Construction and Building Materials 81 (2015) 42–46

Contents lists available at ScienceDirect

Construction and Building Materials

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

Impact of incorporated gamma irradiated crumb rubber on the short-term aging resistance and rheological properties of asphalt binder

I.M. Ibrahim [b], E.S. Fathy [a], M. El-Shafie [b], Mona Y. Elnaggar [a,*]

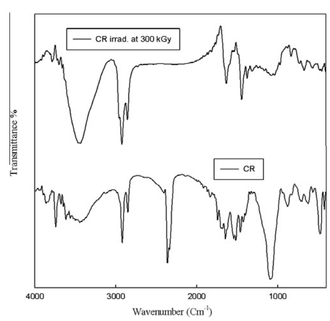
[a] *National Center for Radiation Research and Technology, Nasr City, Egypt*
[b] *Egyptian Petroleum Research Institute, Nasr City, Egypt*

HIGHLIGHTS

- The objective was to study the effects of irradiated crumb rubber on asphalet binder.
- The results showed that the asphalet binder is influenced by the irradiated dose.
- CR irradiated at 300 kGy modified the penetration, softening point, ductility.
- CR irradiated at 100 and 200 kGy modified asphalt was impaired more heavily.

GRAPHICAL ABSTRACT

FTIR spectra of CR and CR irradiated at 300 kGy.



ARTICLE INFO

Article history:
Received 1 July 2014
Received in revised form 15 December 2014
Accepted 4 January 2015

Keywords:
Gamma irradiation
Crumb rubber
Asphalt
Rheological study
Anti-ageing

ABSTRACT

In this new study, the effect of gamma irradiation on the waste tire rubber for its using as modified asphalt binder was elaborated. The study was initiated to investigate the anti-aging performance and rheological properties of asphalt modified crumb rubber impregnated. In this context, three samples of crumb rubber (CR) obtained from waste tire were irradiated by gamma at 100, 200 and 300 kGy and used with two different percentages 5% and 10%, by mass of total asphalt binder. The modified asphalt binders (CRM) were evaluated from the perspective rolling thin film oven method (RTFO) and Brook field viscosity. The results showed that using 10% of CR subjected to gamma rays at 300 kGy with asphalt had high temperature stability, low temperature ductility and anti-aging performance. Also the rheological studies illustrated that the modified asphalt binder contains CR irradiated at 300 kGy have the largest adsorption of the asphalt molecules.

1. Introduction

With the motor industry developing and spreading at a higher pace in all parts of the world, high amount of scrap tires were produced every year, which makes the disposal of tires a serious environmental problem [1]. Crumb rubber, which is obtained from the grinding of scrap tires, has proved to be an efficient solute ion to the environmental concerns surrounding the accumulation of waste tires in recent years [2,3]. The beneficial use of crumb rubber into virgin asphalt binder and pavements provides an environmentally sustainable method of disposing of the millions of tires generated annually [4]. Using crumb rubber as modifier instead of expensive polymer modifier (SBS, SBR, etc.) can also reduce the cost of road asphalt. Recently, CRM used in asphalt has attracted a close attention of many countries [5]. The structure of asphalt

* Corresponding author.
E-mail address: mona_ncrrt@yahoo.com (M.Y. Elnaggar).

http://dx.doi.org/10.1016/j.conbuildmat.2015.01.015
0950-0618/

can be described as net structure formed by amphoteric asphaltene in which a type of oil phase was embedded. The size distribution of the oil phase molecule and polar interaction between the oil phase and the net structure are the most important factors determining asphalt's properties. The swelling of rubber is one of the key factors to prepare successfully the crumb rubber modified asphalt binder [6]. The specific surface area of the CRM particles plays an important role in the CRM binder behavior [7]. Therefore, any modification to the surface area properties could have an effect on the rheological properties of the CRM binder.

The use of radiation in the processing of polymers is gaining more and more interest because it can be suggested as an alternative to the traditional chemical methods to modify the molecular structure of polymers [8].

It is known that the main effect of the interactions between gamma rays and polymers is the formation of free radicals, whose further evolution can cause crosslinking with increase in the molecular weight, scission, with decrease in the molecular weight, and chain branching. Usually all these phenomena co-exist, the prevalence of each depends on many factors which can affect the concentration of the reactive species and, consequently, the kinetics of the reactions involved [9].

High-energy irradiation offers unique solutions to the problem of recycling due to its ability to induce crosslinking or scission of a wide range of material without introducing any chemical initiators and without dissolving the sample, thus, avoiding phase separation. This method can possess a significant economical and ecological advantage as compared to the conventional chemical, thermal and mechanical methods. However, testing methods and specifications have not been well established for polymer modified asphalt. Lee et al. characterize control binder, SBS-modified binder and rubber-modified binder of two short-term aging methods, rolling thin film oven (RTFO) aging and short-term oven aging (STOA) [7]. The objective of this research is to utilize crumb rubber from scrap tires with known grain size irradiated by gamma at 100, 200 and 300 kGy to enhance the rheological and ageing properties at different temperatures of asphalt binders.

2. Experiments

2.1. Materials

2.1.1. Asphalt 60/70

Local asphalt of penetration grade 60/70, produced by El-Nasser Petroleum Company Suez – Egypt was used. The physical properties of this asphalt as follows: softening point 52 °C (ASTM D36), penetration 6.5 mm (ASTM D5), viscosity 398 C.st. at (135 °C, ASTM D4402), and fractional composition (34.5% Oils 40.3% resins, 25.1% asphalten). The main properties of asphalt are listed in Table 1.

2.1.2. Crumb rubber (CR)

Crumb rubber was kindly provided by Narobine Company, Cairo, Egypt, of particle size 10 meshes from the sidewalls of passenger tire. It contained approximately hydrocarbon, 59.8% (30% NR, 40% (SBR), 20%-NBR and 10% butyl and halogenated butyl rubber), 24% carbon black, 15% acetone extract, approximately 0.92% sulfur and approximately 0.98% ZnO. It is free from steel, fibers and any foreign containment in the rubber tire.

2.2. Experimental scheme materials

2.2.1. Gamma radiation treatment

Irradiation was carried out at the National Center for Radiation Research and Technology, Atomic Energy Authority, Cairo, Egypt. The samples of CR were subjected to gamma radiation (gamma cell type 4000 A, India), in air, at ambient humidity and temperature. The absorbed doses were 100, 200 and 300 kGy at a dose rate of ≈2.8 kGy/h.

2.2.2. Preparation of modified asphalt

Unirradiated and irradiated three samples of WR at 100, 200 and 300 kGy of two different percentage 5% and 10%, by mass of total binder were blended with asphalt 60/70 to form four different modified binders (CRM). The CRM was gradually added to the 170 °C preheated asphalt and a mechanical and thermal energy was applied through a high-speed shearing and dispersing emulsifying machine at 7000 rpm and a heated plated controlling the asphalt binder mix temperature. This setup was continued for 60 min, were after it the asphalt rubber mix was removed from the plate and allowed to cool for further testing.

2.3. Experimental scheme tests

2.3.1. Rolling thin film oven test (RTFOT)

The RTFOT for the three modified asphalt binders was conducted at 163 °C for 85 min to simulate the short-term aging of an asphalt binder [10]. The process is presented as follows: the bottle filled with sample is laid inside the bottle fixture. Then the rotating switch is started to move the annular frame in speed of 15 rpm after the oven gate turned off. At the same time hot air flow is jetted into the sample bottle with velocity of 4000 ml/min lasting for 85 min. Attention should be paid that the oven temperature is designed to rise to 163 °C in 10 min, ensuring the heating time over 75 min. The penetration, softening point, ductility at 5 °C and mass loss were used to evaluate the anti-aging performance of the three modified asphalt.

2.3.2. Evaluation method of anti-aging performance

The ratio or difference value of a certain index between original asphalt and its residual having experienced RTFOT is recommended to evaluate asphalt potential of aging resistance [11].

The corresponding expression is:

$$K = \frac{\text{original asphalt values}}{\text{residual asphalt values}}$$

Penetration ratio, softening point increment ductility ratio and mass loss were used to evaluate asphalt potential of aging resistance. Penetration ratio, softening point increment, ductility ratio and mass loss could be calculated according to formula.

Table 1
Properties of two asphalt binder types.

Test properties	Unit	Asphalt 60/70	Asphalt 80/100
Penetration (25 °C, 100 g, 5 s)	0.1 mm	65	94.7
Softening point	°C	52	47.5
Ductility (25 °C, 5 cm/min)	cm	+100	+100
Viscosity (60 °C)	Poise	1878	927
RTFO aged asphalt residue			
Mass loss	%	−0.05	−0.34
Penetration ratio for asphalt residue (25 °C)	%	67	72.9
Ductility for asphalt residue(25 °C)	cm	+100	+100

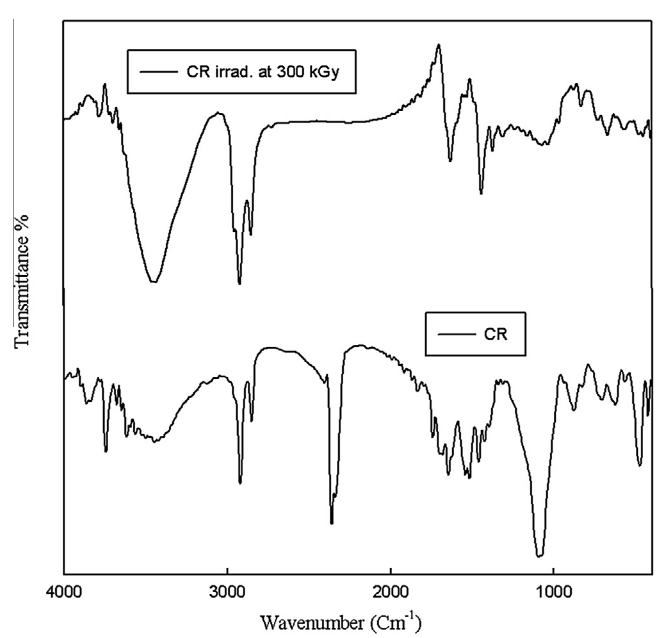


Fig. 1. FTIR spectra of CR and CR irradiated at 300 kGy.