

Pavement Materials, Structures, and Performance

Selected Papers from the 2014 Geoshanghai International Congress

Geotechnical Special Publication No. 239

**Shanghai, China
26-28 May 2014**

ISBN: 978-1-63266-670-3

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Editors:

**Baoshan Huang
Sheng Zhao**

ISBN: 978-1-63266-670-3

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Preface

A variety of topics in pavement structure and materials were covered in this special publication that contains 42 technical papers. The selected papers were organized into three technical sections: (1) Paving Materials Characterization and Modeling; (2) Pavement Evaluation, Analysis and Construction; and (3) Pavement Base and Subgrade. The materials presented in *Paving Materials Characterization and Modeling* section include aggregates, asphalt binder, hot mix asphalt (HMA), warm mix asphalt (WMA), recycled asphalt pavement (RAP), recycled asphalt shingles (RAS), and asphalt binder additives and fillers. Some new technologies include microwave heating, 3D surface roughness measurements and nano-technology. The *Pavement Evaluation, Analysis and Construction* section covers pavement field evaluation, structural analysis, as well as the construction technologies for asphalt pavement and concrete pavement. Several models are introduced to analyze and predict major pavement distresses. Pavement preservation technologies are also covered in this section. In the *Pavement Base and Subgrade* section, the papers concentrate on characterization and performance prediction of subgrade soils and other treated base materials used for pavement construction.

Each paper was reviewed by two or more reviewers as well as the editors prior to being published in this ASCE Geotechnical Special Publication (GSP). The authors were required to address the reviewers' comments until the paper met the satisfaction of the editors. All published papers are eligible for discussion in the Journal of Geotechnical and Geoenvironmental Engineering, Journal of Materials in Civil Engineering, and are also eligible for ASCE awards.

The papers collected in this publication were presented during GeoShanghai 2014 International Conference held in Shanghai, China, May 26-28, 2014. The conference was chaired by Professor Wenqi Ding and co-chaired by Professor Lianyang Zhang. The organizations that hosted this conference include Tongji University, the Chinese Institution of Soil Mechanics and Geotechnical Engineering, the Chinese Society for Rock Mechanics and Engineering and the Shanghai Society of Civil Engineering in cooperation with ASCE Geo-Institute, the International Society for Soil Mechanics and Geotechnical Engineering, the International Association of Chinese Infrastructure Professionals, the Deep Foundations Institute in the USA, the Alaska University Transportation Center (USA), University of Edinburgh (UK), Ruhr University Bochum (Germany), University of Cambridge (UK), Ecole des Ponts Paristech (France), Virginia Polytechnic Institute and State University (USA), the Shanghai Society of Theoretical and Applied Mechanics, Nagoya Institute of Technology (Japan), University of Arizona (USA), the Transportation Research Board (TRB) (USA), University of Kansas (USA), Georgia Institute of Technology (USA), Vienna University of Natural Resources and Applied Life Sciences (Austria), and University of Tennessee (USA).

Editors:

Baoshan Huang, Ph.D., P.E., and Sheng Zhao

The University of Tennessee, Knoxville, TN

January 22, 2014

Acknowledgements

The editors would like to appreciate the organizing committee providing technological support in administrating the paper submission. Thanks are extended to Donna Dickert of ASCE, Robert Schweinfurth of ASCE Geo-Institute (G-I) and ASCE Construction Institute (CI). Special thanks are given to the following individuals that provided timely and high-quality technical reviews for one or more papers submitted to this conference:

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Laboratory Preparation and Microwave Heating Test of CIPs/Asphalt Binder

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ABSTRACT: Microwave heating technology has been adopted in asphalt pavement maintenance to reduce the total cost resulting from the energy consumption. In this paper, laboratory preparation and microwave heating test of carbonyl iron powders (CIPs)/asphalt binder were carried out. The modeling procedure, microwave heating efficiency and the properties of the CIPs/asphalt binder, such as penetration, softening point and ductility, were studied. The results show that microwave heating efficiency of CIPs/asphalt binder is enormously higher than that of ordinary asphalt binder. Adding a certain amount of CIPs can improve the asphalt binder's resistance to deformation at high temperature. All these can put forward a theoretical basis to design asphalt mixtures being suitable to be used in snow and ice removal by microwave pavement maintenance vehicles.

INTRODUCTION

As to the problem that conventional heating methods requires that the energy propagates through the asphalt materials by diffusion, power microwave was adopted to heat asphalt binder with CIPs by its microwave absorbing characteristics at different frequencies (Zivkovic et al. 2012). Microwave heating is a relatively new technology, which provides alternative approaches for enhancing material properties (Chun et al. 2013). There had been many studies on the construction and evaluation of asphalt mixes pavement with microwave technology. For example, Jaselskis et al. (2001) measured the density of asphalt in real time using a differential microwave signal approach. Sun et al. (2008) built a two-dimensional heat transfer model for the asphalt mixtures within the heating range based on the theory of unsteady heat conduction to solve for temperature fields in microwave heating for recycling asphalt mixtures. Meanwhile, a volume

element was established including asphalt mixtures, liquid water and vapor to realize mass transfer analysis for microwave hot in-place recycling of asphalt pavements (Sun et al. 2012). Gallego et al. (2013) studied the technical viability of heating asphalt mixtures with microwaves and how the microwaves influence the heating process.

Carbonyl iron is a highly pure iron, prepared by chemical decomposition of purified iron pentacarbonyl. It usually has the appearance of grey powder, composed of spherical micro particles. Most of the impurities are carbon, oxygen, and nitrogen. In electronics, carbonyl iron is used to manufacture magnetic cores for high-frequency coils, and in production of some ferrites. Spherical particles manufactured of carbonyl iron are used as a component of the radar absorbing materials used in military. CIPs with the morphology of spheroid embedded in an insulating polymer matrix have been proved to be a promising microwave absorption material within a frequency range from 2.0-4.0 GHz (Abshinova et al. 2007 and Yang et al. 2009). CIPs have been widely used as conventional electromagnetic wave absorbing materials due to their low price, high specific saturated magnetization, and Snoek's limit (Tong et al. 2011). It is a technical task to make the asphalt binder possess the electromagnetic performance with the addition of CIPs. Thus, it is expected that perfect asphalt absorbent may be obtained by mixing spherical CIPs with asphalt.

The objective of the present study is to prepare the CIPs/asphalt binder with microwave absorbing function and evaluate microwave heating efficiency of CIPs/asphalt binder. The research efforts were made to balance the content of CIPs and asphalt emulsion in the asphalt binder so that it is easy to absorb microwave to obtain higher heating efficiency. In this study, three asphalt absorbent-to-asphalt weight ratios (0.1:1, 0.2:1 and 0.3:1) were designed to prepare the CIPs/asphalt binder. The properties of the CIPs/asphalt binder were studied through microwave heating test, the penetration test, softening point test and ductility test, to analyze the reason for the effects of CIPs.

MATERIALS AND EXPERIMENT SETUPS

Properties of the materials

AH-90 asphalt was adopted and its properties were shown in Table 1. DT-50 CIPs were used and the apparent density was 1.520g/cm^3 . The morphology (Figure 1) of the CIPs was analyzed by scanning electron microscope (SEM, Hitachi S-4800) shows that the particles are spherical like bulb, and the diameters are in the range of $1\sim6\mu\text{m}$. Trichloroethylene (C_2HCl_3) was a chlorinated hydrocarbon commonly used as an industrial solvent. KH-550 silane coupling agent was used, whose chemical formula was $\text{H}_2\text{N}(\text{CH}_2)_3\text{Si}(\text{OC}_2\text{H}_5)_3$ and density was 0.944g/cm^3 .

Table 1. Properties of the asphalt binder

Properties	Values
Penetration/ (25°C, 100g, 5s, 0.1mm)	92
Softening point/ ($t_{R\&B}$, °C)	48.2
Ductility/ (15 °C, cm)	112
Density/(g/cm ³)	1.012

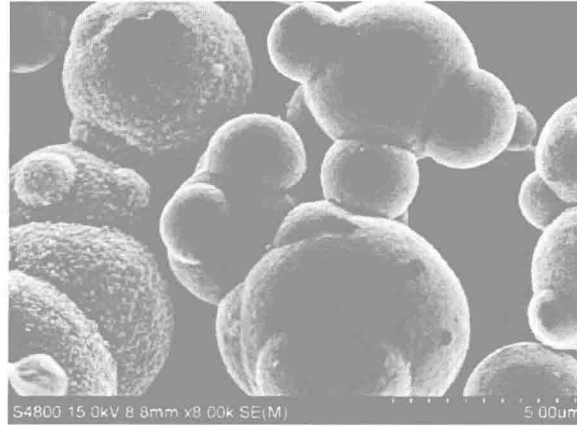


FIG. 1. SEM picture of the CIPs.

Experiment setups

The penetration, softening temperature and ductility of the modified asphalt were tested according to Standard Test Methods of Asphalt and Asphalt Mixtures for Highway Engineering (JTJ 052-2000). The complex permeability and complex permittivity of the composite samples was obtained using an Agilent E83628B network analyzer in the 2.0-4.0GHz. The specimen size for microwave heating efficiency test was 20mm (diameter) × 20mm (thickness). Microwave heating efficiency was tested in experimental microwave oven (800W power, 2.45GHz). A handled digital thermometer was used to test the surface temperature of the specimens.

RESULTS AND DISCUSSION

Laboratory preparation of CIPs/asphalt binder

Proportions and procedures

The spherical shape CIPs were used as starting material. These CIPs were first mixed with coupling agent, asphalt and trichloroethene in a mass ratio (1:0.05:0.01:2) in a glass pot; then disperse the mixture with ultra wave for 30min; and then heated the mixture for 30min with 85-95 °C to make the trichloroethene evaporate. An asphalt absorbent was obtained. Then, the asphalt absorbent sample was mixed in a glass pot containing asphalt, where the absorbent-to-asphalt weight ratio is (0.1-0.3):1. A high-speed shear was used to mix the mixtures for 30min with temperature 160 °C to obtain the CIPs/asphalt binder. Procedure for laboratory preparation of CIPs/asphoCalt binder was shown in Figure 2.

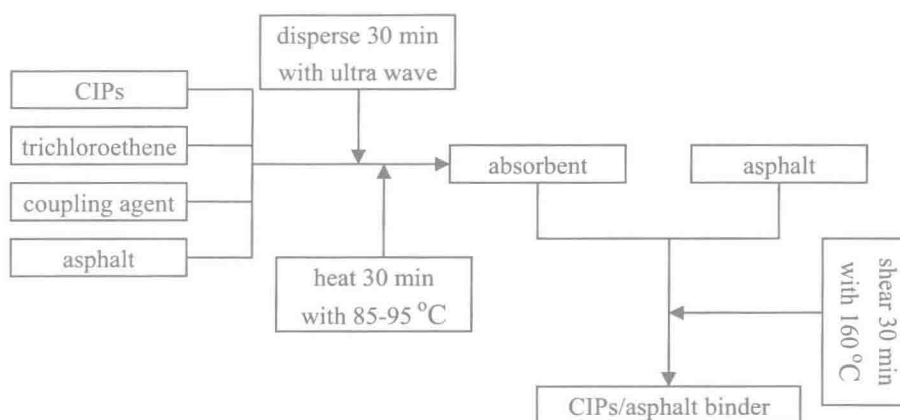
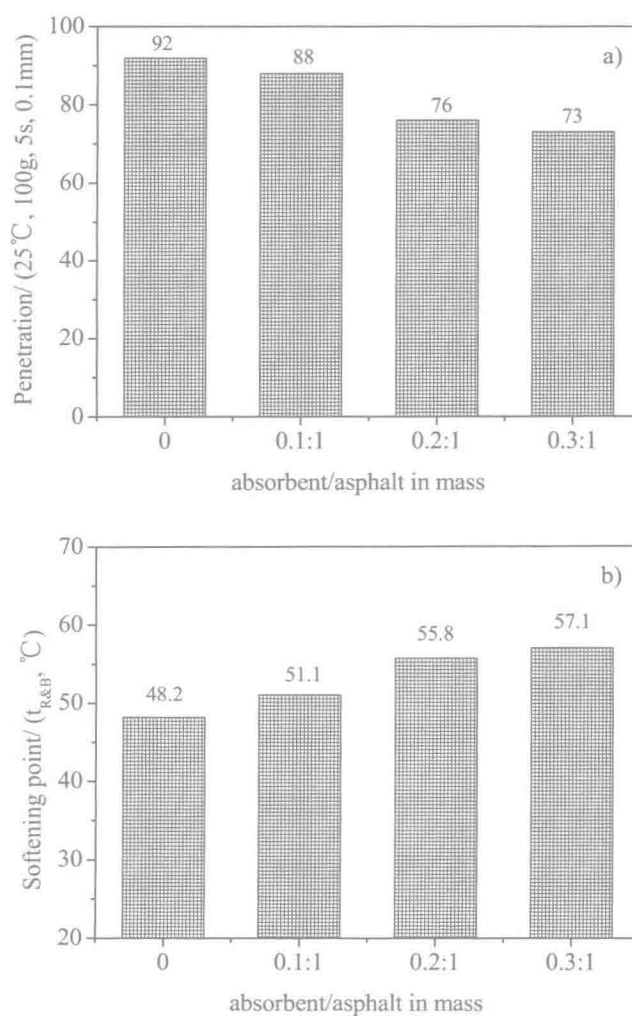


FIG. 2. Procedure for laboratory preparation of CIPs/asphalt binder.



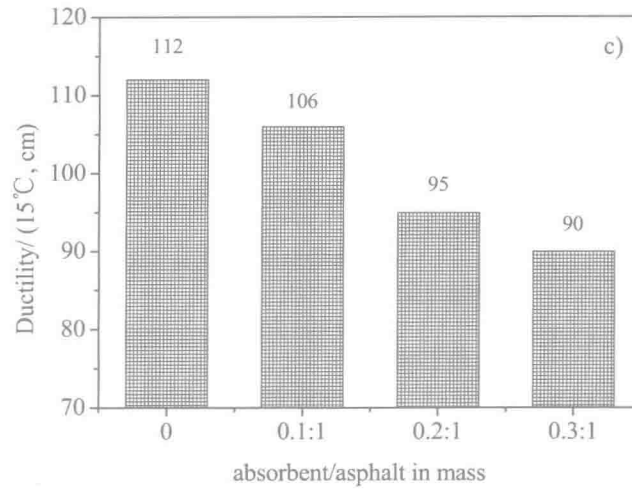


FIG. 3. Properties of the CIPs/asphalt binder: a) penetration; b) softening point; c) ductility.

Figure 3 a) and c) shows that the penetration and the ductility of the CIPs/asphalt binder decrease slightly after the addition of the CIPs. The higher the absorbent/asphalt is, the lower the penetration and the ductility are. It suggests that higher contents of CIPs make the asphalt binder brittle. Adding a certain amount of CIPs can improve the asphalt binder's resistance to deformation. In contrast to the penetration and the ductility of the CIPs/asphalt binder, the softening point evidently increases after the addition of the CIPs, shown in Figure 3 b). It indicates that CIPs is not only the key material for microwave absorbing of the asphalt binder, but also the admixture enhancing the performance of the asphalt binder at higher temperature.

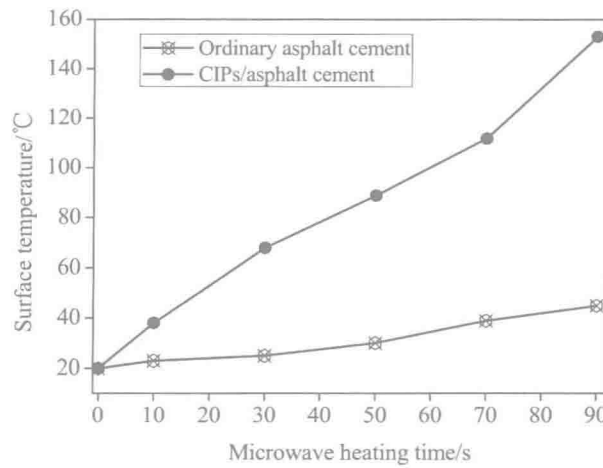


FIG. 4. Surface temperatures of the different asphalt binders

Microwave heating efficiency test

Figure 4 shows that the surface temperature of the ordinary asphalt binder increases very slowly with the increase of the microwave heating time. However, it is evident that the surface temperature of the CIPs/asphalt binder (0.1:1 in absorbent/asphalt mass) enormously increases at different heating interval time. The surface temperature is enhanced by 133 °C for the CIPs /asphalt binder after 90s microwave heating time, while the temperature is improved by 25 °C for the ordinary asphalt binder. It suggests that CIPs addition can lead to 6 times heating rate increase.

Mechanism for microwave heating efficiency enhancement

Table 2 shows that after the addition of the CIPs, the reflectivity dielectric loss tangent both increase, which can enhance the microwave absorbing function (Li et al. 2008). Especially, the enhanced $\tan\delta$ (dielectric or magnetic loss tangent) is very beneficial to improve the microwave absorption properties in the 2.0-4.0 GHz lower frequency range (Wang et al. 2008).

Table 2. Electromagnetic parameters of the asphalt binders

Kinds of asphalt binders	Relative permittivity	Relative magnetic permeability	Dielectric loss tangent	Magnetic loss tangent
Ordinary asphalt binder	5.10	1.00	0.03	0
CIPs/asphalt binder	19.20	1.56	0.05	0.14

CONCLUSIONS

(1) A novel procedure to prepare the CIPs/asphalt binder was put forward. Preparation of the asphalt microwave absorbent and the determination of the proportion between the absorbent and the asphalt are the key factors influencing the making of the CIPs/asphalt binder.

(2) The higher the absorbent/asphalt is, the lower the penetration and the ductility are. It suggests that higher contents of CIPs make the asphalt brittle. The softening point evidently increases after the addition of the CIPs, which can enhance the performance of the asphalt binder at higher temperature.

(3) After the addition of the CIPs, surface temperature of the asphalt mixes distinctively increases at different heating interval time; and microwave heating rate for the asphalt binder with CIPs is higher 16 times than that for ordinary asphalt.

FUTURE RESEARCHES

This is a laboratory study on the preparation and microwave heating test of the CIPs/asphalt binder. The road properties of the CIPs/asphalt mixtures, such as Marshall stability, dynamic stability and splitting strength ratio at low temperature should be included in future studies.

ACKNOWLEDGEMENTS

The authors thank for the supports from National Natural Science Foundation of China (No. 51210105015). Zhenjun Wang is supported by a grant (No.201206565001) from the Chinese Scholarship Council as a visiting scholar at the University of Tennessee at Knoxville (UTK). He also expresses thanks to Prof. Baoshan Huang of UTK for his assistance.

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Stone Matrix Asphalt Using Aggregates Modified with Waste Plastics

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ABSTRACT: Stone Matrix Asphalt (SMA) is a gap graded asphalt mixture performing better than conventional dense graded mixtures. It contains high concentration of coarse aggregates, forming stone on stone contact between them, and high asphalt content. The coarse aggregate skeleton results better load distribution and the high asphalt content adds durability to the mixture. Due to the high mastic (filler and asphalt) content, there is possibility of drain down during various stages in construction. SMA mix should be prepared with suitable stabilizing additive to prevent the drain down of mastic material from the mixture. In this study, SMA mixtures are prepared in Superpave Gyratory Compactor (SGC) with shredded waste plastics, which are mixed with aggregates prior to the addition of Viscosity Graded (VG) – 30 asphalt. Mixtures are prepared with asphalt contents of 5.0 to 7.0 per cent (by weight of aggregates) and stabilizer contents of 0, 4, 8, 12 and 16 per cent (by weight of asphalt). Volumetric and Marshall properties, tensile strength, moisture susceptibility characteristics, etc. are determined. From the laboratory studies it is observed that addition of waste plastics in shredded form can be used instead of stabilizers by controlling the drain down and enhancing the performance.

INTRODUCTION

A new type of Hot Mix Asphalt (HMA) was developed in Germany in the 1960's to resist the wear and damage of pavements caused by the usage of studded tires. This was a gap graded mixture with comparatively higher coarse aggregate fraction and asphalt content. Since the mixture was found to be highly rut resistant and durable it was utilized by many countries in Europe with a common name Stone Matrix (Mastic) Asphalt (SMA). These successful stories of SMA opened its way to the United States (US) and countries like South Africa, New Zealand, Japan, Australia, Saudi Arabia, Canada etc. (Brown 1992; Campbell 1999; Schimiedlin and Bischoff 2002; Ibrahim 2005).