The impact that crushed rubber can have on the quality of bitumen and asphalt concrete

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Abstract. The results influence of finale dispersed rubber crumb on the properties bitumen and asphalt concrete are presented in the study. The parameters of the optimal regime of bitumen and rubber crumb mixing are established. The influence on the rubber crumb mixing with bitumen or added directly in the process of asphalt concrete mixing on the properties of asphalt concrete is studied. The effects that fine rubber has on the properties of petroleum bitumen and asphalt concrete are measured. The best options available for combining bitumen and rubber crumb are given. Moreover, it is also described how and to what extend crumb can influence the quality of rubber-bitumen binder for roads and how rubber-bitumen binder is affected when crump is added to this asphalt mixture. The influence that rubber crumbs have on the quality of bitumen and asphalt concrete. In the study, the influence of crumb on the properties of bitumen and asphalt concrete are shown. The conditions at which a high-quality mixture of bitumen and rubber crumb can be produced. Furthermore, the effects of crumb on the rubber-bitumen binder and the direct introduction of crumb into mixture are thoroughly investigated.

1. Introduction
Since old tires are considered resistant to various factors, they are regarded as one of the pollutants which affect our surroundings. Those tires substantially contribute to the amount of polymer waste worldwide, with 300 million pieces of tires being produced each year in Europe alone.

According to official statistics of the state Committee of Ecology of the Republic of Uzbekistan, the recycling rate of worn-out tyres is too low, at 14-15 % period [1].

The State Committee of Ecology of the Republic of Uzbekistan states that only a minority number of those tyres is recycled, about from 14% to 15% of the total. Therefore, the recycling of these tires is of great environmental and economic concern in almost all developed countries.

At present, as we now know that the majority of old tyres end up either in landfills or along the courtyard, not to mention people who burn them which has a detrimental effect on the environment and humans alike. On top of that, when they are burned, toxic smokes are released into the air, leading to poor air quality. Most importantly and surprisingly, when they are dumped, it takes over a century for them to decompose in the soil.

The constant and increasing pressures on the road by various modes of transport make it difficult to provide people with high-quality and smooth roads. For this reason, new technologies are necessary to improve the quality of bitumen which can also extend the maintenance period [2]. The use of rubber crumb for the improvement of road bitumen and asphalt concrete can be effective, by which along the way it also helps deal with the burning global issues, particularly mass disposal of old tyres [25, 26].
2. Methods
The project has thoroughly studied the parameters of oil-free bitumen production using model equipment.

Experiments to test the physical and mechanical properties have been carried out in newly-equipped laboratories of the country applying at a wide range of industrial facilities. Predominantly, the project has received an international certificate of compliance with ISO9001 for new kinds of products.

3. Results and Discussion
The use of rubber crumb for the production of asphalt concrete mixtures is not new since it has been used from the 1950s onwards [7, 9, 10, 14, 17, 19, 20, 23].

If we directly add rubber crumb to asphalt concrete mix, which is simple and without labour intensive, we cannot improve the quality as we expected as rubber can stick out from the road which can lead to destruction. A more efficient way of producing high-quality asphalt concrete is to use rubber crumb for preliminary improvement of bitumen, with further process of producing asphalt concrete mixture, which is mostly used method in many countries [1, 3].

The project which involves collecting old tyres from the population, enterprises, and various sections of the economy in Uzbekistan has been set up by «Tashkent tyre repair». By only giving away your unusable tires to the company, we can contribute to tackling those environmental issues [2].

The problem involving recycling old tyres exists worldwide and approximately 900 million of them are produced, with only 20% of them being used for the second time. Moreover, the rate of an increasing number of old tyres is accelerating with the corresponding growth of the vehicles. Worn-out tyres being damped or just thrown away is not a new phenomenon for us, which seriously damages many ecosystems.

In Uzbekistan, as pioneering of the project, bitumen for purposes of construction was extracted from waste oil and fat plants. This was developed by one of the domestic start-up projects backed up by the government- the Khorezm enterprise 'Scientific center for anti-corrosion isolation'. The objective of the project is successful commercialization and thereby creating technology that can substitute for imported oil-construction bitumen and export this breakthrough method throughout the world.

The project has also thoroughly studied the parameters of oil-free bitumen production using model equipment. Experiments to test the physical and mechanical properties have been carried out in newly-equipped laboratories of the country applying at a wide range of industrial facilities. Predominantly, the project has received an international certificate of compliance with ISO9001 for new kinds of products. Samples of oil bitumen were presented at many conferences, even in international ones in Asia, Europe, and CIS countries [4, 6, 8, 12, 13].

Generally, the cost of bitumen per ton is in the range of 2.5 million soums and 2.6 million soums, while it is sold for 3.5 million soums in territories of Uzbekistan, compared to 600 US dollars overseas. With the high production of bitumen produced from oil, it is more expensive on the stock exchange (approximately from 4.5 million soums to 5 million soums per ton).

Research result
For the experiment BND 60/90 bitumen produced locally was used. Crushed rubber with a size of 0.1 mm was obtained from tyres (Table 1). Paddle mixer equipped with heat was used to create the mixture of oil bitumen and rubber crumb.

| Table 1. Technical properties of BND 60/90 bitumen |
|---------------------------------------------------|
| **Indicators**                                  | **Value** |
| Penetration, 0.1 m, with 25°C                   | 77        |
| Softening point                                | 47.9      |
| Elongation sm, with 25°C                       | 80        |
| Fragility temperature, °C                      | -20       |
The process of preparing the modified binder was divided into some set of stages: Firstly, the substance (bitumen) was given a heat up to 180°C. Crushed rubber which was put into bitumen accounted for 6% - 12% of the mixture. To lowing this, the mixture was rotated at the speed of 1000 turnover in minutes in the agitator shaft, we found out the proper amount of time and the effects it can have on the quality of the mixture[18; 22]. The bitumen binder was mixed as much as 4 hours. As a consequence, we figured out that when the penetration is at 250°C, the solid substances started to soften. From this, we also studied that within the first hour of mixing, there was a change in the quality of binder, which we hope will not change much in the long run (Fig-1).

![Figure 1. Effect of mixing time on penetration and softening temperature of a binder](image)

Having said that it became clear that a maximum one hour was enough for mixing crushed rubber and bitumen [11, 12, 13, 16]. High dispersion of the rubber crumb is the reason why it took only an hour. The information about bitumen improved with a rubber crumb is given in Table 2.

**Table 2.** The effect of rubber crumb on the properties of bitumen.

| Astringent           | $P_{25, 0.1 m}$ | $T_p^\circ C$ | $T_{chp}^\circ C$ | $D_{25, sm}$ |
|----------------------|-----------------|---------------|-------------------|-------------|
| BND 60/90            | 77              | 47.9          | -20               | 80          |
| BND 60/90+6%         | 45              | 55.1          | -18               | 64          |
| rubber crumbs        |                 |               |                   |             |
| BND 60/90+9%         | 40              | 39            | -17               | -           |
| rubber crumbs        |                 |               |                   |             |
The rubber was extracted from rubber-bitumen binder by three sets of clear stages: In the first place, benzine was introduced in the binder, in which the binder was dissolved. Following the dissolution of binder, rubber pieces were taken with the help of filter paper. Once it is added to bitumen, rubber particles slightly stuck out from the bitumen. As a result this forms a spatial grid in the rubber-bitumen binder, which became clear by swellings of strands of rubber pieces. Besides bitumen and rubber didn't dissolve well, implying that when bitumen reacted with rubber there were seen some changes. To find out the properties of asphalt concrete, a mixture of gramolometric type 'G' was employed according to [24] as this concrete isn't composed of gravel and ut also shows great promise to take the role of binder in the formation of physical and mechanical properties of asphalt concrete.

The mineral part of asphalt concrete mainly includes granite screenings (92%) and a small quantity of limestone (8%). By means of an optical microscope it is revealed structure [5,15,22].

The quality was tested at the optimal binder content, which is indicated by the max strength of asphalt concrete at 20 and 5000C. The most appropriate amount of BND 60/90 bitumen is 8%; however, when it is modified with a rubber crumb, there can be seen a partial increase in that amount, thereby the viscosity of the binder increases. If we put rubber crumb straightly into the half-ready composition, a slight increase in the quantity of binder can be experienced (to 8.5%) because the rubber crumb absorbs light fractions of bitumen more.

The experiment involving 6% rubber crumbs of the total mixture is carried out as follows: Onto the heated screen (1800) the rubber crumbs were added to mineral powder before it was 'dry' mixed for 2 minutes. Finally, hot bitumen was put into the mixture and this mixture was 'wet' mixed for 3 minutes.

A further point of interest is that, both methods proved effective (the combination of rubber crumb and BND 60/90 and direct introduction of rubber crumb into the production of asphalt concrete). It turned out the more we add rubber into the mixture, the better the quality of asphalt concrete is. For instance, when it is heated up to 200°C, the strength of it goes up from 3.3 MPA to 4.8 MPA, only when rubber crumb accounted for 12% of the mixture.

Similarly, with 500°C heat, it also increases from 1.48 MPA to 2.23 MPA. Consequently, the more there are rubber crumbs in the binder, the better the properties of asphalt concrete; however the intensity of increase of strength declines with the increasing amount of additives. This led to the conclusion that 6% of rubber crumb is the optimal amount.
When rubber crumb put directly into the rotating asphalt concrete mixture, the physical and mechanical properties of asphalt concrete become lower in indicator than the previous modification of bitumen, owing to significantly shorter duration of reaction between particles and bitumen fractions.

| Type of binder | Binder quantity % | P g/sm³ | W, % | Property metrics | Water resistance coefficient |
|----------------|-------------------|--------|------|------------------|----------------------------|
| BND 60/90 +6% rubber crumbs | 9.0 | 2.29 | 2.8 | 3.30 R20, MPa | 0.96 |
| BND 60/90 +9% rubber crumbs | 9.5 | 2.25 | 23.7 | 2.06 R50 MPa | 0.98 |
| BND 60/90 +12% rubber crumbs | 9.5 | 2.23 | 4.6 | 2.25 R0 MPa | 0.90 |
| BND 60/90+6% rubber crumbs | 8.5 | 2.28 | 3.5 | 6.94 R0 MPa | 0.88 |

4. Conclusions
The effectiveness of using rubber crumbs for the improvement of bitumen and asphalt mixture has been tested and confirmed.

Due to the proper amount of rubber crumb in the range between 6% to 12%, there can be seen several improvements both in bitumen and asphalt concrete.

The effect of rubber crumb in the composition of the binder on the resistance of asphalt concrete has been shown, on the compression alike.

For this process to take place there is no need for new and expensive technologies, with only one equipment that can do that.

The more efficient way of improving bitumen is turned out to be the use of rubber crumb before the process rather than a direct introduction into asphalt mixture.

Moreover, if we add crumbs to the composition, the quality of asphalt concrete improves as it is not unlikely to see the sticking-out crumbs on the surface of the concrete.

The addition of crumb rubber to bitumen has several beneficial effects on the binder properties with respect to short and long term ageing, cohesion, plasticity range.

The higher temperatures and binder contents of modified binder mixes meant workability is not compromised but has a consequence for installation.

Improvements to the binder also reflected in better performance in surface courses and binder courses compared with a similar control mixture. Particularly noteworthy is the significant improvements in durability parameters. It should be noted that the mixtures adopted in this study were recipe mixtures, optimization should be possible.

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