EVALUATION OF ASPHALT RUBBER IN COLD CLIMATE

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ABSTRACT

During the period of 2007-2009, the Swedish Transport Administration has performed about 20 road sections with Asphalt Rubber in various locations in Sweden. The technology of Asphalt Rubber has been obtained from Arizona in the United States. They have long experience of using asphalt mixes containing crumb rubber. Crumb rubber is based on recycling of tires, which are milled into rubber granules. Asphalt Rubber is produced by adding crumb rubber to the binder in a special shear mixer, and after a reaction time the new binder is used in an ordinary asphalt plant. This process is normally referred to as the wet process.

There were several goals for the introduction of this type of asphalt mix, in a cold climate like Sweden. Mainly longer technical lifetime caused by better wear resistance against studded tyres and less crack propagation in pavements on cement stabilized layers, but also some noise-reducing effects. In addition, the environmental aspects were an important issue for this project. Results so far have shown that this mixing technology works well in a cold climate. The test sections show good performance according to road surface measurements and performed laboratory tests. In order to assess lifetimes, additional follow up work is important in the future. It takes several years to determine if the additional cost of Asphalt Rubber gives a cost-benefit by longer lifetime, in reality, than conventional pavements. The results are so far promising and expectations are met.

Keywords: asphalt rubber, durability, crack propagation, wear resistance, mechanical properties

1 INTRODUCTION

In 2006 the Swedish Transport Administration began a project to evaluate Asphalt Rubber pavements for Swedish conditions. Experience was taken from the state of Arizona in the USA, where Asphalt Rubber is a well-tested type of pavement. The Arizona Department of Transportation (ADOT) has drawn up a specification for rubber bitumen/asphalt. A pilot study was conducted in 2006, which primarily involved studying environmental impact and experience from the USA, and in 2007 Asphalt Rubber was tested on a number of sections on different roads in Sweden. Some roads were executed both with Asphalt Rubber and traditional asphalt in order to be able to compare for example wear and durability. Rubber Asphalt was laid on a section of the E6 where cement-bound base courses had led to cracking in the wearing courses from the stresses that arise in the cement layer when the temperature changes. Our hope is that the rubber asphalt will absorb and distribute these forces better so that cracking will be slowed or prevented. Also the open concept has been tested with success on a short section of a minor road, but with severe problems on a larger road laid late in the autumn.

Almost all tyres are collected and recycled in Sweden today, most being used to produce energy primarily in the cement industry. Some go to produce artificial turf and a small proportion of the recovered tyres end up in children's playgrounds. The challenge is to be able to exploit the rubber's positive qualities to modify bitumen for use in asphalt pavements.

The earlier studies of Asphalt Rubber were conducted in other countries, mainly in the USA. The results of the studies are good and they show that:

- Useful life increases with Asphalt Rubber
- Fewer particles are released from the asphalt to the atmosphere with Asphalt Rubber
- Asphalt Rubber can reduce traffic noise on our roads
- Hazardous substances are not leached out of the rubber when it is mixed with bitumen and used in asphalt in this way

The Transport Administration's aim is determine the benefits of rubber asphalt and to see if there are any obstacles to introducing it in Sweden. Asphalt Rubber has been is use in the USA for 25 years and the technique is now spreading around the world. Asphalt Rubber is beginning to become common practice in many places, for example Canada, Brazil, Australia, South Africa and parts of Europe. It is expected to have a considerably longer life than traditional asphalt, which benefits both environment and finances. Fewer measures save both money and emissions. Asphalt Rubber also has qualities that make it possible to reduce the noise caused by traffic.

Amount of rubber pavement produced 2007-2009

- Over 60,000 tons of asphalt compound
- > 60 km of road
- ~15 road objects
- Over 1,000 tons of rubber granulate (0-1 mm) used

2 EQUIPMENT FOR CRUMB RUBBER

In the manufacture of Asphalt Rubber containing asphalt rubber bitumen special mixing equipment is used which is docked with the asphalt plant. The equipment has control systems for mixing the asphalt and safety functions that stop the equipment if the mixture is not correct.

Figure 1: Crumb rubber and rubber blender connected to an Asphalt plant.

The method used in Sweden today is the so-called wet method, i.e. rubber granulate is mixed into the bitumen. Asphalt Rubber bitumen is then added to the asphalt plant in the traditional manner. The proportion of rubber granulate in the binder is approximately 17-20 pw, which means that the amount of rubber mixed in is approximately 1.5-2% of the total quantity of asphalt compound based on a content of asphalt rubber bitumen of approximately 8%. The temperature of the bitumen being added must be at least +175 °C and the rubber and bitumen must be allowed to react for at least 30 minutes while being stirred and circulated.

Rubber granulate is made by shredding worn-out tyres, which can be some at varying temperatures. For making Asphalt Rubber bitumen (AR), shredding at room temperature is to be preferred. Rubber granulate from shredded industrial rubber is not suitable for this application (since industrial rubber consists of many different qualities of rubber). The rubber granulate must come from car and/or truck tyres. The proportions of car and truck tyres must be kept constant during the production process. The rubber granulate supplier must state how it was manufactured and the approximate ratio of car tyres to truck tyres.
The rubber granulate must consist or 0/2 mm grade rubber and must not contain more than 0.01% steel or other impurities, nor may it contain more than 0.5% textile material. The rubber granulate must have a specific weight of 1.15 ± 0.05. The moisture content may not exceed 0.2 pw.

3 LABORATORY TESTS

At the Swedish Transport Administration’s request VTI conducted tests and measurements on a number of objects to verify different properties such as friction [3], noise, rolling resistance [4] and functional characteristics by means of laboratory experiments [1]. Laboratory tests have also been carried out by Swedish contractors (Svevia and Skanska) and by Arizona State University (ASU) [2].

The purpose of the investigations was to study whether the properties of rubber pavements match the properties of equivalent conventional pavements.

Figure 2: Manufacture of sample slabs

From the studies conducted of a Gap Graded Asphalt Rubber mix (GAR 16) in question, it is clear that it meets the Swedish requirements concerning equivalent wearing course layers. The factors where the Asphalt Rubber shows the most positive properties are primarily good resistance to wear and slow crack propagation. The pavement also shows good durability.

The Asphalt Rubber shows good characteristics in the durability tests conducted, both as regards the standard method for determination of water sensitivity and the winter conditioning method developed at VTI. The indirect strength ratio and the stiffness modulus ratio, before and after conditioning, is over >85% in both tests.

Resistance to wear measured with the Prall method shows good results with Prall values below 20 ml. Prall wear in winter-conditioned samples only gave 1-2 units higher Prall values. (However, it is uncertain whether the Prall method correctly reflects the wear caused by studded tyres on Asphalt Rubber).

Results from stability test according to EN 12697-25 (dynamic creep test) shows ordinary value of about 15 000 micro strain and fatigue test according to EN 12697-24 shows that this mix are approximately in the same level as the reference mix, SMA 16 70/100 (*Figure 3*).

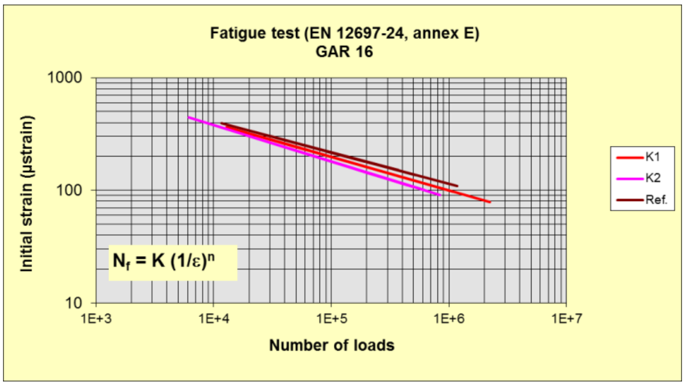

Figure 3: Fatigue test. (K1 and 2 is mix from Lane 1 and 2 with GAR 16 mix and Ref is an SMA 16 70/100)

Crack propagation tests have shown good results. The Asphalt Rubber can cope with considerably more passages before cracks originating in the bottom of the pavement penetrate to the surface, compared with a reference pavement consisting of SMA 16 70/100 (*Figure 4* and 5).

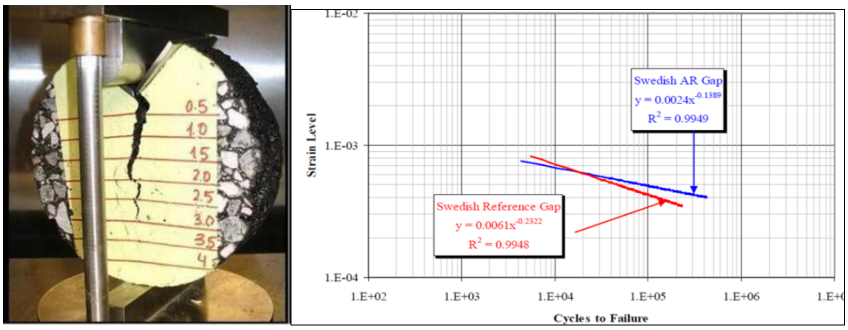

Figure 4: Crack propagation. ”C*Integral Test” (Arizona State University)[2]

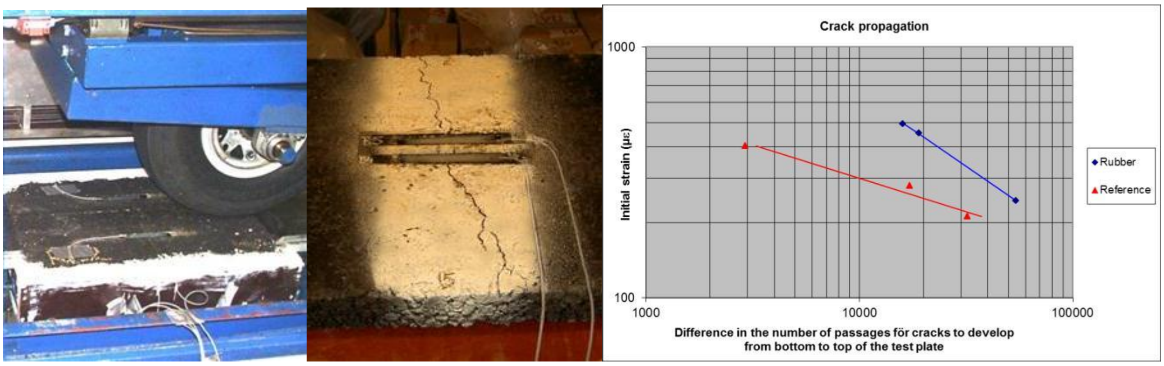

Figure 5: Crack propagation. Wheel Tracking Test (VTI). Asphalt rubber (GAR 16) and Reference (SMA 16 70/100) [1]

Results so far have shown that rubber pavements fully meet today's requirements concerning rubber pavements as regards stability, flexibility, fatigue and durability, and have somewhat better properties as regards cracking and resistance to wear. Regarding resistance to wear, however, it is uncertain whether the Prall method (EN 12697-16) reflects wear from studs correctly for this "elastic" product.

4 FIELD MEASUREMENTS

At the request of the Swedish Transport Administration, VTI has carried out recurring measurements of noise, rolling resistance and friction on a selection of Asphalt Rubber pavements and on a large number of conventional road pavements.

All Asphalt Rubber pavements have very good friction, both directly after laying and after several years of use. Noise measurements have shown interesting noise reductions with the open-graded variant but not with the gap graded variant. Rolling resistance does not appear to be affected by the rubber mixture.

Figure 6: VTI's friction measurement car with the braked measuring wheel located under the car.

Figure 7: Towed recording device for noise measurement closed (measuring) and open.

Figure 8: Towed trailer from GUT for measurement of rolling resistance. Photograph courtesy of GUT.

5 ENVIRONMENTAL INVESTIGATIONS

"The environment shall be free from substances and metals that have been created or recovered from society and can threaten human health or biodiversity". (Swedish National Environmental Objective; "A non-toxic environment")

The environmental studies carried out on rubber pavements concern both the surrounding environment and working environment aspects. In the early stages of the project the Swedish Transport Administration conducted studies of the literature and made investigations of their own to ensure that Asphalt Rubber can be used as road pavement without any negative environmental impact. This investigation says that most of the studies conducted elsewhere (most of them in the USA) do not show any great differences in emissions to air between use of conventional pavement materials and pavement materials containing a certain proportion of rubber tyres.

In the aspect of Asphalt Rubber in cold climate wear from studded tyres have been investigated. Wear on road pavements from studded tyres causes emissions of inhalable particles (PM_{10}), concentrations of which in the surrounding air are regulated according to an environmental quality norm. One way to reduce particle emissions is to adapt the pavements' characteristics. In two projects a total of three different asphalt pavements with rubber were tested against reference pavements, with the aim of investigating how the addition of rubber to the pavement's bitumen phase affects particle formation.

In order to study the wear particles separately without particles from vehicle exhaust gases and other anthropogenic and natural sources, the particles must be able to be generated and sampled in an environment where other sources are minimal. This was able to be achieved by placing the measuring instruments in the sealed room around VTI's circular road simulator, which is normally used to study wear on different types of road pavements and tyres. The circular road simulator consists of a 16-metre long circular track that can be paved with any road pavement. The simulator rotates around a central vertical axle to which six wheel axles are attached, on which different types of tyre can be fitted. Four of the axles are powered and are driven by electric motors. During the test, the wheels are lowered to the track until the desired axle pressure is reached and the machine is then rotated by driving the wheels. The speed can be continuously varied up to 70 km/h. At speeds above 30 km/h an eccentric motion can be switched in, which means that the wheels are not running in the same track all the time but moving over almost the entire width of the pavement.

Concentrations and size distributions of generated PM_{10} were studied using a variety of instruments. In the first project, samples of PM_{10} were taken and the particles' chemical and morphological properties were analysed, partly by means of scanning electron microscopy elemental analysis (SEM/EDX) and partly by means of particle induced X-ray emission (PIXE). Any differences in wear and micro-texture were also measured in the first project.

When testing studded tyres in the circular road simulator, a fraction of very small particles, called ultra-fine particles (<100 nm) also occurred. The particles are not worn-off stone material, the dominant type of PM_{10}, but have a more complex and volatile composition. The source and formation process are at present unknown, but are connected to the studs in the tyres. Any effects on this particle fraction were also studied in both projects. All pavements were tested with Nokian Hakkapeliitta type 4 studded tyres [5] [6].

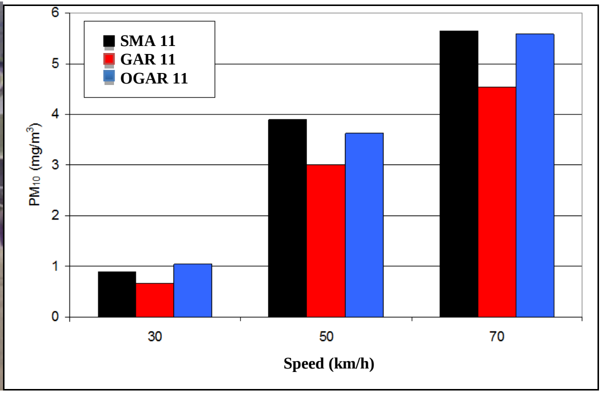

Figure 9: Road simulator at VTI. Median values of PM_{10} (TEOM) over a fifteen-minute period at the end of speed ranges 30, 50 and 70 km/h for three different pavements.

In summary, the following conclusions can be noted:

- Mixing rubber in the asphalt generally appears to reduce the generation of PM_{10} in case of wear from studded tyres but the reduction is dependent on the design. For example, the open-graded OGAR 11 pavement gave no reduction in the second project.
- Ultra-fine particles are formed, as in all experiments involving studded tyres, but the effects of the pavements with rubber mixed in on these particles' concentrations is not consistent.
- The stone material in the first project (quartzitic sandstone), in particular the reference pavement, gave rise to higher particle concentrations than the material in the second project (rhyolite). The size distribution of the PM_{10} also differs somewhat between the stone materials.
- The size distribution of the PM_{10} from the Asphalt Rubber pavements is similar to that from the reference pavements in both projects, but the design appears to affect where in the distribution the reduction mainly occurs.
- There is no difference as regards the elemental composition of individual PM_{10} particles. The PM_{10} appears to consist exclusively of fragments of the pavements' stone material. Particles from tyres or bitumen have not been able to be detected by means of SEM/EDX.
- The elemental composition analysed with PIXE shows no distinct difference between the two pavements. Unlike in the SEM/EDX analysis, however, the elements associated with tyres and possibly bitumen can be noted. Sulphur and zinc occur, particularly in the finer fractions and are considered to come from tyres.
- Wear from the pavements in the first project developed in a very similar fashion after some initial running in. In the second project, the open graded asphalt rubber mix (GAR 11) wore slightly faster than SMA 11 while under water spray, but somewhat more slowly during the dry measurement. Measurements of OGAR 11 are regarded as uncertain because of its open-graded design. These wear measurements are however only indications. Proper wear measurement is carried out with water spray and many more rotations.
- The micro-texture, represented by the friction value, did not differ significantly between the pavements in the first project. (Micro- and macro-texture were not measured in the second project.)

6 CONCLUSION

Conclusion of the advantages and disadvantages of the different techniques and environmental characteristics of Asphalt Rubber are based on the trial sections executed and the investigations made within and outside the project.

The conclusions arrived at during the course of the project, in summary:

- Asphalt Rubber functions well on roads with heavy traffic
- Asphalt Rubber has good crack-reducing capabilities
- No increased environmental risk from using Asphalt Rubber

- Technical instructions have been drawn up for the concept with gap graded mix (GAR)
- Open-graded types of pavement for noise reduction are still under development

The Swedish Transport Administration intends to carry out to implement and put Asphalt Rubber into operation in Sweden.

Activities for this are:

- Inclusion of Asphalt Rubber in the toolbox of methods for administration of the road network (GAR).
- Continued follow-up of the development of already produced sections of Asphalt Rubber pavement.
- Dissemination of information about Asphalt Rubber and encouragement of collaboration between client, producer and suppliers.
- Conduct a new project to identify more applications for Asphalt Rubber, deliver courses on Asphalt Rubber and carry out a number of demonstration projects:
  - Investigation of the use of Asphalt Rubber Bitumen in other pavement layers in an asphalt design with the potential to reduce the total pavement thickness while maintaining useful life.
  - Investigation of the impact of additives/techniques that allow the temperature to be reduced during manufacture.
  - Continued development of international development of using rubber as a performance enhancing additive to bitumen and asphalt pavements

Figure 10: Asphalt Rubber (GAR 16) on a high traffic road in the Gothenburg area (E6, Ullevimotet)

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