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# Responses of snow-melting airfield rigid pavement under aircraft loads and temperature loads and their coupling effects

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A B S T R A C T

Heat pipe technology has been demonstrated to melt ice and snow in airfield rigid pavement, and field observations indicate that it achieves satisfactory effects. However, the impacts of heat pipes on pavement responses are unclear. This paper compared the responses of traditional versus snow-melting airfield rigid pavement under aircraft loads, temperature loads, and their coupling effects by the means of field tests and a three-dimensional finite element (3D FE) model. The effects of types of interface contact on pavement responses were also modeled and discussed. The results show that introduction of heat pipe does not change the mechanical-induced responses of pavement. However, it significantly decreases the maximum thermal stresses by reducing the internal temperature gradient of concrete layer. Besides, the maximum principle stress induced by coupling effects of aircraft loads and extremely thermal loads decreases significantly when heat pipe is embedded. Such coupling stress is independent on the type of interface contact conditions. Overall, heat pipe can potentially postpone pavement deterioration and damage extents, such as thermal cracking and fatigue cracking.



## Introduction

Heat pipe was first invented in Key State Laboratories in Los Alamos in America by George Grover in 1963 [1]. Gravity heat pipe is one of the most widely used heat pipe, as shown in Fig. 1(a), its circulation mechanism of refrigerant is explained in Fig. 1(b). The operation mechanism of gravity heat pipe applying in pavement engineering to melt ice and snow is presented in Fig. 1(c): liquid ammonia as an effective heat exchange medium stored in gravity heat pipe, when pavement surface experiences an extreme low temperature in cold winter, heat pipe inserts into deeper soil and absorbs energy from deeper soil through vaporization of liquid ammonia, and then the energy is transmitted upwards and releases to pavement surface through liquefaction of ammonia, which results in a sharply improvement of surface temperature. By self-gravity effect of liquid ammonia, the medium circulates inside the heat pipe and the purpose of melting snow automatically for a long term is achieved. Also another superiority of heat pipe is to reduce the temperature of concrete surface in hot summer, as shown in Fig. 1(d), under the circumstance of an extreme high temperature, heat pipe absorbs energy from concrete surface and transmits energy and stores energy to deeper soil to reduce pavement temperature. What's more, the recommended snow-melting technology [2] does not require any maintenance and operating costs after the initial investment. As its unique work characteristics and superiorities, it has been applied as a heat exchange medium for transiting and transforming energy to solve engineering problems such as melting ice and snow in some special area (Bridge Deck, Roof, sharp turn covered with ice and snow, permafrost) [3–10]. As a new snow-melting technology, heat pipe possesses great application prospects.

At present, heat pipe has attempted to introduce into snow melting of airfield rigid pavement. Harbin Institute of Technology (HIT) in cooperation with China Airport Construction Group Corporation (CACC) has established corresponding full-scale snow-melting test platforms in Harbin and Beijing, respectively, as illustrated in Fig. 2(a) and (b). In Beijing Daxing International Airport (under construction), heat pipe technology was first applied in airfield rigid pavement to melt snow, as shown in Fig. 2(c) and (d), and the application of heat pipe to melt snow in airfield rigid pavement were initially proposed. What have been conducted provided experimental basis and practical precedent application of heat pipe in snow melting of airfield rigid pavement. Through a long term observation and monitoring, a satisfied snow-melting effect was observed, as illustrated in Fig. 3, which implied and confirmed the feasibility of this deicing and melting

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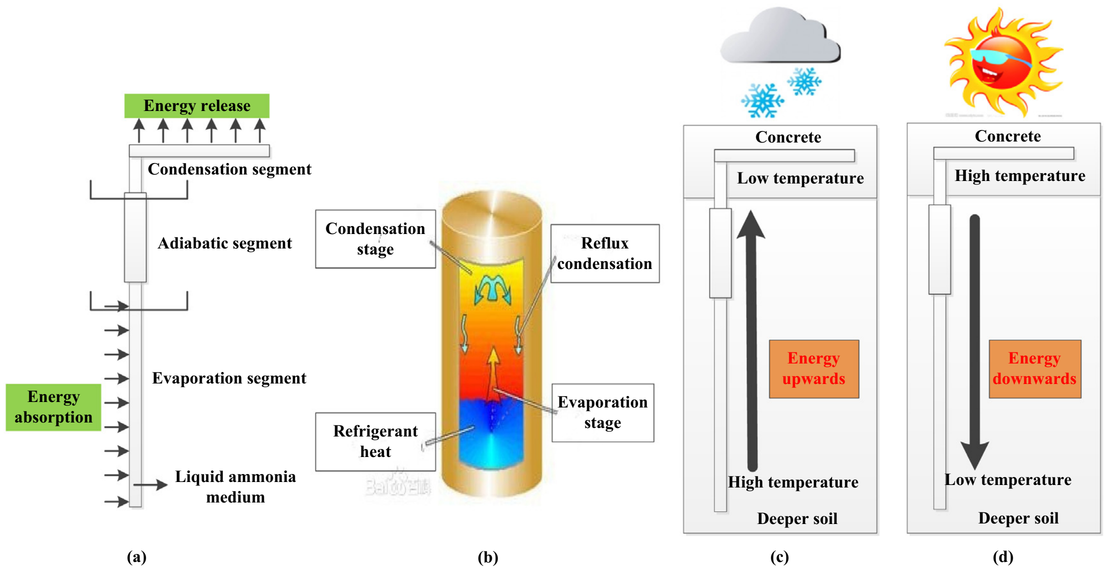


**Fig. 1.** Introduction of heat pipe and its operation mechanisms for: (a) Sketch graph of heat pipe, (b) Circulation mechanism of refrigerant, (c) Energy transformation in cold winter and (d) Energy transformation in hot summer.


**Fig. 2.** Engineering applications of heat pipes for: (a) Snow-melting test platform in HIT, Harbin, (b) Snow-melting test platform in CACC, Beijing, (c) Testing road of New Airport, Beijing and (d) Parking apron of New Airport, Beijing.

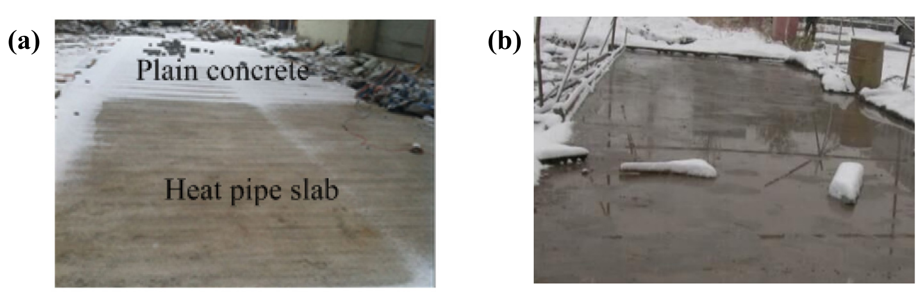


**Fig. 3.** Snow-melting effects for: (a) In HIT and (b) In Beijing.

technology. The enumerative programs and research provide engineering basis and scientific theory basis for application of this technology.

Airfield rigid pavement is subjected to complex and variable load cases, including complicated aircraft landing gear configurations, changeable temperature loads and severer coupling loads [11–13]. Heat pipe, as thin-wall hollow steel tube, not only affects static and dynamic responses characteristics of pavement structure, also affects and alters the temperature field distribution of pavement. When taking temperature induced stress and mechanical induced stress into consideration, the impacts of heat pipe would be more visible and could not be ignored. Simultaneously, with heat pipe introduced into pavement, new interfaces between heat pipes and surrounding concrete are appeared, the impacts of interface contact conditions on mechanical response of pavement are worth for a further study.

Summing up, some mechanical problems exist for new airfield rigid pavement buried with heat pipes (in the paper, we define it as "snow-melting airfield rigid pavement"). Structure responses are unclear, especially considering a complex coupling loads subjected on airfield rigid pavement due to embedding of heat pipes; The influences of interface contact conditions on mechanical responses of pavement under diverse of load conditions are also uncertain. Relevant studies and reports have not been reported yet for those issues. Based on the above, the study on snow-melting airfield rigid pavement response behaviors under aircraft gear loads, temperature-induced loads and their coupling effects is of great value.