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A REVIEW OF THE BEST EXPERIENCE ON CRUMB RUBBER – DRY PROCESS MODIFIED ASPHALT MIXTURE PERFORMANCE

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Abstract

The use of crumb rubber made from end of life tyres for asphalt mixtures modification in order to improve their properties or just utilize waste products may be considered as potential solution. Crumb rubber can be used as a bitumen modifier (wet process) or supplementary component of the asphalt mixture (dry process). Dry modification process has more potential due relatively unsophisticated technology and higher possible to use amount of crumb rubber comparing to the wet process. The performance of asphalt mixtures modified by dry process mainly depends on several factors as crumb rubber type, content and size. However, limited number of publications reported the results of dry method crumb rubber modified asphalt mixtures performance. This paper summarizes the latest findings from literature review on the modification technologies and specifications related to dry modification process, the effect of crumb rubber type and amount on modified asphalt mixture performance in terms of stiffness, rutting resistance, water sensitivity, resistance to fatigue and low temperature cracking. The algorithm of crumb rubber modified asphalt mix design was introduced.

Keywords: tyre recycled rubber, crumb rubber, dry process, rubber modified asphalt mix

1 Introduction

Each year increasing amount of vehicles is the reason of endless number of used tyre, which now is a worldwide problem. Nevertheless, according to European Tyre and Rubber Manufacturers' Association (ETRMA) 3.5 million tonnes of used tyres were collected and treated for material recycling or energy recovery [1]. One of possible solution may be tyre recycling [2, 3]. Recycled tyres rubber can be reused in other products. One popular way is to obtain crumb rubber from tyres and to use it in road section [3]. In order to effectively apply crumb rubber into pavement the most rational process must be chosen. There are two traditional ways to do it: wet process and dry process. Many researches prefer wet process [4–7] because it has better performance than dry process. Usually better performance is caused by adhesion between binder and crumb rubber, because in wet process firstly are mixed binder and crumb rubber, while in dry process binder and crumb rubber are added directly into mixer with the others mixture components. Due to, uncertain bond is form between crumb rubber and binder in dry process. Nevertheless, from 2 to 4 times higher amount of crumb rubber can be used during dry process [4, 7, 8]. Moreover, dry process does not require any special equipment and it is more easier to apply crumb rubber into mixture because crumb rubber is added to mixture into common mixer just before binder [4, 9, 10].
Moreover, there is lack information of amount of required crumb rubber, how to correctly ap-

ply crumb rubber to asphalt mixture, if additives are needed or not. This article/paper represents literature review of general crumb rubber applying into asphalt mixture in dry process.

2 Existing crumb rubber modifying technologies

There are two main technologies of applying crumb rubber into asphalt mixtures. First one is wet process, the second one is dry process. Essential difference between these methods is that crumb rubber is added to into bitumen in wet process and like other component of mixture in dry process (Fig. 1). Dry process is described more in details (mixing queue, temperature, time) in 2.2 paragraph.

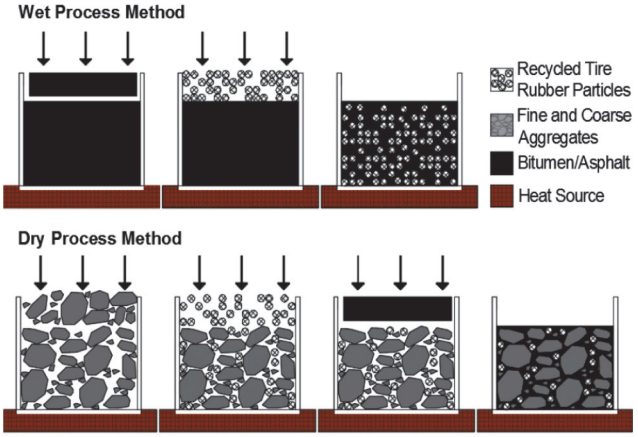


Figure 1 Wet and dry processes principles [11]

2.1 Crumb rubber size and amount in dry process

In the past, there were popular to use larger size crumb rubber, which could be up to 10 mm [8, 12, 13], but due to poor performance of asphalt mixture, smaller particles were started to use. It is important to note that smaller crumb rubber particles react faster and better with bitumen. Moreover, swell up to five times while contacting with the binder, because crumb rubber absorbs binder molecules. Due that fact, some researches advice to increase the amount of binder [14, 15].
Nowadays most commonly used amount of crumb rubber in dry method is 1 – 3 % by total weight of mixture [8, 9, 14, 16–19]. However, Moreno et al. [5, 20] used 0.5-2.0 % crumb rubber, which size ≤ 0.6 mm.

2.2 Mixing procedure in dry process

In many cases this will not be necessary as this template is programmed In order to correctly apply crumb rubber into mixture authors [9, 18, 21, 22] suggest following steps. Firstly, aggregates are preheated at 175 - 190 ºC and mixed. Secondly, crumb rubber is added to mixture and again mixed and mixed for 1 - 1.5 min, while Arabani et al. [9] and Moreno et al. [5] suggest mixing 20 seconds and according to technical regulations by FGSV [22] it is possible mix only 10 seconds. Thirdly, binder, which was preheated at 160 ºC, are added to the mixture and once again mixed for 1 - 2 min at 175 - 190 ºC. Finally, mixture is conditioned in the oven at 160 ºC for 60, 90 or 120 min [5, 6].

2.3 Crumb rubber additives

Using unmodified crumb rubber usually cause poor performance asphalt mixture's properties. Poor performance mostly comes from insufficient adhesion between crumb rubber and bitumen.
One of possible additives are filler and cross-linking agent modified crumb rubber. Usually this additive consists of 62 – 65 % crumb rubber, 20 – 25 % soft bitumen, 15 – 20 % filler and small amount of cross-linking agent. Soft bitumen improves viscosity and workability even if high amount of crumb rubber is used while filler is used to improve interaction between crumb rubber and bitumen. Better adhesion leads to reduced water sensitivity. Elastomeric crumb rubber particles evenly mixes with bitumen, then filler molecules creates an interconnected network with the rubber particles, thereby, forming a cohesive blend of asphalt, rubber, and the stabilizer [23]. This type modified crumb rubber additive is suitable for use with any type of Hit Mix Asphalt: Dense, Open Graded, Gap-graded, SMA to improve resistance to permanent deformation, noise reduction and increase fatigue strength [23, 24].
Another possible crumb rubber additive is a semicrystalline polyoctenamer, which chemically reacts with both crumb rubber and bitumen, due that fact rubber-like, homogenous composite is formed, while alone crumb rubber is recognized as non-reactive additive to bitumen. It can be used with all kind of bitumen and in every sort of asphalt mixtures. This additive is applied to the aggregate mixture before bitumen in dry process to improve workability, properties of mixture such as rutting, cracking, traffic noise. This additive allows to work in lower temperatures as a result decrease emissions, also it helps to avoid sticking between rubber particles. Moreover, rubber less stick to machines of compacting or transporting [25].
To sum up, all additives are smaller than 1 mm, and can be added during both wet and dry process, dosage varies on the type of additive. All crumb rubber additives improve reaction between crumb rubber particles and bitumen. Effect of crumb rubber and additives on asphalt mixtures performance

2.4 The effect of crumb rubber on modified asphalt mixture properties

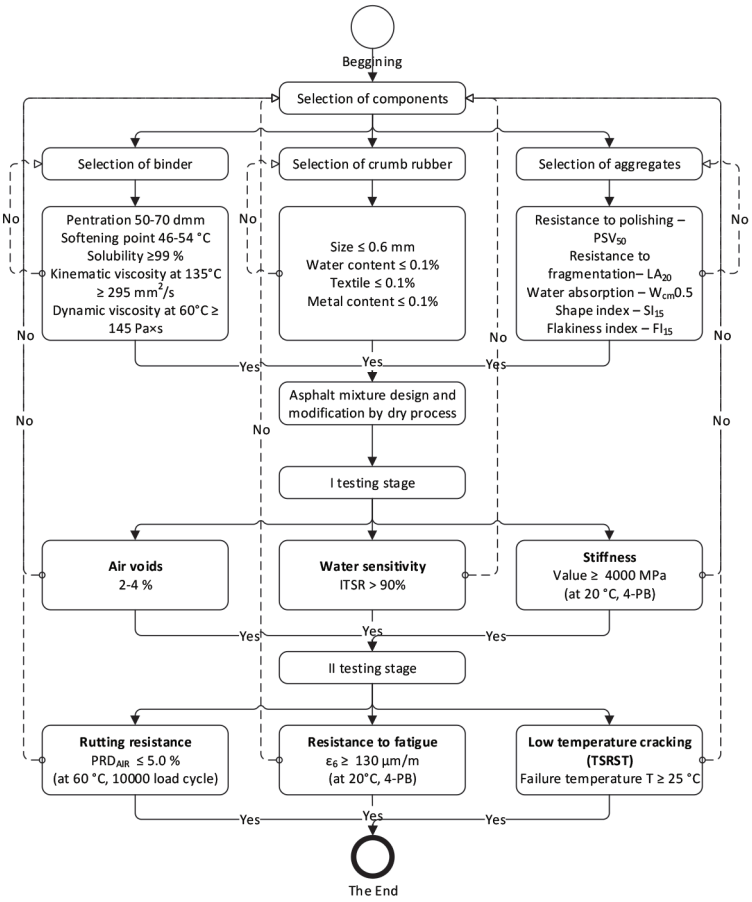
Many researchers agree that the use of crumb rubber as component in asphalt mixture can not only reduce environmental problems, but also increase asphalt mixture properties: stiffness, rutting resistance, water sensitivity, fatigue, low temperature cracking [9, 20, 26–28].
Arabani et al. [9] found that stiffness modulus using 1 %, 3 % and 5 % of crumb rubber has lower values than conventional mixtures. It is because of low adhesion between crumb rubber and binder during dry process. This theory was supported by other researches Navarro et al. and Rahman et al. [26, 29]. Hassan et al. [14] states that finer crumb rubber particles reacts faster and better in which case values of stiffness is higher. Navarro et al. [30] found that after stiffness test in different temperatures crumb rubber improves stiffness, yet SBS has greater impact on mixture stiffness.
Gradually using crumb rubber from 1 % to 3 % improve rutting resistance of asphalt concrete [13, 31]. Comparing wet process and dry process it was found that increasing amount of crumb rubber increase resistance to rutting of asphalt mixtures in both process. Moreover, using dry process helped to achieve even better result than during wet process [20] or even there is no important difference between values during both process [32]. Rahman et al. [33] adds that using 3 – 5 % and ≤ 1.0 mm crumb rubber fatigue resistance and stiffness improves. Besides, higher amount of crumb rubber helps to achieve better resistance to rutting.
Because of poor adhesion between crumb rubber and binder moisture sensitivity is higher in dry process compared to conventional mixtures [34, 35]. Rahman et al. [33] established that using 3 – 5 % crumb rubber by amount of aggregate, asphalt mixtures are more sensitive to water comparing to conventional asphalt mixture. Navarro et al. [30] found that indirect ten-

sile strength slightly decreases with usage of crumb rubber, nevertheless, water sensitivity remains great even after freeze-thaw cycles.
Crumb rubber applied to asphalt mixture improves fatigue resistance comparing to traditional mixtures [18, 29]. Higher resistance to fatigue is due to higher amount of bitumen and crumb rubber [14, 18]. Tahami et al. [4] found that increasing amount of crumb rubber cause contrary reaction on fatigue.
The addition of 3 % crumb rubber into asphalt mixture cause the best results of resistance of deformation at high (-60 ºC) and low (-10 ºC) temperatures [19]. Cao [19] performed an experiment where crumb rubber was used in amounts 1 %, 2 % and 3 % (crumb rubber size was 1 – 3 mm). It was observed that increasing amount of crumb rubber improved asphalt resistance to cracking at low temperatures (-10 ºC) and the most rational amount of crumb rubber is 3 %.
Although there are many possible crumb rubber additives in crumb rubber market, and all manufactures ensure that their product improves performance, there is lack of published test, which would confirm advantages of different additives – the most of above analysed researches involves not raw crumb rubber modified asphalt mixtures results. According to this, it is necessary to perform experimental research and evaluate the effect of modified crumb rubber on asphalt mixture properties.

3 The algorithm of crumb rubber modified asphalt mixture design

After analysis of literature following chart is drawn, which represents the usage of crumb rubber in asphalt mixture algorithm (Fig. 2). Research should start with proper selection of components, which includes selection of binder, crumb rubber and aggregates. If all components meet requirements, then laboratory test starts. In first testing stage, these properties are determined: air voids, water sensitivity and stiffness. If acceptable values are obtained, then test continue to second testing stage, if not – test returns to selections of proper components. In second testing stage, values of rutting resistance, resistance to fatigue and low temperature cracking are determined. If all properties show good performance, then laboratory test succeed, if not – all test are repeated from proper selection of components.

Figure 2 The algorithm of crumb rubber modified asphalt mix design



4 Conclusion

This paper has intended to collect the newest information about the experience of crumb rubber usage for asphalt mixture modification by dry process. Following conclusions can be drawn:

- Literature analysis has shoved the nominal size of crumb rubber – dry process is ≤1 mm (mostly ≤0.8 mm). Smaller particles react better and faster with bitumen, better adhesion between these two components is achieved. Moreover, larger particles in asphalt mixture distributes unevenly and can segregate, while fine particles distribute homogeneously. The most commonly used amount of crumb rubber is 1 – 3 % by mixture weight.
- Most successful dry asphalt modification process starts with aggregate preheating, addition of crumb rubber and intermixing at least 20 seconds. Finally mixing of asphalt mixture for 1-2 minutes after bitumen insertion.
- In general crumb rubber insufficiently decrease asphalt stiffness, but sufficiently increase rutting resistance. Moreover, raw crumb rubber decreases water sensitivity values because of poor adhesion between crumb rubber and bitumen. There is still lack of relative results regarding resistance to low temperature cracking.
- There are several modified crumb rubber additives in the market. Some additives are based on semicrystalline polyoctenamer, which chemically reacts with both crumb rubber

and bitumen, while other additives are based on filler and cross-linking agent. The purpose of these additives is to improve interaction between crumb rubber and bitumen. The addition of modified crumb rubber to asphalt mixture should improve properties as rutting resistance and stiffness, but there is still lack of comprehensive research that would prove it.

It can be stated that there is no unified opinion about the usage of crumb rubber for asphalt mixtures modification by dry process and how it impacts the performance of asphalt mixture. Because of many contradictory opinions from researches and the fact that the effect of modified crumb rubber on asphalt mixture performance still is not completely analysed, following experimental research of the modified crumb rubber effect on asphalt mixture properties should be done. Moreover, the difference between raw crumb rubber and modified crumb rubber should be determined.

Remark

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