

Correlation Analysis of Thermal Physical Indexes in Subway Engineering

Quan Cao^{1,*}, Shuhua Gong¹, Peigang Li¹, Heng Wan¹ and Daolai Cheng²

¹School of Railway Transportation, Shanghai Institute of Technology, Shanghai 201418, China

²School of Mechanical Engineering, Shanghai Institute of Technology, Shanghai 201418, China

*Corresponding author e-mail: caoquanrang@126.com

Abstract. By collecting and sorting the thermal physical indexes of the 1, 2, 5, 7 and 11 lines of Shenzhen metro, the relationship between the physical properties and the physical properties of gravel clay was analyzed. The correlation statistics of factors affecting the thermal physical indexes of gravel clay are carried out. The empirical formula of specific heat capacity and heat conductivity are proposed on the basis of moisture content, void ratio and density. It provides a new way to obtain the thermal physical indexes in the investigation and design of the subway engineering.

1. Introduction

The thermal physical indexes of soils reflect the heat conductivity, heat storage and thermal diffusivity. The accurate determination of these is of great practical significance to reducing the cost of the subway construction, saving energy and controlling the environment [1-2]. In traditional geotechnical engineering, such content is seldom involved. What's more, there are no relevant test specifications at present. Therefore, it is difficult to accurately test the thermal physical indexes of soils.

It is the current situation that the need for thermal physical indexes in subway ventilation design and freezing method construction is increasing while the experimental measurements are not popular. Many researchers have tried to investigate the influence factors, the heat conduction mechanism, and the empirical formula [3-9]. The results show that the correlation between thermal physical indexes and void ratio, moisture content and density is relatively high.

Based on more than 30 years of experimental practice and accumulation in domestic metro construction, the correlation between measured thermal physical indexes and the main physical properties of soils has been explored, providing an empirical calculation method for the design and construction of subway projects.

2. Collection and arrangement of soil thermal physical indexes

The original data collected a total of 183 work stations and 812 sets of geothermal physical indexes, including subway stations, sections, entrance and exit lines, and tie lines, with geotechnical thermal physical testing indexes for the Shenzhen Metro Lines 1, 2, 5, 7 and 11. Different types of soil determine its different influence factors of thermal physical properties. This article takes the experimental data of 14 sets of gravelly clay test data that Xiangmei North Station of Shenzhen Metro



Line 2 involved as an example to carry out the correlation study of the geophysical thermal physical test indexes, and the related data are shown in Table 1. The correlation formula was calculated by linear-regression analysis method and its coefficient of determination was calculated by the least square method, so as to evaluate the correlation degree quantitatively.

Table 1. Properties of gravel clay sample.

Drilling number	Sampling depth m	Moisture Content %	Void Ratio (e)	Density (ρ) g/cm ³	Heat Conductivity (I) W/m • K	Specific Heat Capacity (C) kJ/kg • K
Z3-2SXMB-07-1	9.6-10.0	27.50	0.77	1.79	2.55	1.32
Z3-2SXMB-07-1	13.0-13.4	32.40	0.93	1.75	2.16	1.48
Z3-2SXMB-10	14.6-15.0	30.30	1.00	1.70	1.84	1.44
Z3-2SXMB-17-1-3	12.2-12.6	32.90	1.01	1.73	2.07	1.52
Z3-2SXMB-17-1-4	12.6-13.0	31.20	1.02	1.69	1.91	1.45
Z3-2SXMB-05	8.1-8.5	25.60	0.74	1.83	2.56	1.10
Z3-2SXMB-16-1	17.0-17.4	29.30	0.98	1.74	2.15	1.38
Z3-2SXMB-16-2	11.2-11.6	35.80	1.03	1.68	1.70	1.68
Z3-2SXMB-17-1-1	7.0-7.4	28.60	0.81	1.75	2.48	1.23
Z3-2SXMB-17-1-2	7.4-7.8	26.80	0.89	1.77	2.25	1.18
Z3-2SXMB-18	14.2-14.6	33.90	1.06	1.68	1.44	1.61
Z3-2TXX-15	17.6-18.0	36.10	1.04	1.65	1.49	1.69
Z3-2TXX-20	17.5-17.9	35.40	1.08	1.67	1.36	1.65

3. Correlation analysis of thermal physical indexes of gravel clay

3.1. Thermal physical index and Moisture Content

The moisture content of the 14 sets of samples are analysed respectively with specific heat capacity and heat conductivity. Results are shown in Figure 1 and Figure 2.

Figure 1 shows that the specific heat capacity of gravel clay increases with the increase of moisture content and the linear fitting relation between the two is as follows:

$$C=5.4339w-0.2560 \quad (1)$$

The above-mentioned coefficient of determination $r^2=0.95738$. It indicates that the moisture content of gravel clay is highly linearly related to the specific heat capacity.

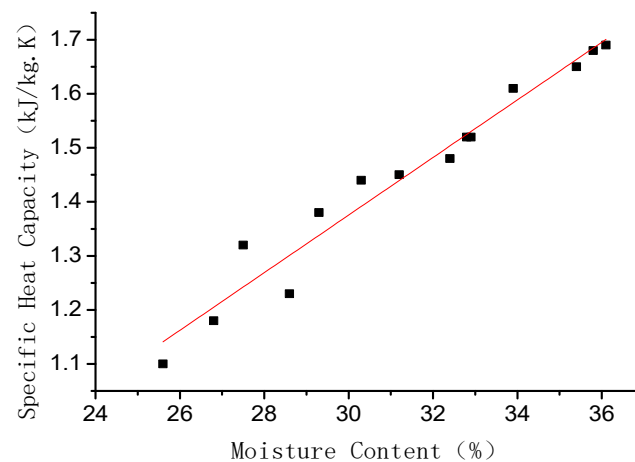


Figure 1. Curve of moisture content vs. specific heat capacity of gravel clay.

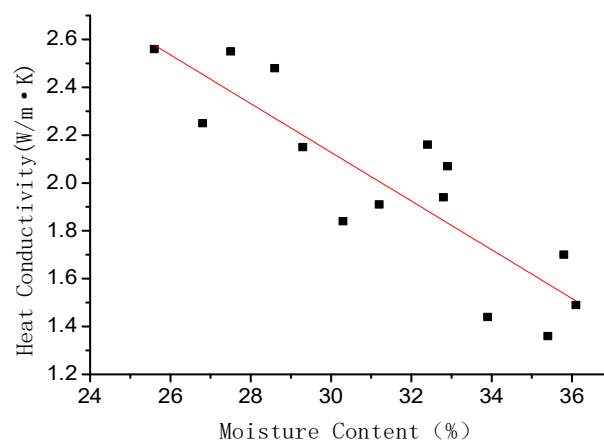


Figure 2. Curve of moisture content vs. heat conductivity of gravel clay.

Figure 2 shows that the heat conductivity of gravel clay decreases with the increase of moisture content, mainly because the thermal conductivity of gravel and solid soil particles in gravel clay is higher than that of pore water. With the increase of moisture content, the proportion of gravel and solid soil particles is reduced correspondingly, which leads to the decrease of heat conductivity. The linear fitting relationship between the two is as follows:

$$I = -0.10181w + 5.1825 \quad (2)$$

The above-mentioned coefficient of determination $r^2=0.76223$. Although it can also be shown that there is a high linear correlation between heat conductivity and moisture content of gravel clay, it is not as good as the linear correlation between specific heat capacity and moisture content.

3.2. Thermal physical index and Void Ratio

The void ratio of the 14 sets of samples are analysed respectively with specific heat capacity and heat conductivity. Results are shown in Figure 3 and Figure 4.

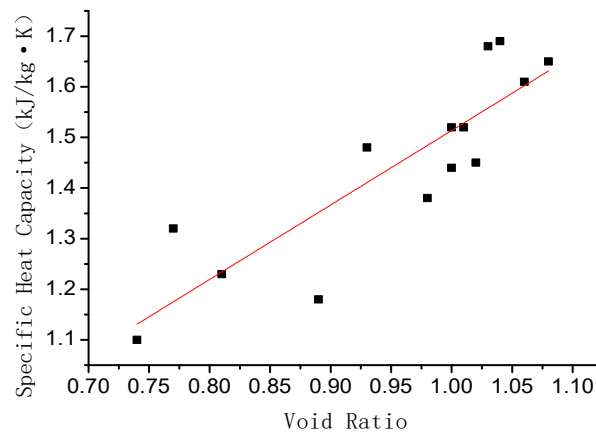


Figure 3. Curve of void ratio and specific heat capacity of gravel clay.

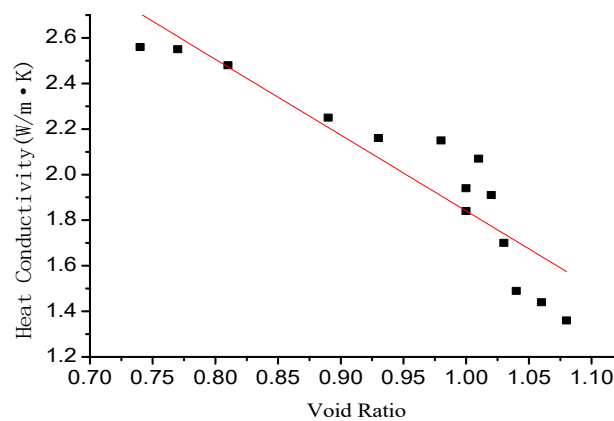


Figure 4. Curve of void ratio vs. heat conductivity of gravel clay.

It is known from Figure 3 that the specific heat capacity of gravel clay increases with the increase of void ratio and the linear fitting relation between the two is as follows:

$$C = 1.4721e + 0.04162 \quad (3)$$

The above-mentioned coefficient of determination $r^2 = 0.75575$. It shows that their linear correlation is not very high. It is related to the randomness of the spatial distribution of the void ratio of the gravel clay, and is the main reflection of the anisotropy of soil.

It is known from Figure 4 that the heat conductivity of gravel clay decreases with the increase of void ratio and the linear fitting relation between the two is as follows:

$$I = -3.3416e + 5.1818 \quad (4)$$

The above-mentioned coefficient of determination $r^2 = 0.84293$. It shows that the void ratio and the heat conductivity of gravel clay are highly linearly correlated.

3.3. Thermal physical index and Density

The density of the 14 sets of samples are analysed respectively with specific heat capacity and heat conductivity. Results are shown in Figure 5 and Figure 6.

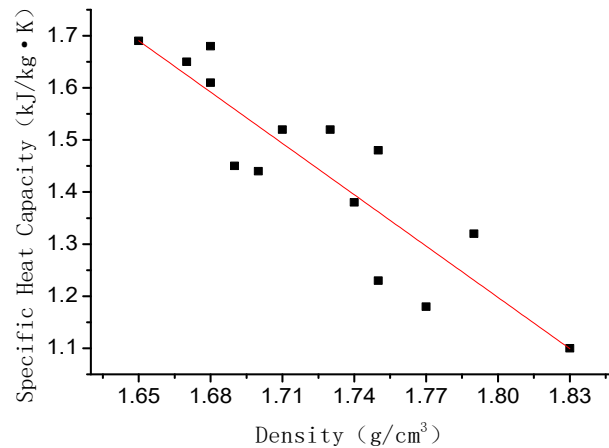


Figure 5. Curve of density vs. specific heat capacity of gravel clay.

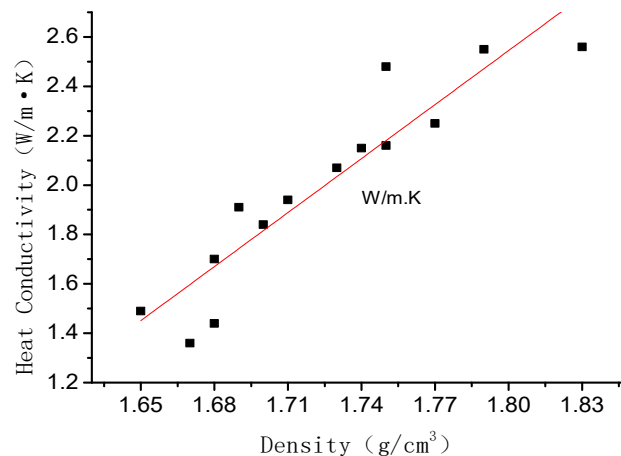


Figure 6. Curve of density vs. heat conductivity of gravel clay.

According to Figure 5, the specific heat capacity of gravel clay decreases with the increase of density and the linear fitting relation between the two is as follows:

$$C = -3.2849\rho + 7.1106 \quad (5)$$

The above-mentioned coefficient of determination $r^2=0.80021$. It demonstrates that the density and specific heat capacity of gravel clay have a high linear correlation.

According to Figure 6, the heat conductivity of gravel clay increases with the increase of density. It is mainly due to the greater soil density, the greater the proportion of soil solids, the greater the contact area between the soil particles, the heat transfer capacity of soil increases, so the heat conductivity increases. The linear fitting relation between the two is as follows:

$$I = 7.29\rho - 10.577 \quad (6)$$

The above-mentioned coefficient of determination $r^2=0.86039$. It demonstrates that the density and specific heat conductivity of gravel clay have a high linear correlation.

4. Conclusion

(1) The specific heat capacity and heat conductivity of gravel clay are closely related to moisture content, density, and void ratio.

(2) The specific heat capacity of gravel clay increases with the increase of moisture content and void ratio, while decreases with the increase of density. It has a less linear correlation with the void ratio.

(3) The heat conductivity of gravel clay increases with the increase of density, but decreases with the increase of moisture content and void ratio. The linear correlation between heat conductivity and moisture content is slightly worse.

(4) The above statistical rules are consistent with the research conclusions of references [4], [5], [6], [7] and [8], indicating the rules of this article are universal, but they still need to be further demonstrated and explained from the mechanism.

Acknowledgments

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