EXPERIMENTAL STUDY ON THE THERMAL CONDUCTIVITY OF LIGHT SOIL MIXED WITH EPS PARTICLES

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ABSTRACT

This paper presented the experiment and study on the thermal conductivity of light composite soil mixed with EPS particles (LCSEP) through the application of ISOMET heat character analyzer. The influence of the factors including density, water content and EPS particles dosage on the thermal conductivity of light composite soil mixed with EPS particles under frozen and unfrozen conditions were discussed. The experimental results indicated that the increase of the contents of EPS particles, cement and mineral admixtures resulted in the decrease of thermal conductivity. The mentioned results contributed to heat insulation and preservation, which could lead to the reduction of depth of frost penetration. The decrease of density and water content could resulted in the decline of thermal conductivity. Under frozen condition, thermal conductivity would decrease.

Keywords: Thermal conductivity, EPS particles, light composite soil

INTRODUCTION

In deeply seasonal permafrost region, EPS or XPS heat insulation boards were usually applied to prevent frost damage of hydraulic structures. On one hand, EPS or XPS boards could weaken the frost heave and reduce the depth of frost penetration. On the other hand, they could prevent the frost damage and freezing and thawing induced destruction. However, the use of boards mentioned above could lead to the increase of cost. As a new type composite material of soil engineering, the light composite soil mixed with EPS particles were prepared through the addition of EPS particles and cement solidified agent to the filling soil. This material, mixed and compacted in field engineering, could contribute to prevent frost heave.

EXPERIMENTS

Experimental Materials

Experimental materials included 42.5 ordinary Portland cement, EPS foaming particles, high range water reducing agent, air inducing agent, interface agent for particles and water. The soil sample, collected from test field for frost soil in Wanjia town of Harbin, was powder like clay with low liquid limit. EPS foaming particles, prepared from heat foaming of polystyrene resin, were spherical and have plenty of close micro pores. The diameter of the particles was between 3 and 5 mm and the bulk density of the particles were 0.026 g/cm^3.

Experimental Apparatus

The main experimental apparatus was ISOMET heat character analyzer. The transient method was adopted with following steps. The sensors were put on the surface of the specimen, and then the specimen was heated through the probes. The variation of heat of the specimen was investigated periodically, then thermal conductivity of the specimen was calculated according the change of surface temperature with time. The accuracy of investigation was ±5%+0.001W/mK.

Experimental Design

Experiments included tests under normal temperature and frozen condition.

Normal temperature tests were done under the temperature of 20±2℃. During tests in frozen condition, specimens were sealed with plastic wrap and placed in the refrigerator with temperature of -15±0.5℃ for 24 hours. Then the sensors were put into the refrigerator and the investigation was done according to test methods under normal temperature.

EXPERIMENTAL RESULTS

Experimental Mixing Proportions

The mixing proportions were determined

according mass method. The soil, cement, EPS particles, fly ash and silica fume were mixed together. In order to improve workability and accelerate the hydration of cement, high range water reducing agent and air inducing agent were adopted to improve freezing resistance.

The experimental mixing proportions were listed in Table 1.

Influence of Density and Temperature on Thermal Conductivity

Density had significant influence on the thermal conductivity of LCSEP. Figure 1 indicated that the lower density resulted in the smaller thermal conductivity. The particles in the soil with higher density contacted with each other more closely, which contributed to the temperature conduction and led to the linear increase of heat conductivity.

Table 1 The experimental mixing proportions

Sample	Soil (%)	Cement (%)	Water (%)	EPS particles (%)	Fly ash (%)	Silica fume (%)	Admixture (%)	Density g/cm^3
R1	100	12	35	0.5	0.05	0.05	0.5	1.59
R2	100	16	35	0.5	0.05	0.05	0.5	1.49
R3	100	20	0.5	0.5	0.2	0.05	0.5	1.30
R4	100	20	35	1	0.05	0.05	0.5	1.25
R5	100	12	45	1	0.1	0.05	0.5	1.26
R6	100	16	30	1	0.2	0.05	0.5	1.41
R7	100	16	45	2	0.05	0.05	0.5	0.99
R8	100	12	35	2	0.2	0.05	0.5	1.09
R9	100	20	30	2	0.1	0.05	0.5	1.13
R10	100	20	40	3	0.1	0.05	0.2	0.94
R11	100	20	35	3	0.1	0.05	0.2	0.91
R12	100	20	35	3	0.1	0.05	0.5	0.89
R13	100	16	35	3	0.1	0.05	0.2	0.95
R14	100	16	30	3	0.1	0.05	0.2	0.97
R15	100	20	35	3	0.1	0.05	0.2	0.98
R22	100	20	30	4	10	5	5	0.78
R23	100	20	40	4	10	5	5	0.82
R24	100	20	35	4	10	5	5	0.86
R25	100	20	35	4	10	5	5	0.85
R26	100	20	35	4	10	5	5	0.85
R27	100	20	30	3	10	5	5	0.98
R30	100	20	30	4	5	2.5	5	0.97
R31	100	20	25	3	5	2.5	5	1.0

Under frozen condition, the thermal conductivity was lower than that in normal temperature.

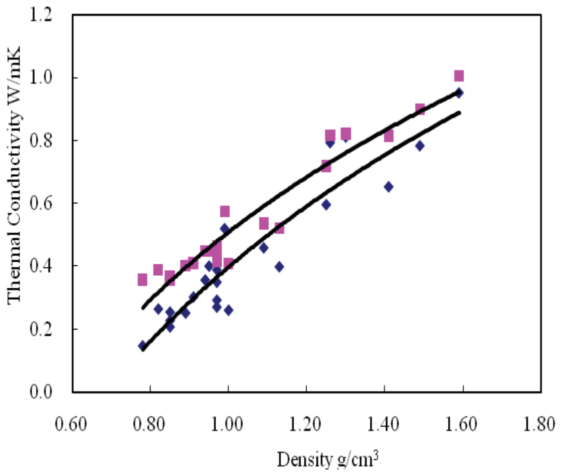

Fig.1 Relation curve of density vs. thermal conductivity

Influence of Water Content on Thermal Conductivity

Figure 2 presents the relationship between thermal conductivity and water content. When water content was in the designed range from 25% to 45%, thermal conductivity increased with the increase of water content.

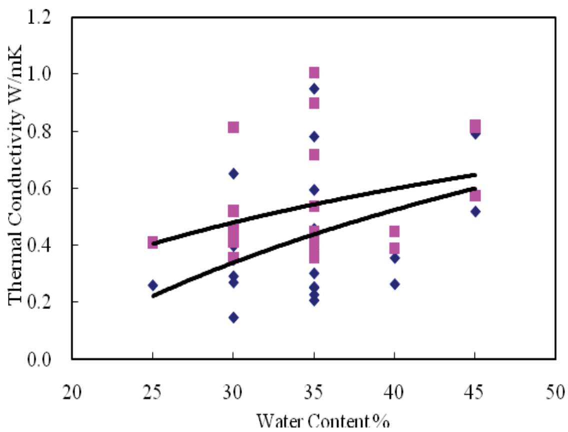

Fig. 2 Relation curve of water content vs. thermal conductivity

Influence of EPS Particles Content on Thermal Conductivity

In the experimental design of LCSEP, the addition of EPS particles was essential to modify the property of the filling soil. Figure 3 indicated that the increase of the EPS particles content could significantly reduce the thermal conductivity. However, too much EPS particles influenced the binding among particles and resulted in difficult molding.

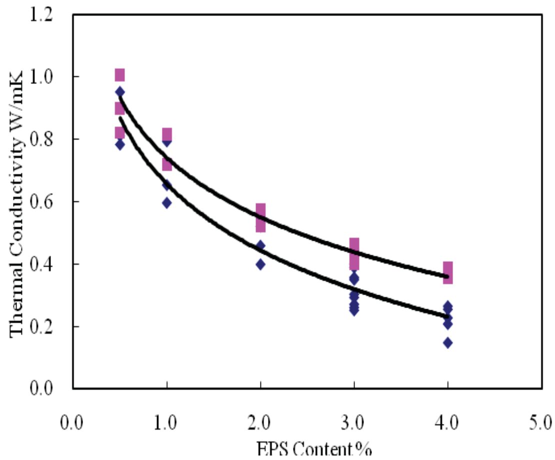

Fig. 3 Relation curve of EPS content vs. thermal conductivity

Influence of Cement Content on Thermal Conductivity

Figure 4 presented the influence of cement content on thermal conductivity. The results indicated that thermal conductivity decreased with the increase of cement content. The increase of cement content intensified the cement hydration, which led to the reduction of free water in the soil, decrease of saturation degree, increase of thermal resistance and decline of thermal conductivity.

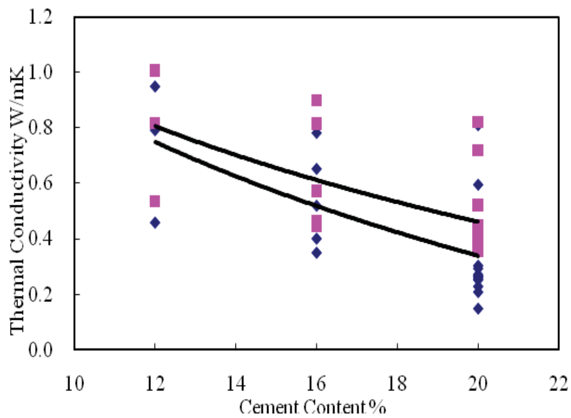

Fig. 4 Relation curve of cement content vs. thermal conductivity

Influence of Mineral Admixtures Content on Thermal Conductivity

Figure 5 presented the relationship between mineral admixtures content and thermal conductivity. The results indicated that thermal conductivity decreased with the increase of content. Plenty of light and hollow glass microspheres existed in the mineral admixtures, which helped to heat preservation.

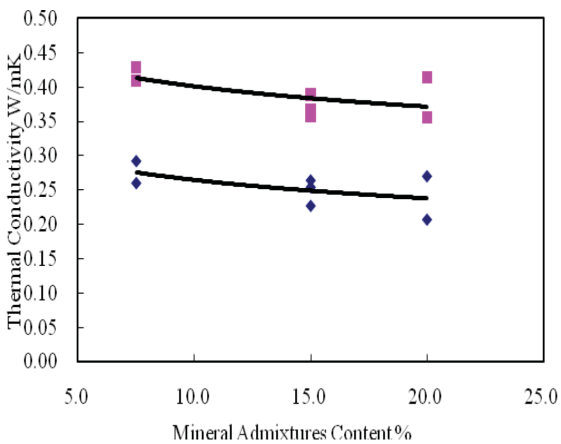

Fig. 5 Relation curve of mineral admixtures content vs. thermal conductivity

CONCLUSIONS

(1) Compared with normal filling soil, the thermal conductivity and density of light composite soil mixed with EPS particles decreased substantially. The main factor influencing thermal conductivity was EPS particles content.

(2) Temperature had great effect on light composite soil mixed with EPS particles. In frozen state, thermal conductivity of light composite soil mixed with EPS particles increased and was lower than that of normal filling soil.

(3) The thermal conductivity of soil could be significantly reduced through the addition of EPS particles. The increase of EPS particles content resulted in the sharp decline of thermal conductivity, but too much EPS particles could influence the binding among particles.

(4) Increase of density and water content could lead to the significant increase of thermal conductivity of light soil.

(5) The addition of cement solidified agent and mineral admixtures including fly ash and silica fume could obviously improve the workability and thermal conductivity of light composite soil mixed with EPS particles. The increase of the mentioned materials led to the decline of thermal conductivity.

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