Performance Analysis of Polypropylene Filament Geotextile Heat-Resisting Asphalt Mixture

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Abstract. To illustrate the damage effect of polypropylene filament geotextile against the thermal shock of hot asphalt mixture, the simulation analysis is carried out with ABAQUS finite element software, and the single filament structure of polypropylene filament geotextiles was observed by electron microscopy from the point of view of physical structure, a conclusion is drawn like this: Thermal shock of hot asphalt mixture higher than melting point of polypropylene filament geotextiles will not damage polypropylene filament geotextiles during paving process, its monofilament structure, with a smooth surface and a tight organization, is one of the reasons for resistance to the impact of hot asphalt mixture.

1. Introduction

Compared with traditional engineering materials, geosynthetics have both certain strength of traditional engineering materials and the special properties of large deformation and elongation without being damaged. Therefore, with the rapid development of infrastructure project, geosynthetics are widely used in the engineering construction. Among them, the use of geotextiles to prevent the road reflection crack is an important application. Polypropylene filament spunbond needle punched nonwoven geotextiles (hereinafter referred to as geotextiles) have a high strength, a high elongation and anti-tear characteristics which are of great use in preventing reflection cracks. However, the melting point of polypropylene is between 164 °C and 170 °C. In accordance with Technical Specifications for Construction of Highway Asphalt Pavements (JTG F40-2004), the minimum paving temperature of asphalt mixture is related to the on-site construction. It is necessary to consider the problem between asphalt paving materials and the melting points of polypropylene geotextile, and whether there is thermal damage to the geotextile during the paving process of asphalt mixture. Fu Wei [1] conducted a thermal shock effect test of polypropylene geotextiles about whether polypropylene geotextiles go through the thermal shock from heated asphalt and asphalt mixtures during construction. The test shows that polypropylene can stand against the thermal shocks. Fang Yuanyuan [2] et al. did thermal aging researches into polyester geotextiles at different temperatures and tested its ageing resistance. Yan Xili [3] et al. studied the thermal conductivity of semi-rigid base asphalt pavement by developing a test unit, summed up the factors affecting the thermal conductivity, and described that the thermal conductivity of asphalt pavement was usually in a transient state instead of a steady state. By combining the principles of heat transfer, Sun Yuchai[4] et al. introduced the practical application of finite element method in the heat transfer process of textiles, and simulated the heat transfer process through the finite element software, and analyzed systematically the factors affecting the heat transfer of the fabrics. Zhang Heyu [5] et al. summarized the research results of numerical simulation of fabric heat transfer in recent years, and proposed that the modeling research of fabric three-dimensional structure heat transfer was a growing trend of numerical simulation of fabric heat transfer in the future. The numerical simulation of heat transfer for the fabric system conducted
by Wu Jiajia et al. [6] by means of the three-dimensional model of fabrics and heat transfer theory has won them the temperature distribution characteristics of the fabric during the heat transfer process. They also obtained the time-varying situation of the simulation value and experiment value for fabric surface temperature by using the finite element analysis software ABAQUS. Fan Jian [7] et al. studied the two-dimensional heat transfer numerical model of the fabric unit, analyzed the distribution characteristics of temperature field inside the fabric, and compared the heat transfer effects of fabrics with different structures. By analyzing and simulating the calculating results, it is concluded that the fabric structure is the main factor affecting the temperature distribution of the fabric during the heat conduction process. Li Yanwei [8] et al. tested the heat conductivity coefficient of asphalt mixtures, and chose different types of mixtures for testing, listed the factors interfering with the heat conductivity coefficients, and found out the heat conductivity coefficients of upper surface course had an obvious impact on the temperature field distribution of the surface course by calculating the distribution of the pavement temperature field through ABAQUS modeling and changing the heat conductivity coefficients of different structural layers.

2. Application of Relevant Heat Transfer Theory

2.1. Heat Conduction

The temperature field can indicate the temperature of each position in the object space at a certain moment, the expression is:

$$T = f(x, y, z, t)$$

Where T is the temperature field; x, y, and z are spatial coordinates; t indicates the time.

From the above formula, we find that the temperature of an object is related to spatial position and time. When the temperature field changes with time, it is called an unsteady temperature field. When the temperature field does not change with time, the temperature field at this time is called the steady-state temperature field. At the same time, different dimensional temperature fields can be divided into according to the temperature of the interior point of the temperature field. But it is the one-dimensional transient heat conduction due to the contact between the asphalt mixture and the geotextile.

![Figure 1. Schematic diagram for heat conduction](image)

2.2. Heat Convection

The convective motion of fluid under the action of external force is called forced convection. The convective motion caused by the uneven density resulted from its temperature difference is called natural convection. The convection in highway engineering refers to the heat transfer process happening on the contact surface of the two when the moving air flows through thermal asphalt mixtures of different temperatures. This heat transfer is often not simply convective heat transfer, but a
heat transfer process performed by both heat convection and heat conduction, so it is called the convection heat transfer process.

3. Correlation Analysis of the Application Process of Geotextile Pavement

In the pavement engineering, the procedures in which geotextiles are laid to prevent reflection cracks are as follows[9]. First cut the original pavement, clean the cut pavement, oil the base layer, lay geotextiles, roll the anti-cracking layer, pave the asphalt surface, and compact the pavement, and adjust the paver with the construction method when asphalt mixtures are paved. After the anti-cracking layer is rolled, the surface layer can be laid. When the surface layer is laid, the paver must be operated at a constant speed, slowly and uninterruptedly. And the paver must advance at a certain speed, any optional stop is not allowed. The condition of the paving material must be observed at any time. When the segregation and crack phenomena happen, we must find out the reasons so as to deal with the problems in time. Construction conditions should be consistent with the relevant standard codes. The temperature when asphalt mixture is paved shall be monitored in real time. The paving temperature of asphalt mixture shall not be lower than 110 °C ~ 130 °C. The analysis of heat loss of asphalt mixtures is subjected to three processes. First, asphalt mixtures are loaded into the transport cart from the amalgamator. During this process, much heat loss will occur. The second process is the transportation one, during which the heat loss is related to the length of the transportation distance. The third process as well as the most important process is that the heat loss of asphalt is the severest when asphalt mixtures are paved.

4. Analysis of Heat Resistance of Geotextile

4.1. Analytic Explanation of Heat Resistance of Geotextile

When the geotextile is paved on the pavement and the lower surface layer of asphalt mixtures is paved, first, the geotextile stands against the thermal shock of asphalt mixtures, and it is necessary to analyse the heat loss of asphalt mixtures. Some heat loss is conducted to the basement layer through the geotextile, while the rest is diffused to the ambient air.

| Density kg/m³ | Thermal conductivity(W/J°C) | Specific heat J/(Kg°C) |
|---------------|-----------------------------|------------------------|
| Asphalt mixture | 2400 | 1.5 | 1034 |
| Geotextile | 140 | 2.34×10² | 1300 |
| Basement layer | 2300 | 1.1 | 810 |

4.2. Simulation Analysis of ABAQUS Application

With a powerful function, ABAQUS is a kind of finite element software for engineering simulation. Its problem-solving ranges vary from the relatively simple linear analysis to many complex nonlinear problems. ABAQUS can simulate many problems in relevant engineering fields, such as heat conduction, mass diffusion, analysis of thermoelectric coupling, acoustic analysis, analysis of rock and soil mechanics (fluid permeability / stress coupling analysis) and piezoelectric medium analysis. The dimensions of models made by ABAQUS application are 4×4×0.57125, the surface layer is made of 21cm-thick asphalt mixture, the geotextile is 1.25mm thick, the basement layer is 36cm thick, the temperature field of the surface layer is 170 °C, and the surface temperature field of the basement layer and geotextile is 50 °C in summer.
Based on the simulation results, it can be seen that the heat loss of asphalt mixture is mainly from the upper part of the surface layer. The upper surface layer is in contact with the air, and a large quantity of heat is quickly dissipated. When the heat is transferred to the surface of the geotextile, the temperature has dropped below the melting point of the geotextile. When the asphalt mixture is paved, the area where the mixture surface is in contact with the air is the largest, thus, the heat is fully volatilized.

For the instantaneous thermal shock, only when the heat is accumulated to a certain degree, will the geotextile be affected. However, the overall thermal energy of the asphalt mixture at this time is not enough to have a destructive effect on the geotextile. As shown in Table 2, the temperature variation of the structure layer is gradually decreased.

**Table 2. Temperature Variation in Structure Layer of Model**

| Structural temperature layer | Degree |
|------------------------------|--------|
| 1                            | 170    |
| 2                            | 160    |
| 3                            | 150    |
| 4                            | 140    |
| 5                            | 130    |
| 6                            | 120    |
| 7                            | 110    |
| 8                            | 100    |
| 9                            | 90     |
| 10                           | 80     |
| 12                           | 70     |
| 13                           | 60     |
| 14                           | 50     |
Figure 3. Microscopic Display of Geotextile by Electron Microscope

We also observed the microscopic surface structure of the geotextile through an electron microscope. We can see that in the picture the monofilament surface structure of the geotextile is smooth, the structural organization is tight and complete, with a sparsity structure made of silk, and the geotextile has good heat dissipation.

Asphalt mixture will go through the heat loss during the transportation in actual engineering, and some heat will be lost again when asphalt mixtures are paved. Hence, in fact, the damage caused by thermal shock of geotextiles is not significant.

5. Conclusion
This article, combining the general theory of heat transfer, simulates and analyzes the damage caused by the thermal shock of polypropylene filament geotextile when heated asphalt mixtures are paved. The result shows that the heat loss of asphalt mixtures is mainly concentrated in the place where the upper part of the surface layer is in contact with the air, and no damage is done to the geotextile. Besides, by observing the surface microstructure of the geotextile, we find that the geotextile monofilament has a good microstructure, which provides a good precondition for standing against the thermal shock of asphalt mixture in some degree.

6. References
[1] Fu Wei. Experimental study on absorptive characters and thermal shock effect of polypropylene geotextile asphalt [J]. Highway, 2016, 61 (03): 196-199.
[2] Fang Yuan yuan, Jin Xiangyu. Study on heat aging properties of polyester geotextiles [J]. Nonwovens, 2010, 18 (01): 21-24.
[3] Yan Xili, Ai Tao, You Qinglong, et al. Heat-conduction test characteristics of semi-rigid base asphalt pavement [J]. Journal of Chang’an University: Natural Science Edition, 2016, 36 (5): 1-7.
[4] Sun Yuchai, Feng Xunwei and Liu Chaoying. Finite element analysis of textile heat transfer [J]. Journal of Donghua University (Natural Science Edition), 2006 (02): 50-53.
[5] Zhang Heyu, Zhao Xiaoming and Zheng Zhenrong. Research progress on numerical simulation of fabric heat transfer [J]. Shandong Textile Science & Technology, 2014, 55 (01): 50-53.
[6] Wu Jiajia and Tang Hong. Finite element analysis of fabric heat transfer through the application ABAQUS [J]. Journal of Textile Research, 2016, 37 (09): 37-41.
[7] Fan Jian, Ni Bo. Numerical modeling study of heat transfer for fabric unit structure [J]. Journal of Donghua University (Natural Science Edition), 2002 (04): 5-11.
[8] Li Yanwei, Zhang Qian, Xie Laibin, et al. Thermal conductivity test of asphalt pavement and simulation of its impact on pavement temperature field [J]. Functional materials, 2012, 43 (S1): 129-132.
[9] JTG F40-2004, Technical specifications for construction of highway asphalt pavements [S].