# Hot In-Place Recycling of Asphalt Pavement: Current Practice and New Technology

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## Current practice of hot in-place recycling

Hot in-place recycling has been widely used in asphalt pavement engineering because of its low financial cost and less consumption of non-renewable material. Currently, infrared heating is the most common heating method in hot in-place recycling as it can heat the pavement to high temperature in short time, rehabilitating deteriorated asphalt pavements and minimizes the use of new materials.

However, when using hot in-place recycling, the damaged asphalt pavement must be heated to the softening temperature before mixing, placing and compaction, and the heating process is one of the most challenging operations among them. Although infrared heating can heat the pavement to high temperature in short time, it transfers heat through heat conduction, which often causes the defect of surface coking and internal unsoftening. As a result, the round-trip intermittent heating is necessary and thereby more time and energy are needed. The longer heating time will also lead to more greenhouse gas emission.

Fig. 1. Hot in-place recycling

## New technology of hot in-place recycling

Recently, microwave heating has been proposed as an alternative to infrared heating because it has advantages of rapid heating rate, short processing time, no air emissions. More importantly, it can avoid surface coking and heat deeper material of the pavement.

Fig. 2. Microwave heating machine

## Objective

To evaluate the potential applications of microwave heating in hot in-place recycling, this study investigated its heating characteristics and compared them with infrared heating by laboratory experiments and numerical modelling.

## Laboratory experiments

Thermal property test was conducted to measure the thermal conductivity and specific heat capacity of materials with different gradations. The microwave heating test was conducted to measure the temperatures after different heating times, which was further used with numerical models to back calculate the electromagnetic properties.

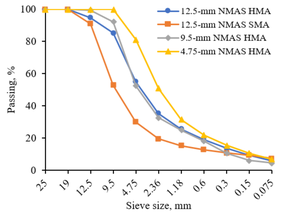


Fig. 3. Gradation information of asphalt mixtures

Fig. 4. Thermal property test

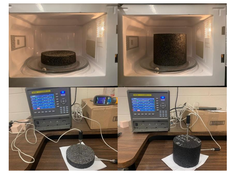

Fig. 5. Microwave heating test

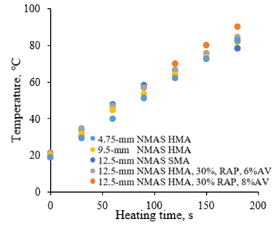


Fig. 6. Temperature measurement

## Infrared heating vs Microwave heating

Numerical modelling was conducted to investigate the temperature distributions, heating rates, and energy consumption of two heating methods.

**Temperature distribution**

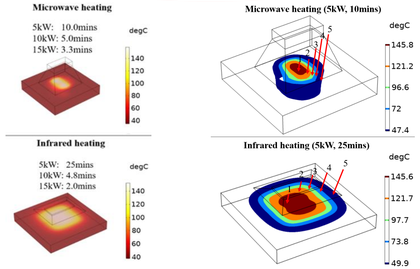


Fig. 7. Temperature distribution comparison

- Microwave can heat the pavement to a greater depth while infrared heater can only heat the shallow area of the pavement.

**Heating rate**

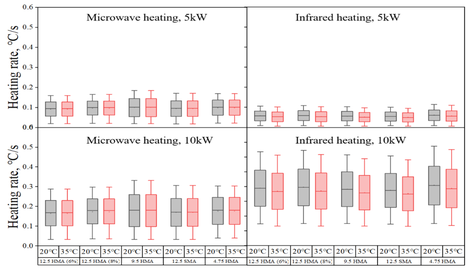


Fig. 8. Heating rate comparison

- Microwave heating rate was similar under different temperatures while the higher the ambient temperature, the lower the infrared heating rate.

**Energy consumption per lane**

*100℃ at 5-cm depth*

| | Power/m, kW | Heating time, min (heating-cooling cycle) | Energy/m, kJ | Equivalent gallon of gasoline/m |
|---|---|---|---|---|
| Microwave heating | 80 | 6 | 28,800 | 0.23 |
| | 160 | 3 | 28,800 | 0.23 |
| | 240 | 2 | 28,800 | 0.23 |
| Infrared heating | 80 | 35 | 168,000 | 1.29 |
| | 160 | 16 | 153,600 | 1.18 |
| | 240 | 10 | 144,000 | 1.11 |

Note: A gallon of gasoline is assumed to generate 1.3 $\times 10^5$ kJ

- Increasing the microwave power can reduce the heating time. Infrared heating needs much more energy than microwave under the same power.

## Conclusions & Future Direction

1. Microwave can heat the pavement to a greater depth while infrared heater can only heat the shallow area of the pavement. To heat the internal area of the pavement, heating-cooling cycle is necessary for infrared heating. However, the total time needed is much more than microwave heating.
2. From energy consumption point of view, increasing the microwave power would not increase the energy consumption but can reduce the heating time. While for infrared heating, it needs much more energy than microwave heating under the same power. Thus, microwave heating has a great potential to be applied in hot in-place recycling.
3. This study is still ongoing, and the authors will conduct field test and observation in the future.

## Acknowledgement

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