EVALUATION OF PERFORMANCE OF JOINT SEALANTS IN COLD CLIMATE AREAS

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1 Introduction

Today, almost all agencies building and maintaining concrete airport pavements require joint sealing for new pavements. The provision of joints is an integral part of the construction. Their role is to provide relief from tensile and warping stresses and to accommodate movements caused by thermal expansion and contraction. The purpose of a joint sealant is also to seal a joint or a crack against certain environmental factors like infiltration of surface water and incompressible material into the joint system. Secondarily, sealants are also purported to reduce the potential for dowel bar corrosion by reducing entrance of de-icing chemicals. It is known that water can contribute to subgrade or subbase softening and lead to pumping of subgrade or subbase fines under heavy traffic. This degradation usually results in loss of structural support, pavement settlement, and/or joint faulting. In the cold climate areas, the infiltrating water can cause frost heaving that leads to break of concrete slabs and thus risk for accidents in traffic. The other function of modern joint sealants is to prevent incompressible material from entering the joint reservoir. In some circumstances, incompressible materials may contribute to spalling, and in extreme cases, may induce pavement migration and "blow-ups." These problems are caused when incompressible materials obstruct pavement expansion in hot weather and create compressive pressure along the joint faces.

Sealants may be poured or preformed. The poured sealants may be applied hot or cold and are required to meet performance specifications related to the environmental conditions rather than compositional recipes. In the cold climate areas the width of joints and cracks is changing widely with temperature. The joint sealant must thus be flexible enough to compensate for the relatively large dimensional changes within a broad temperature range, sometimes down to - 30°C. In this context, particular attention must be paid to the cyclic mechanical stresses of the sealant. Re-sealing joints is costly and the remedial work can cause considerable traffic disruption.

2 Joint/crack movements

Little information was available as to the magnitude and the rate of movements that occurs in airfields pavements during service in the cold climate areas. An extensive field study started twenty years ago in Sweden with the purpose to determine the magnitude and the rate of joint and crack movements. The most extensive measurements were performed in Kallax, Östersund and Sundsvall, all located in the northern part of Sweden. The largest movements were detected at the Midlanda airport located in Härnösand-Sundsvall. During a period of 200 days the movement reached 63 % at the maximum. The rate of the thermally induced movements was $1{,}5 - 6\cdot10^{-5}$ mm/min with some faster movements superposed on it[i]. During the extension a force is exerted on the sealant and on the walls of the groove. The force reaches its highest value at the lowest temperature when the opening of the joint is at its maximum. At this point, if the sealant exerts a force that exceeds the stress at break value of the pavement, the pavement will crack. On the other hand, if the sealant is not flexible enough at the low temperatures, adhesive or cohesive failure will occur.

In the case of preformed sealants the situation is different. The sealant is placed in a compressed state in the crack or joint where it expands. The expansion force (compression force) of the sealant is responsible for keeping the seal in place and preventing water from penetrating the joint. The expansion force of a seal depends on temperature, nominal width and range of movements of a joint (working range) and on geometry and flexibility of a seal. A seal is therefore judged as not functioning well when the expansion force is reduced to zero.

3 Laboratory test method for evaluation of performance of joint sealants

Using the results from the field study a laboratory test method (function test) was drawn up to simulate the influencing parameters which occur in service life, such as fluctuating temperature, slow movements and simultaneous dynamic load. A test apparatus and different test procedures were developed for the evaluation of the performance of different joint sealants in cold climate areas. The testing apparatus consists of a climatic chamber capable of regulating the temperature between +25 and - 30 °C. Inside the chamber, a tensile and compression test rig is placed having six pairs of beam for testing of six specimens simultaneously. The test rig is motor driven, giving a constant rate of movement. Six load cells placed are connected to an electronic data collection device for measuring and recording of the tensile and compression force continuously. The movement of the beams is then synchronised with the change of the temperature in such a way that the minimum width is achieved at the highest temperature and the maximum width at the lowest temperature (-20 °C or -30 °C). The rate of deformation is normally 0,60 mm/h.

4 Test results

The function test is used as the performance criteria for all types of joint sealants in concrete pavements. It is also used for testing of hot-applied normal joint sealants in bituminous surfacings and between bituminous surfacing and concrete pavements for the same uses.

Poured sealants are usually subjected to three repeated cycles of the function test composed of the temperature variation between +25 and –30 °C, the joint movement between 20 % compression and 60 % extension (high elastic products) and the water spray during 20 % of the total time at the temperature interval 5 °C up to 20 °C. After completion of the test cycles the sealant is not allowed to show any damages and the maximum tensile stress at the lowest temperature must not exceed 0,3 N/mm^2 in asphalt concrete or 1,0 N/mm^2 in cement concrete. Therafter the following visual inspections are performed:

The joint is elongated to 60 % at room temperature and inspected to check for visible damages and fractures, such as adhesion or cohesion fractures. Then, the joint is compressed to the original dimensions and a 3 mm deep notch is made with a sharp knife next to the supporting material at the short side of the joint. The joint is once more elongated to 60 % and inspected with respect to visible damage and fractures such as adhesion or cohesion failure.

Additional requirements can be specified according to the function test for sealants intended to be used in areas where risk of fuel spillage exists, as well as for those in contact with asphalt pavements (e.g. products to seal the longitudinal joint between a concrete carriageway and an asphalt shoulder) or for sealants to be used in areas where the risk of leakage of fuels exists. It is also intended to apply this specification in industrial areas where the ground has to be proof against the treated water-dangerous chemicals and solvents.

Preformed joint seals are evaluated in similar way. Test specimens are placed between the beams and compressed to their nominal width being specified for each product by the manufacturer. The movement of the beams is then synchronised with the change of the temperature in the same way as for poured sealants. The test samples are however not subjected to water spray. The expansion force (compression force) of the seals, which is responsible for keeping the seal in place and for preventing penetration of water and dust, is recorded continuously. A seal is judged as not functioning well when the expansion force is reduced to zero.

Service life of rubber joint seals is depending among other things on the ability of the material to retain its elastic properties after prolonged compression at ambient temperature. The effect of the prolonged compression is often measured as compression set which is a measurement of recovery of the material after the removal of an applied stress or strain.

Accelerated conditions are frequently used in order to achieve information about long term performance in a short time. In this test procedure, accelerated ageing is also performed at +70 °C with the joint seals compressed to their nominal width. The ageing is performed in 30 days periods. A renewed functional test is made every 30 days of ageing. If the expansion force (compression force) during the functional testing is near zero, i.e. no change in force with movement is noticed, the ageing is terminated.

The experience from the function tests shows the importance of performing such a test on joint sealants, within the entire field of application, in order to verify the properties specified by the manufacturers. This test procedure makes it possible to determine limits in working range and temperature for sealants. The method is also suitable to evaluate the influence of the environmental factors like temperature, liquid chemicals, UV-light, ozone, ect on the performance of joint sealants. The method is now in the progress of acceptance as EN standard in three versions: for hot applied sealants, for cold applied sealants and for preformed rubber sealants.

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[i] S. Linde, “Investigations on the cracking behaviour of joints in airfields and roads”, SP report 1988:23, Borås 1988