The Durability and Performance Test methods of the New Type of Pavement Filling Material – An Holistic Review

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Abstract: Airport pavement joint weaknesses are one of the important factors that affect airport performance and threaten flight safety. The traditional pavement caulking materials are mainly asphalt-based materials of heating construction type, which are prone to aging, loss of adhesion and other shortcomings in natural environment. Based on the shortcomings of traditional pavement caulking materials, this paper introduces the research and application status of new type of filling caulking materials represented by high-performance elastic polymer materials, with emphasis on its durability, performance testing methods. Finally, it summarizes the existing problems and prospects of the new type of pavement filling caulking materials.

1. Introduction
As the weak link of the airport pavement, the performance of the joint filling material used in the joint and the sealing effect it can achieve have a serious impact on the service performance and service life of the airport [1,2]. Due to the existence of these joints, it is easy to cause water infiltration and hard object embedding. Therefore, it is necessary to fill and seal them with caulking materials in time to avoid damage to soil foundation and pavement panel [3]. Road surface weaknesses caused by the failure of caulking materials have become a serious safety hazard in the airport, which often leads to flight accidents and threatens flight safety [4]. For example, due to channel surface weaknesses such as stagger and floor clearance, the flatness of the channel surface becomes worse, which is likely to make the aircraft vibrate to break the airspeed tube and damage the landing gear during takeoff and landing [5]. More seriously, when the plane takes off, damaged concrete fragments or invalid caulking materials in the pavement will be sucked into the engine under the strong suction of the aircraft engine, causing damage to the aircraft and even leading to the fatal accident [6].

Therefore, at present, there are problems in the use of airport pavement caulking materials. At the same time, the actual demand of airport pavement security should be improved. Therefore, it is necessary to study and prepare a kind of high performance joint filling material with good durability and strong deformation coordination ability. It also applies to the characteristics of the airport engineering environment. In order to solve the problems of poor environmental adaptability and weak durability of the existing airport pavement caulking materials, it is necessary to master its performance characteristics. Cut down the hidden dangers of the airport road surface to ensure the smooth completion of the flight mission.
2. Background status quo

Currently, new types of caulking materials have been widely used in pavement joint engineering, among which the typical ones are silicone, polysulfide, polyurethane and other high-performance elastic polymer materials [7]. Among them, polyurethane caulking materials are mainly composed of polyurethane, which can be divided into two types according to the different types of raw materials, namely polyether type and polyester type. Due to the fact that polyester polyurethane is easy to hydrolyze, polyether polyurethane is widely used in pavement joint engineering. Due to the existence of strong polar groups such as -nco and -oh in the molecular structure of polyurethane, a series of excellent properties were obtained after reaction curing. These include good oil resistance, high and low temperature resistance, wear resistance and strong bond deformation performance [8]. However, polyurethane elastomers are still prone to degradation in humid environment or water, so their heat and moisture resistance is poor. At the same time, the durability of polyurethane caulking material is also affected by its easy pulverization and yellowing under long-term solar irradiation [9].

Polysulfide caulking compound is formed by polymerizing metal peroxide and liquid polysulfide rubber through vulcanization reaction. This kind of joint sealant usually has good aging resistance, corrosion resistance, excellent air tightness, low temperature flexibility, water tightness and tear resistance. According to the fluidity and packaging form, polysulfide joint sealant can be divided into non-sag type and self-leveling type, single-component type and two-component type. Due to the slow curing and high non-sagging tensile modulus of single-component type, two-component self-leveling type is more commonly used in pavement joint workers [10].

Another kind of silicone caulking compound polymerized from a series of polydimethylsiloxane with different molecular weights is silicone oxide polymer. Thanks to the existence of silicon-oxygen bond structure similar to inorganic silicate in this type of joint sealant, it not only shows outstanding water resistance and aging resistance, but also has good high and low temperature resistance, stretching and bonding [10]. However, due to the high production cost and poor embedding resistance and oil resistance of silicone materials, their application scope is limited to a certain extent.

In summary, compared with the traditional joint sealant, the new joint sealant has been greatly improved in aging resistance, cohesiveness, environmental adaptability, elastic deformation and other aspects. In addition, this kind of material can smoothly reach the purpose of construction solidification under normal ambient temperature, so it can also be free from the negative impact caused by heating construction.
3. Durability

This research is mainly through a series of indoor tests to study the durability of various types of commercial joint sealants under different working conditions, and to analyze its influencing factors and changing rules. Among them, the durability includes high and low temperature resistance, water resistance, corrosion resistance, aging resistance and chemical stability. Relevant representative studies at home and abroad are as follows:

Liu Xiaoxi et al. [11,12] (2003, 2008) compared and analyzed the properties and characteristics of polysulfide, silicone, polyurethane and acrylate as four kinds of caulking materials. At the same time, the samples of the above four kinds of caulking materials were tested under different working conditions. The results show that silicone joint sealant has poor oil resistance, acrylate joint sealant has low elastic recovery rate, polyurethane joint sealant has relatively optimal cost performance, and different brands of similar joint sealant have different performance. Chen Guoming et al. [13] (2004) conducted low-temperature tensile test research on 7 kinds of normal-temperature construction joint sealants, and established corresponding low-temperature performance evaluation system in combination with relevant specifications. Liu Xiaoxi et al. [14] (2006) studied the tensile and shear fatigue properties of polyurethane and polysulfide joint sealant after treatment at room temperature and freeze-thaw cycles. The results show that the curing degree of joint sealant has a significant effect on its early performance, and polysulfide joint sealant has relatively better anti-fatigue performance and is suitable for areas with large temperature difference. Shou Chongqi et al. [15] (2007) studied the influence of different interface states (clean interface, wet interface, cement slurry treatment interface and interface agent treatment interface) on the bonding performance of joint sealant. The results show that wetting the interface is easy to cause debonding of the joint sealant, and bottom coating of the interface agent or dilution of the joint sealant with solvent are beneficial to improving the bonding strength. Shou Chongqi et al. [16] (2007) have comparatively studied the fatigue aging resistance of silicone and polyurethane joint sealant under cyclic load of cold drawing and hot pressing. The results show that the silicone joint sealant has excellent aging resistance due to the existence of silicone bonds, and its adhesive strength retention rate can reach more than 95%. Sun Kunjun [17] (2007) conducted a systematic study on the properties of a polyurethane caulking compound modified by petroleum asphalt, including curing process, cohesiveness, heat aging resistance, frost resistance, etc. At the same time, the cost performance of the caulking compound and its application effect in actual projects were analyzed and tested. Liu Xiaoxi et al. [18] (2008) studied the effects of curing rate and curing degree of various commercial joint sealants on their early deformation properties. The results show that the curing rate of the two-component joint filler is the fastest, and the lower the early curing degree of the joint filler, the worse the elastic recovery performance. Cai Wen [19] (2012) conducted a series of comparative tests on the performance of a self-made two-component polyurethane joint sealant and a variety of commercially available joint sealants, and analyzed and discussed their respective cost performance and scope of application. Li Huajian et al. [20] (2015) and Liu Bo et al. [21] (2015) reviewed the performance characteristics, requirements and research and development status of existing silicone caulking compounds. In addition, the corresponding technical approaches to improve its adhesive deformation and durability are put
forward.

4. Performance Test Methods

It is often difficult to predict and analyze the field application effect of joint sealant in actual engineering. One of the important reasons is that the current performance test of caulking material is only limited to a few basic indicators required in the specification. Due to the lack of relevant laboratory testing methods, it is not possible to further accurately simulate the actual operating environment under various working conditions. In view of this, some scholars at home and abroad have carried out a series of researches on equivalent test methods to simulate various actual working conditions. Relevant representative studies are as follows:

Al-Qadi et al. [22] (1999) developed a test device capable of applying cyclic shear load and constant horizontal load to joint sealant to simulate the effects of shrinkage and expansion of pavement slab and traffic load in actual working conditions. On this basis, the effects of joint displacement, concrete aggregate type, freeze-thaw cycle and other factors on fatigue performance of joint filler were studied. The corresponding failure prediction model is established. Soliman et al. [23] (2007) put forward two kinds of test methods for evaluating the field performance of heated construction joint filler. It is in -30 °C environment pressure cycle test (to test the caking property of the material was tested), as well as 5 ~ 64 °C in the environment dynamic shear test (to test the rheological properties of the material). Through comparison with the field observation results, it is believed that the above two indoor test methods can replace the field test to a certain extent. Lacasse et al. [24] (2010) proposed a fatigue test method for evaluating the performance of joint sealant under cyclic load, and compared the anti-fatigue performance of silicone, polyurethane and polysulfide. White et al. [25] (2011) applied a stress relaxation test method to the evaluation of non-linear viscoelastic properties of joint sealant, and realized the monitoring of its apparent modulus changes with time. The obtained results can be used as a precursor of joint sealant failure. Li et al. [26] (2012) designed a test device for creep testing of joint sealant, and studied the temperature sensitivity of creep of two silicone joint sealants (including 0 ~ 60 °C and freeze-thaw cycling). White et al. [27] (2013) developed an accelerated aging test device capable of independently controlling ambient temperature, humidity, ultraviolet radiation and stress deformation value of joint sealant. The device can simulate the joint action of various environmental factors on joint sealant to study its long-term durability. Li et al. [28] (2014) designed a test method for bonding strength of caulking materials that can take into account the influence of different temperature, humidity and displacement change rate. The variation of bond strength of two kinds of silicone sealants under different working conditions was studied by using this method.

Wang Jinyong et al. [29] (2012) designed a set of indoor and field test methods capable of detecting the water sealing performance of joint sealant on pavement. The method uses artificial spraying to simulate rainfall intensity and uses the amount of water seepage per unit volume and time to characterize the water sealing performance of joint sealant. Wang Baosong et al. [30] (2012) developed a fatigue tester for testing the anti-fatigue performance of pavement joint sealant under tension-shear cyclic load by modifying the existing Weber consistency tester. Meng Xu et al. [31] (2014) improved the original testing device to solve the problems existing in the high-temperature fluidity testing method of joint sealant, designed a positioning measuring workbench, and standardized the specifications of the copper mold and tin plate used.

5. Conclusion

Based on the above summary and analysis of the research status of the new type of pavement joint filler, scholars at home and abroad have done a lot of research work on its preparation and related properties. In general, there are still three shortcomings in the current study of pavement joint sealant and it can be used as the research direction for further study:

1) Influenced by the performance defects of organic materials, the above caulking materials still have some deficiencies in durability, aging resistance and bonding compatibility with cement substrates.

2) The above-mentioned caulking materials still have some limitations in actual use. In addition, the
construction technology still needs further improvement to adapt to the convenient and fast caulking construction with higher quality assurance under different conditions.

(3) In actual production and construction, the on-site use effect of joint sealant needs to be ensured by testing. But at present there is still a lack of corresponding more accurate index testing method, which is not conducive to the further large-scale popularization and use of the material and limits its development.

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