambers, reaction and blending tanks, and oversized pumps are required).

According to the ASTM definition 0 asphalt rubber is “a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles”. By definition, asphalt rubber is prepared using the “wet process”. Caltrans specifications for asphalt rubber physical properties fall within the ranges listed in 0. Recycled tire rubber is used for the reclaimed rubber and is currently referred to as crumb rubber modifier (CRM)0.

The utilization of ground rubber – advantages and disadvantages

In general the positive aspects of utilizing ground tire rubber in hot asphalt mixtures are:

- the same volume of asphalt mixtures is made with less volume asphalt binder
- disposal of a large amount of waste, with less negative environmental impact, when compared with burning waste tires.

Disadvantages of this recovery method:

– increased costs for the preparation of modified binder (increased viscosity is a complication for laying the asphalt mixture).

Positive characteristic of ground tire rubber is its low density. The addition of ground rubber to the asphalt mix brings a higher frost resistance and resistance to fatigue and permanent deformation. As far as the impact of waste rubber on the environment is concerned the waste tire rubber in the road construction does not influence the environment by zinc oxide which this material contains.

Negative characteristics of tire rubber are low bulk density and low modulus of elasticity, both characteristics results in more difficult compaction of resulting asphalt mixture. The technology of hot asphalt mixtures production requires the exact temperature of mixing and storage time. During the mixing and storing the asphalt mixture becomes very sticky, and its preparation, storage and compacting become more difficult.

Testing of ground rubber – methods and techniques

Tests of materials have to be designed in accordance with valid standards 0. The properties of material are affected by its components. For the supplied samples of ground rubber the sieve analysis was done. The percentages of particles fractions in ground rubber are the result of this test. The chemical and physical properties of ground rubber were studied by nuclear magnetic resonance (NMR) and thermal analysis. Preliminary experiments using these techniques have been done and the results are promising. NMR result was published earlier in [0, 0].

Sieve analysis

In the dry process the rubber acts more like an aggregate. Aggregate grading is one of the fundamental properties of aggregates. For the sample of ground rubber supplied by V.O.D.S. a.s. the grading analysis was done. The sample (Figure 1) denoted A was tested.

Fig. 1. Sample of ground tire rubber

A – rubber granulate, the sample was tested without any previous treatment. The manufacturer specifies the fraction 0 to 1 mm.

Percentages of passing particles are listed in Table 1.

Table 1

The weight percentages of different fractions

Particle size (mm)	2	1	0.5	0.25	0.125	0.09	0.063	0
A (%)	100.00	68.97	13.94	2.29	0.30	0.00	0.00	0.00

Grading curves for the ground tire rubber from VODS a.s. samples is shown in Figure 2.

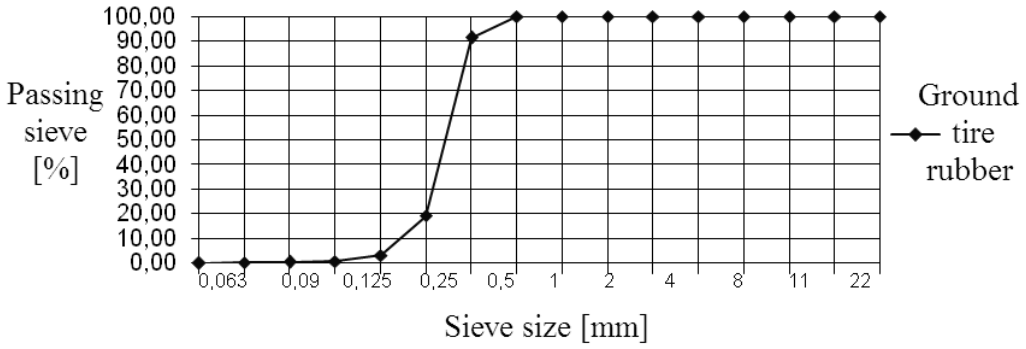

Fig. 2. Grading curve for the samples A

Grading curves show minimal differences in gradation for the as-supplied sample and the samples treated. The size of particles was from 0.009 to 1 mm.

Thermal analysis

Differential thermal analysis (or DTA) is a thermoanalytic technique, similar to differential scanning calorimetry. In DTA, the material under study and an inert reference are made to undergo identical thermal cycles, while recording any temperature difference between sample and reference [0]. This differential temperature is then plotted against time, or against temperature (DTA curve or thermogram). Changes in the sample, either exothermic or endothermic, can be detected relative to the inert reference. Thus, a DTA curve provides data on the transformations that have occurred, such as glass transitions, crystallization, melting and sublimation. The area under a DTA peak is the enthalpy change and is not affected by the heat capacity of the sample. In today's market most manufactures no longer make a true DTA but rather have incorporated this technology into a Thermogravimetric analysis (TGA), which provides both mass loss and thermal information. With today's advancements in software, even these instruments are being replaced by true TGA-DSC instruments that can provide the temperature and heat flow of the sample, simultaneously with mass loss [11].

Thermal analysis results are shown at Figure 3. The experiment was performed in air at heating rate of 10 °Cmin-1. Three exothermic peaks indicate that the decomposition of rubber granulate is a process which include three stages. The TG and DTA curves show no change up to approx 177 ^{o}C.

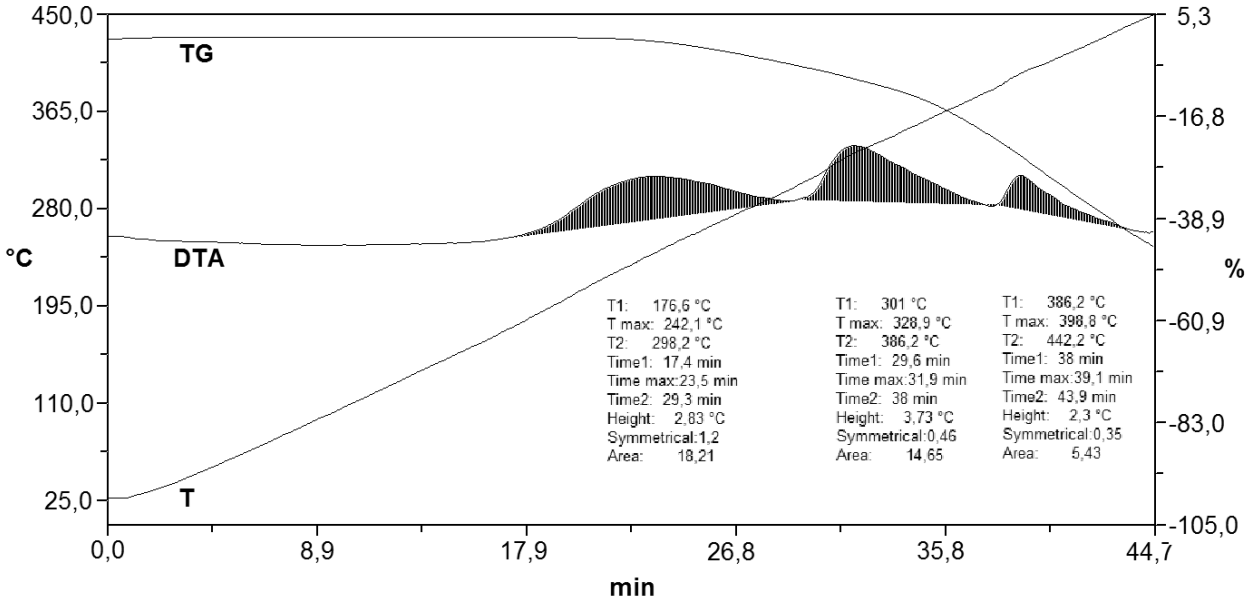

Fig. 3. TG and DTA curves of granulated rubber

Conclusion

The capacity of recycling industry in Slovakia is larger than the amount of used tires, which is produced in this country. In spite of this only about two thirds of them are processed because recycling of waste tires due to the large energy consumption is not sufficiently profitable. Utilization of ground rubber in road surfaces as an admixture to asphalt mixes can improve profitability of this branch of industry and in this way also to induce interest in recycling used tires in more extensive way. There are a large number of used tires from the past, a lot of them ended up at waste storage sites. Development of new materials with ground rubber which will be of better characteristics than these which are used now will help to accelerate waste tires recycling and waste tires could disappear from environment in the next few years.

Sieve analysis of the studied samples confirmed the declared gradation by producer 0-1 mm. TG and DTA analysis limit ground tire rubber processing up to 177 ^{o}C.

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