Construction and Building Materials 128 (2016) 399–409

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Current status and development of terminal blend tyre rubber modified asphalt

Lili Han [a], Mulian Zheng [a,*], Chongtao Wang [b]

[a] *Key Laboratory for Special Area Highway Engineering of Ministry of Education, Chang'an University, Mid South Erhuan Road, Xi'an, Shaanxi 710064, China*
[b] *First Highway Consultants Co., Ltd., 63 Kejier Road, Xi'an, Shaanxi 710075, China*

HIGHLIGHTS

- Basic concepts of terminal blend (TB) crumb rubber modified binder were reviewed.
- Applications, advantages and concerns of TB rubberized binder were presented.
- Incorporation of warm mix additives in TB binder was summarized.
- Composite modification to TB binder using various modifiers was overviewed.

ARTICLE INFO

Article history:
Received 19 August 2016
Received in revised form 11 October 2016
Accepted 14 October 2016

Keywords:
Crumb rubber modified asphalt
Wet process
Terminal blend
Composite modification

ABSTRACT

Wet process Asphalt Rubber (AR) with well-proven advantages such as good anti-rutting and cracking resistant performances has obtained great advancement since 1930s. Nevertheless, the AR suffers from serious problems: it is too viscous to handle and needs special continuous agitating unit to avoid phase segregation. However, a good alternative is wet process Terminal Blend (TB) rubberized binder which is different from AR in terms of manufacturing process, modification mechanism and binder performance. Although been considered as a viable competitor against polymer modified asphalt, TB binder has not received extensive application due to some concerns. The present paper aimed to provide a comprehensive overview on TB recycled tyre rubber modified binder in terms of basic terminology, binder processing, performance evaluation, applications and primary limitations. Most importantly, the latest progresses in TB binders and their limitations were introduced based on up-to-date researches. Special emphases were laid on the composite modification to TB asphalts using various modifiers such as polymers, acids, nano material and natural rock asphalt. In addition, the combination of currently prevailing warm mix additives with TB rubberized binder was also summarized and discussed.

Contents

* Corresponding author.
E-mail addresses: chdhanlili@yahoo.com (L. Han), zhengml@chd.edu.cn (M. Zheng), 81045449@qq.com (C. Wang).

http://dx.doi.org/10.1016/j.conbuildmat.2016.10.080

1. Introduction

Most industrialized countries and regions in current world e.g. the European Union, United States, China, Japan as well as Australia etc. are facing serious situations and challenges from disposal of solid wastes such as end-of-life tyres from automobile industry. According to statistics, approximately 1.4 billion used tyres are produced each year and the anticipated number is about to increase due to the sharp increase in motor vehicle ownership and rapid growth in traffic volume [1–6]. Historically, these used tyres were often stockpiled in open plant and then land-filled without any processing. However, due to the potential threat to environment and public health (fire disaster, bacteria breeding), now land-filling waste tyres has been declined in most nations. Whereas other disposal manners that could recycle rubber materials in these tyres were encouraged by many environment protective organizations and resource reclamation groups. By the shredding and chipping process on a whole tyre combined with the removing procedure of steel and fabric, the tyre chips are further ground at ambient temperature or cryogenically in the presence of liquid nitrogen to produce crumb rubber powder which is one of the most accepted bitumen modifiers in asphalt pavement. There has been a long history of incorporating Crumb Rubber Modifier (CRM) into paving asphalt mixtures since 1930 s due to the advantages of good deformation and fatigue resistance, echo-friendly characteristics as well as noise reduction effect [1–7]. Asphalt mixtures containing crumb rubber can be produced by mainly two processes: the wet process and dry process [8–10]. Rubber chips adopted in the dry process are usually as coarse as fine aggregate and are chiefly used to substitute for a portion of fine aggregate in the mixture [11]. While in the wet process, rubber crumbs act more as binder modifiers which are blended in the first place with hot base asphalt to prepare modified binder prior to mixing with aggregates. Since the dry process is not as widely applied as the wet process because of the mixed reviews for its performance [12–14], this paper mainly concentrates on the wet process CRM modified asphalt technology.

The wet process rubber modified asphalt technology has gained sufficient development after nearly one century of experience and practice. In the literature, ample researches have reported the processing variables, physical and rheological performances as well as possible applications of CRM modified asphalts [15–20]. Generally, the wet process could produce two totally different modified asphalts known as Asphalt Rubber (AR or wet process-high viscosity) and Terminal Blend (TB or wet process no-agitation) binder. The ASTM D8 has given an authoritative definition of AR which contains coarser rubber particles (minus 30 mesh) and greater rubber dosage (minimum 15% by weight of virgin asphalt) [21]. The modification of crumb rubber in AR primarily relies on the swelling mechanism. During the swelling process, some polymer chains in the rubber absorb a fraction of aromatic oils in base bitumen, causing the rubber to swell and soften and forming a gel-like structure. Contemporaneously there is a reduction in the oil fraction and an increase in the rubber particle size in the blend, which probably accounts for the viscosity elevation of the binder. The high viscosity (greater than 1500 cP at 177 °C) of AR binder could enhance the mixture asphalt content without excessive bleeding or draining out. Additionally, asphalt mixtures containing rubber particles usually showed lower modulus and good rubber elasticity [10] than conventional dense graded asphalt concrete due to high elastic recovery of CRM binder. Therefore well-proven resistance to rutting and reflective cracking as well as thermal cracking were reported considering asphalt rubber mixtures [2,19,20]. At present, some mature technical specifications for asphalt rubber have been published by a number of states such as the US, South Africa, Australia etc. [2,9,22]. This kind of CRM modified binder is mostly used in the open and gap grade hot mix asphalt overlays, Stress Absorbing Membrane Interlay (SAMI), chip seal and cape seal. However, some limitations were found due to the exorbitant high viscosity and specific processing of AR [2,22,23]. On the one hand, AR binders are hard to handle because of the poor workability and are unable to store over a long period due to the phase segregation issue. On the other hand, the swelling process usually needs continuous agitating to the blend to maintain a full interaction of the rubber and bitumen. This poses strict requirement to the blending and manufacturing equipment of the mixture. In face of the limitations of traditional AR, a good alternative known as wet process terminal blend that overcomes the viscosity issue by using less and finer CRM (plus 30 mesh,<10% originally) and by introducing high temperature shearing has gained increasing interest since the 1980s [2,10,23–25]. Unlike the swelling mechanism of AR binder, the TB technology primarily relies on the desulfurization or depolymerization of rubber in the hot bitumen and the full dispersion of rubber in the blend to obtain a homogeneous and stable modified binder. It is more like a polymer modified binder since there is no need for special agitating augers or paddles [2,9,13,25]. Researchers found that TB binder holds many advantages such as low viscosity, good workability, especially applicable to dense graded mixture etc. and it could be used nearly in all fields that traditional AR can be used [2,10,13,23–25]. Currently, the TB asphalt is characterized and evaluated using the Performance Grade (PG) specification like a polymer modified bitumen in CALTRANS [2,10,13]. Faced with the situation that the price of polymer bitumen modifiers would continue to grow in the foreseeable future, CRM binders which hold comparable properties to polymer modified asphalts are showing great economic advantages [13,25–27], especially the less viscous terminal blend binders. However, the TB binder yet presents some major issues before its widespread application in the engineering. For example, the deformation and fatigue resistance of TB might be discounted by the reduced viscosity and lost rubber elasticity due to the desulfurization effect [2,25,28,29]. Although several field projects verified the comparable performance of TB applications to its AR or Styrene-Butadiene-Styrene (SBS) counterparts, there is still a lack of enough evidence on its long term performance validation [2,10,13,23]. Additionally, with the rubber content being enhanced to nearly 20% in recent studies, the thermal stability of TB has emerged as a new problem [2,13,25]. Other concerns such as lack of unified definition or terminology, fume or odor emissions etc. can also prevent this new technology from rapid developing [2,10,13].