Construction and Building Materials 164 (2018) 246–254

Contents lists available at ScienceDirect

Construction and Building Materials

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

# Effect of rejuvenators on the crack healing performance of recycled asphalt pavement by induction heating

Ba Huu Dinh, Dae-Wook Park *, Tri Ho Minh Le

*Dept. of Civil Engineering, Kunsan National University, 558 Daehak ro, Kunsan, Jeonbuk 54150, Republic of Korea*

## HIGHLIGHTS

- The optimum SWF content is determined by conductivity, and microstructure tests.
- The induction heating method was processed on recycled asphalt mixes.
- The conductivity increases with an increase in steel wool fiber content.
- The healing performance is effective at a certain temperature.
- The rejuvenators with low viscosity are applicable to RAP in the healing process.

## ARTICLE INFO

*Article history:*
Received 19 August 2017
Received in revised form 6 December 2017
Accepted 27 December 2017

*Keywords:*
Steel wool fibers
CT-scan
Induction heating
Recycled asphalt pavement
Rejuvenator
Cooking oil waste

## ABSTRACT

This paper evaluates the healing performance of recycled asphalt mixture modified with steel wool fibers (SWF) using induction heating method. The optimum SWF content was determined through conductivity and microstructure tests. The healing performance of SWF modified recycled asphalt mixture with different rejuvenators and cooking oil waste was evaluated. The testing results shows that the presence of RAP reduces the induction heating effectiveness due to the long-time oxidization and aging process. For the self-healing purpose, it was suggested that an addition of certain rejuvenator or cooking oil waste with low viscosity can enhances healing performance of the recycled asphalt mixture.



## 1. Introduction

Asphalt mixture can repair its minor damages with self-healing ability [1]; however, the preparation process is very slow and incompletely under service condition, weather and repeated traffic loading [2]. Self-healing ability of bituminous mixtures showed to be a prevailing topic in recent years. Many methods have been investigated and developed to promote this potential phenomenon, such as nanoparticles, rejuvenator encapsulation, and induction healing. With the healing purpose, some researchers have recommended the employment of the steel wool fibers (SWF) into the asphalt mixture to enable the induction heating technology. These studies confirmed that the additive conductive plays an important role in healing performance of asphalt mixture. To promote the use of conductive asphalt mixtures for induction heating, many efforts were concentrated on adding fiber-type conductive particles (e.g. steel fibers, steel wool fibers, iron powder, carbon fibers). Vo [3] made an effort to improve the thermal properties of asphalt mixtures by using graphite and carbon fibers. The results presented that carbon fibers and graphite fundamentally enhance the thermal conductivity of asphalt mixtures. Garcia [4] evaluated the influence of conductive fibers and fillers on induction heating rate of asphalt mastic. The results showed that the fibers content and the ratio of sand–bitumen was directly related to the induction heating rate. Apostolidis [5] used steel fibers and iron powder to improve healing performance of asphalt mortar with induction heating. It was concluded that thermal, electrical conductivity and induction heating rate of asphalt mortar increases with increasing SWF content. They also found that the combination of iron powder and fibers exposed higher thermal conductivity than single additive. These findings indicated that the steel wool fibers with a small diameter and long length were a higher enhancement of electrical conductivity than the big diameter and

* Corresponding author.
*E-mail address:* dpark@kunsan.ac.kr (D.-W. Park).

https://doi.org/10.1016/j.conbuildmat.2017.12.193
0950-0618/

**Table 1**
Particle size distribution of new aggregate.

| Sieve size (mm) | 19 | 12.5 | 9.5 | 4.75 | 2.36 | 0.6 | 0.3 | 0.15 | 0.075 |
|---|---|---|---|---|---|---|---|---|---|
| Percent passing (%) | 100 | 98 | 86 | 60 | 45 | 23 | 14 | 8 | 3 |

**Table 2**
Physical properties of asphalt binders.

| Properties | Standard | PG64-22 | PG58-28 |
|---|---|---|---|
| Flash Point, COC, °C | T48 | 265 | 260 |
| Absolute Viscosity at 140°F (60 °C), Poises | T202 | 2010 | 910 |
| Penetration at 77 °F (25 °C), dmm | T49 | 70 | 130 |
| Specific Gravity at 60 °F (15.6 °C) | T228 | 1.024 | 1.022 |

short length fiber. Furthermore, they suggested that ten percent of the steel wool fibers by volume of asphalt binder is optimal content to acquire a high induction heating rate.

Regards to the utilization of reclaimed asphalt pavement (RAP), this potential trend has become a huge attractive solution to many highway agencies around the world due to the conserve energy, environmental safety and sustainable development generated by this technology. Across some developed countries, RAP has been widely used as an alternated material into hot mixed asphalt (HMA) to shorten the original aggregate consumption and to

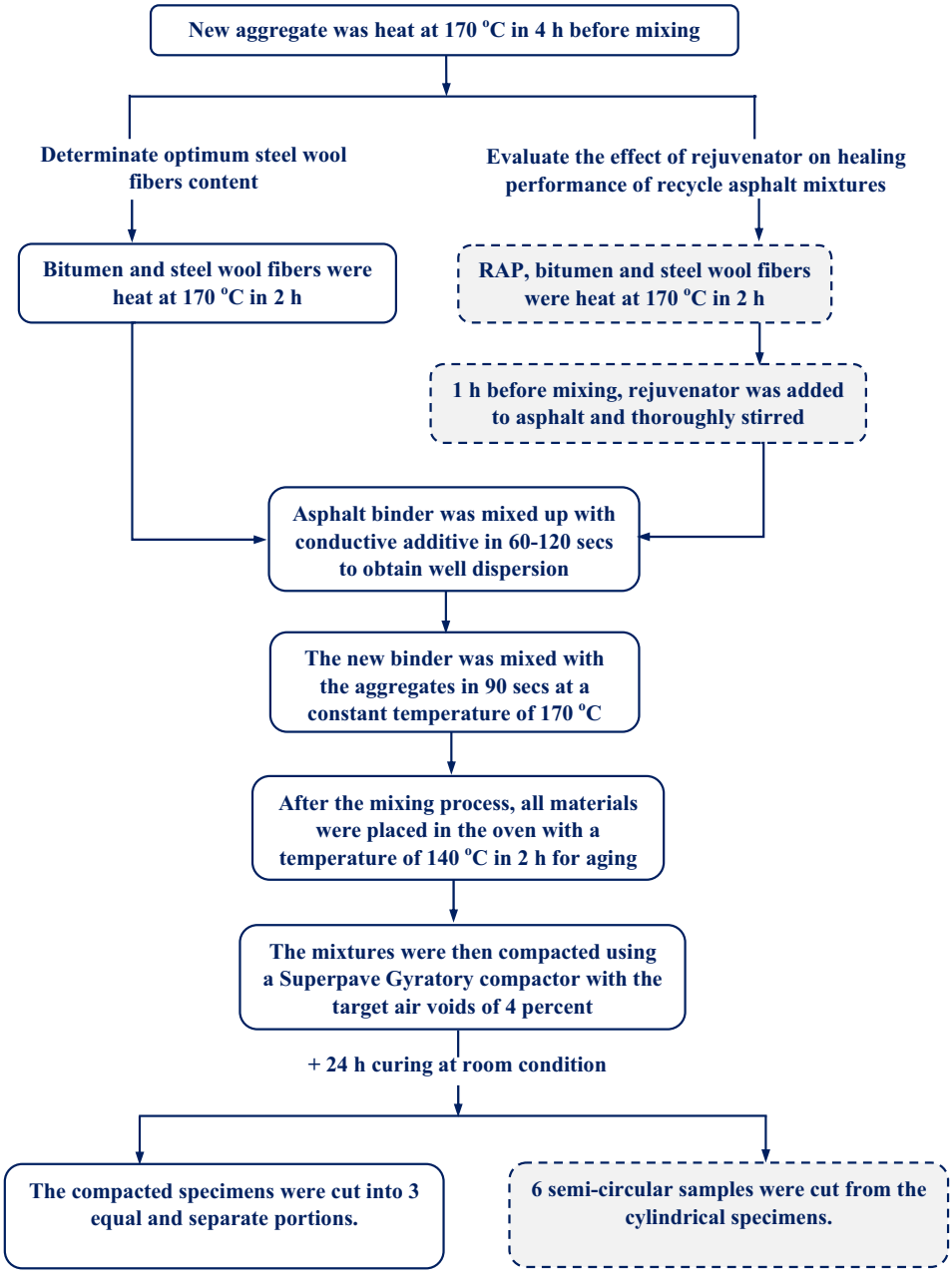


**Fig. 1.** Mixing process.