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Rubber Joint Seals for Roads and Airfields - Evaluation of Performance and Durability

SP
Swedish National Testing and Research Institute
Materials Technology
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Abstract

Rubber Joint Seals for Roads and Airfields - Evaluation of Performance and Durability

Joint seals for use in construction joints in roads and airfields were examined in respect to their performance, within a wide range of temperature. Attention was paid to very slow movements in joints and to compression set of materials. Three EPDM seals were used. The seals were subjected to changing temperature and synchronised movement of the joint. 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, was recorded continuously. A seal was judged as not functioning well when the expansion force was reduced to zero.

A comparison between various seals was difficult to make as the manufacturers have specified various working ranges. Apart from that, only one EPDM seal functioned well at -30 °C. The other two EPDM seals hardly managed to function at -20 °C.

The testing of the EPDM joint seals showed that the compression set in the material after ageing is a limiting factor for the function of a seal. Already after 30 days ageing at +70 °C two of the seals ceased to function at -20 °C. One seal managed 30 days ageing but ceased to function at -30 °C after 60 days ageing. The compression force decreased significantly also at +25 °C after the ageing.

The results from the investigation show the importance of performing a function test on preformed joint seals, within the entire field of application, in order to verify the properties specified by the manufacturers. The proposed test procedure makes it possible to determine limits in working range and temperature for joint seals. 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 seals.

Key words: Rubber, Joint Seal, Performance, Durability, Compression Set, Air Field, Concrete Pavement, Function Test.

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Content

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To the project, a reference group were aligned, consisting of:

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1 Background and introduction

The purpose of a joint sealant is to seal a joint or a crack against certain environmental factors like water, gravel, dust, etc. As the width of joints and cracks is changing with temperature, the joint sealant must be flexible enough to compensate for 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.

During the years 1981-1988 an extensive field investigation regarding the relation between climatic circumstances and crack movements in airfields and roads was realised at the Swedish National Testing and Research Institute (SP). Among other things, the magnitude and the rate of thermal movements has been measured at a number of places in different climatic zones in Sweden during a period of three years. Within the frame of this project, a test method for testing of the performance of viscoelastic joint sealants was developed [(1)].

Lately, another type of products has been introduced in Sweden for the mending of joints, namely prefabricated joint seals. Prefabricated joint seals are mostly made of rubbers or foamed polyurethane (PUR). The most common rubber types used are EPDM (Ethylene Propylene Diene Terpolymer) and CR (Chloroprene Rubber) from which CR is not generally used in Europe.

EPDM can be obtained in a wide range of hardness. EPDM-materials show a number of good properties such as resistance to weathering, low temperature flexibility and ozone resistance. Compression set of sulphur cured EPDM vulcanizates increases very rapidly with increasing temperature in contrast to peroxidic crosslinked EPDM which stays relatively stable [(2)].

Depending on how CR is produced, a distinction is made between sulphur modified and mercaptan modified grades. In addition, one distinguishes grades of low, medium and high crystallizability. CR-materials show good weather and ozone resistance and specially good resistance to oil and chemicals. The stiffening of CR vulcanizates on cooling is often superposed by crystallization processes. Thus the freezing temperature depends on the grade and its tendency to crystallize. The plasticizers used in the material determine to a large degree the dynamic freezing point of CR [(2)].

On installation, 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. When a constant stress is imposed on rubber, physical and chemical degradation occur in the material. Generally, physical effects are dominant at short times and low temperatures and chemical effects are more apparent at long times and high temperatures. The chemical degradation processes are accelerated by increased temperature.

Today, there is no relevant method for testing of the functionality of preformed seals as there is for viscoelastic sealants. Designers, contractors and manufacturers need such a method to be able to predict the products functionality. This is needed in both selection of the material and in purchase quality inspection.

The goal of this project has been to develop a test method for the evaluation of performance of preformed joint seals. Attention has been paid to the wide range of temperature, cyclic mechanical stresses of a seal, and a very low rate of movements.

The test procedure developed is based on the existing method for viscoelastic sealants (3). The test method is also used for the evaluation of effects of compression set on the functionality of the seals. The project is also assumed to give a basis for determination of the minimum demand for the actual type of products.

2 Literature surveillance

The literature search was made using following key words:

- rubber
- joint seal

From the references received the ones with key words bitumen and silicone were excluded. A total of 33 references was found, of which ten were ordered. Of these ten articles, only four were considered as relevant for the project.

L. Smith *et. al* [4] have studied the condition of preformed rubber joint seals installed in Florida 1966. The seals were then 15 years old. Eight seals were made of Chloroprene rubber (CR) and two of EPDM. The joint seals were, to adhere, glued to the concrete.

A number of tests as well as a visual judgement of the condition, tear in tyre tracks and the crack development due to influence of UV-radiation were performed on the seals. The tests performed were hardness of the surface and inside the material, tensile properties, ozone resistance, oil resistance (ASTM oil 3), compression set, recovery, ageing, contact pressure at nominal width, and a judgement of the adhesive condition.

The authors drew the following conclusions on basis of their investigation:

- All the seals perform sufficiently after 15 years of usage.
- There are signs of degradation on the surface of principally CR, in the form of cracks. The degree of degradation is between 40 - 80 % of the original condition.
- The high set has a negligible effect on the performance on the seals function, as it still exerts a sufficient contact pressure on the walls of the joint. Trials to correlate permanent set with properties like joint design, wall thickness, original test results and so on indicate no close relationship between set and a single property.
- The observations indicate that a failure of the seal will probably be by longitudinal cracks trough the upper surface, which leads to a penetration of dirt and sand into the seal.

The article suggests the following measures in order to increase the working life of the seals:

- Take steps to reduce the tensile force, by using minimum possible width of the joint seal for the given joint width.
- Replace CR with EPDM because of the better weather resistance of EPDM. CR has a better oil resistance than EPDM, but the investigation has shown that oil from vehicles is not a problem.

J.E. Bryden *et. al* [5] has investigated, once every three years, three different seals made of CR and installed in New York.

The result of a visual study of the joint seals is, that the seals have performed without any remarks. However, in some areas the seals show signs of compression set. Joints with CR seals have functioned insufficiently due to the penetration of debris into the joints causing damage to the seal. The work has mainly been aimed on the effect of ageing on concrete.

D. Mellot ***et. al*** [6] has investigated joint seals of Neoprene (CR) installed in Pennsylvania, USA, with reference to sealability, weatherability and penetration of debris. Only a visual judgement has been made. According to the article the joint seals show no deterioration concerning these properties after seven years of usage.

F.J. Bashore ***et. al*** [7] has removed cores from joints and compared them with cores taken from concrete plates as reference material. The project was aimed to study the effects on concrete near the joint. The joints were up to nine years old when the last samples were removed.

The results from this investigation show that CR prevent incompressible materials from entering the joint. However, it does not stop road salts and water from penetrating the joint. This is probably due to the harsh surface of the concrete in the joint, which made it hard for the joint seal to take shape after the joint.

3 Experimental

3.1 Materials

Three joint seals from two different manufacturers were used in this project.
The seals were made of EPDM in form of profiles with various geometry and nominal width. The properties are specified in table 1.

Table 1 Specification of joint seals

Material	Designation	Nominal joint width
EPDM	P 20	20 mm
EPDM	P 8	8 mm
EPDM	H 15	15 mm

3.2 Testing of performance

On the basis of the SP-method 0759 for function testing of viscoelastic materials, a function test method for preformed joint seals was developed. The method is drawn up to simulate the influencing parameters which occur in service life, such as fluctuating temperature, slow movements and simultaneous dynamic load.

The testing apparatus (figure 1) consists of a climatic chamber capable of regulating the temperature between +25 and - 30 °C with the accuracy of ±2 °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 without significant slip or backlash, giving a constant rate of movement. Six load cells placed in the chamber are connected to an electronic data collection device for measuring and recording of the compression force with the accuracy of ±2 %.

Joint seals were cut into 70 mm long test specimens. The specimens were placed between the beams and compressed to their nominal width being specified for each product by the manufacturer, see table 2. The test was started at 11 °C with the gap between the beams equal to the nominal width and settled as zero displacement. The movement of the beams was then synchronised with the change of the temperature in such a way that the minimum width was achieved at +25 °C and the maximum width at the lowest temperature (-20 °C or -30 °C), see figure 2. The rate of deformation was 0,6 mm/h. The ranges of displacement and of temperature were specified by the manufacturers and are summarised in table 2.

The test samples were not subjected to water spray. The reason for not exposing the samples to water spray was that the cavities at the ends of the test samples are filled with water which freezes at temperatures below zero. The ice formed has a great influence on the test results, especially the measured force. In reality these cavities are not directly exposed to water.

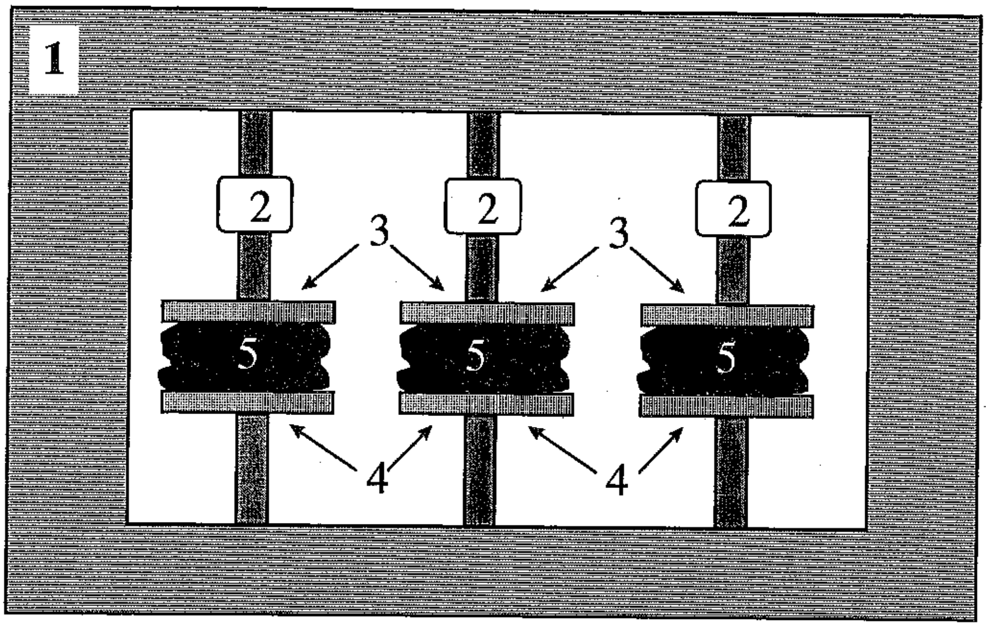

Figure 1. Principle sketch of the testing apparatus

1. Climatic chamber capable of regulating the temperature between +25 and - 30 °C.
2. Load cells connected to an electronic data collection device for measuring and recording of the compression force.
3. Stationary beams.
4. Movable beams.
5. Test specimens

Table 2 **Working properties of the joint seals**

EPDM	Nominal width (mm)	Working range (mm)	Temperature range (°C)	Movement
P 20	20	-1,5 to + 5,0	-20 to +25	-7,5 % at +25 °C +25 % at -20 °C
P 8	8	-1,0 to +3,5	-20 to +25	-12 % at +25 °C +44 % at -20 °C
H 15	15	-3,0 to +3,0	-30 to +25	-20 % at +25 °C +20 % at - 30 °C

EPDM is known for its water and weather resistance, why the water exposure is not critical for the degradation or function of the material.

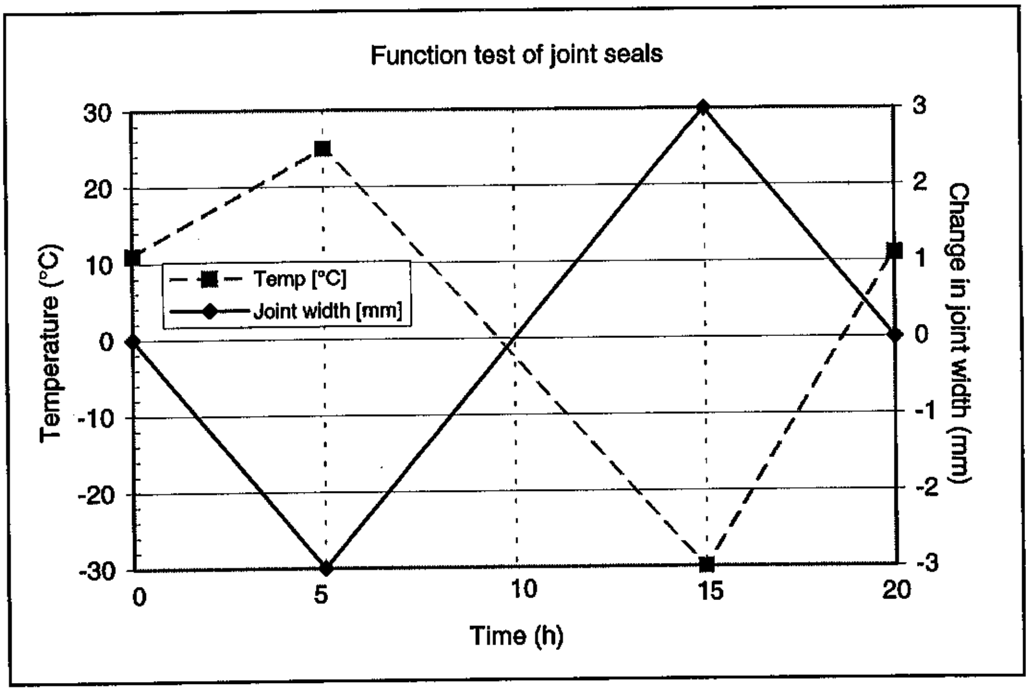

Figure 2. Example of one test cycle showing synchronisation of movement of beams with temperature change.

3.3 Compression set

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 investigation, accelerated ageing was performed at +70 °C with the joint seals compressed to their nominal width. The ageing was performed in 30 days periods. A renewed functional test was made every 30 days of ageing. If the expansion force (compression force) during the functional testing was near zero, i.e. no change in force with movement was noticed, the ageing was terminated.

The maximum ageing time was 90 days in total which corresponds to 15 years at +10 °C if it is presumed that the acceleration factor is 2. In reality, shorter periods of high temperatures, for example temperatures obtained on hot sunny days, have a great influence on the life length, especially in respect to the set of joint seals.

4 Results and discussion

Testing of performance (function test) of the joint seals is based on the measurements of the compression force as a function of temperature and joint width. The seals were subjected to three test cycles (an example is shown in figure 2) and with the test parameters summarised in table 2. The results are presented as curves showing variation of the compression force for the unaged samples and for samples after cycles of 30 days ageing. The maximum compression force is reached at the minimum joint width (at +25 °C). At the maximum joint width (the lowest temperature) the compression force reaches the lowest value. A flat curve at this point and a force near zero indicates that a sealant does not seal a joint properly.

4.1 Testing of preformed EPDM joint seals

The results from the testing of the preformed EPDM joint seal with a nominal width of 15 mm are shown in figure 3. The performance of the unaged seal, as seen in figure 3, complies with the specifications of the manufacturer. The compression force at +25 °C is for the unaged seal and the seal aged for one month around 5 800 N/m. After two ageing cycles (two months) this value is reduced to 3 500 N/m, which means a reduction of about 40 %. The compression force of the unaged seal is 250 N/m at -30 °C. After ageing, the force approaches zero and the pointed peak flattens out. The pointed peak indicates existence of a contact pressure. The values being less than zero are probably due to a combination of somewhat unstable zero point for the loads cells and the temperature effects in the equipment.

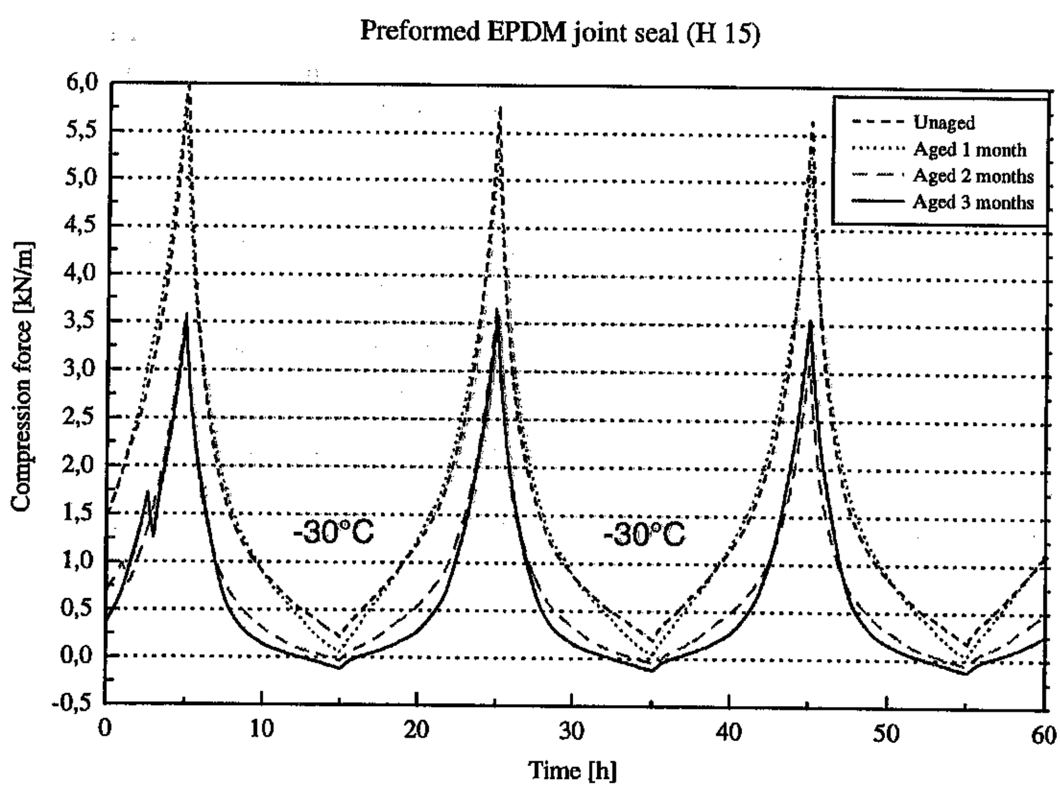

Figure 3. Preformed EPDM joint seal for a nominal joint width of 15 mm with the working range of -3 to +3 mm. Average value graph from three test pieces.

The results from the function testing of preformed EPDM joint seal with a nominal width of 20 mm are given in figure 4. The maximum compression force is 1 500 N/m which is only 25 % of the maximum force of the joint seal for joints with a nominal width of 15 mm. This is mainly due to different geometry and working range of the joint seals. At the lowest temperature (-20 °C) there is a small compression force (less than 100 N/m) and the peak is pointed. After ageing for 30 days, the set of the joint seal was 100 %. For this reason no function testing after ageing was made.

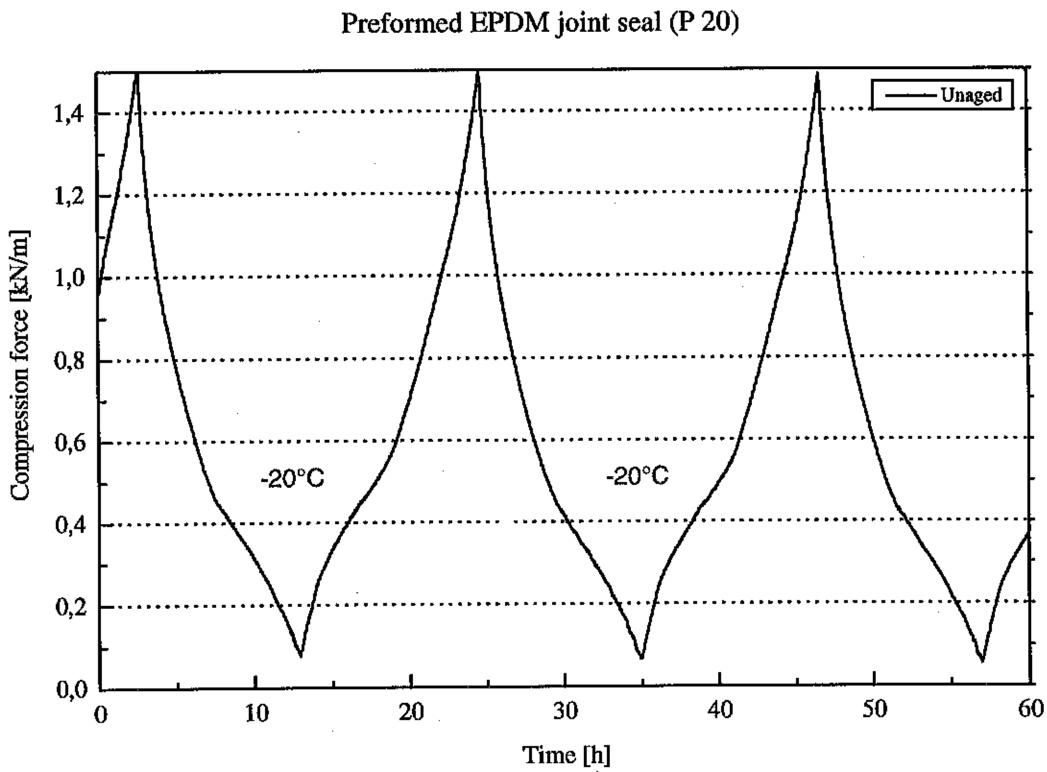

Figure 4. Preformed EPDM joint seal for a nominal joint width of 20 mm with the working range of -1,5 to +5,0 mm. Average value graph from three test pieces.

A trial to reduce the set in the joint seal was performed by postcuring the material for one hour at 160 °C. The results from the function testing of the postcured joint seal are shown in figure 5. The postcuring increased the maximum force, which occurs at +25 °C, from 1 500 to 1 900 N/m. The minimum compression force, which occurs at -20 °C, increased from less than 100 N/m to 200 N/m. After ageing for 30 days a new function test was made. As can be seen from figure 5, the compression force is zero and the curve flattens out at -20 °C which indicates that there is no contact pressure between the joint seal and walls of the test fixture. Therefor, further testing of this joint seal was terminated.

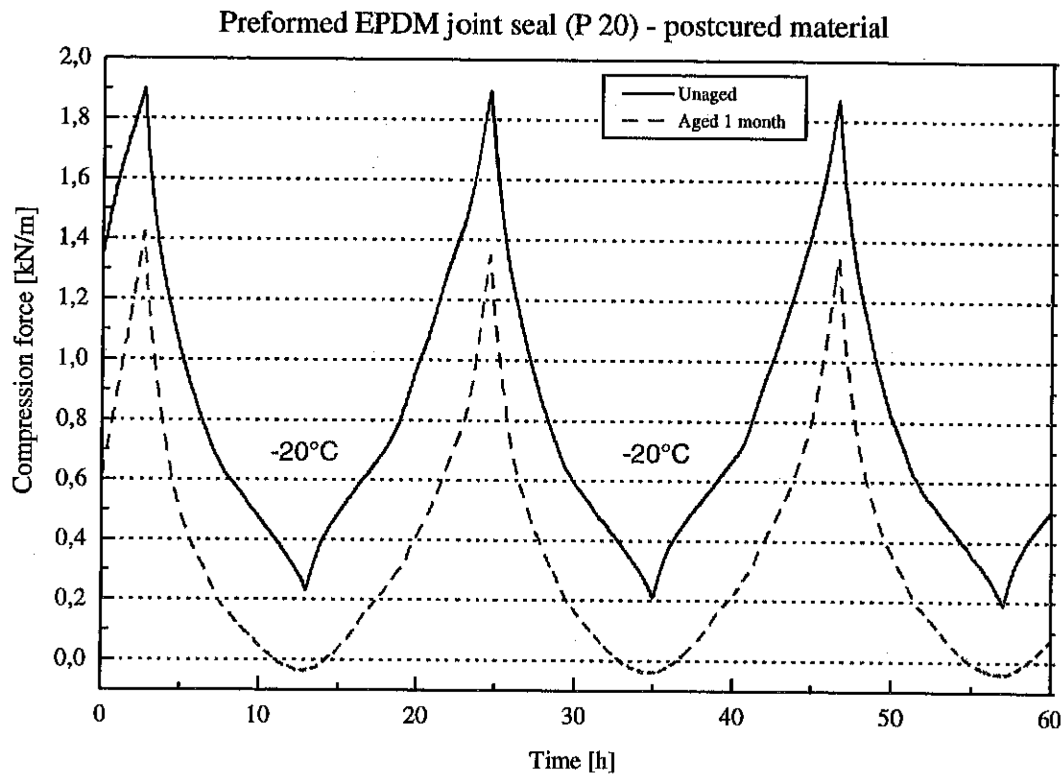

Figure 5. Preformed EPDM joint seal for a nominal joint width of 20 mm with the working range of -1,5 to +5,0 mm. Postcured material. Average value graph from three test pieces.

The results from the function testing of preformed EPDM joint seal with a nominal width of 8 mm are given in figure 6. The compression force at +25 °C is for the unaged seal approx. 1 450 N/m. After one ageing cycle this value is reduced to 1 200 N/m. The compression force of the unaged seal is just above zero at -20 °C. After the accelerated ageing for 30 days at +70 °C, the set in the profile is very high. The curve flattens out when the joint is enlarged and the temperature decreases.

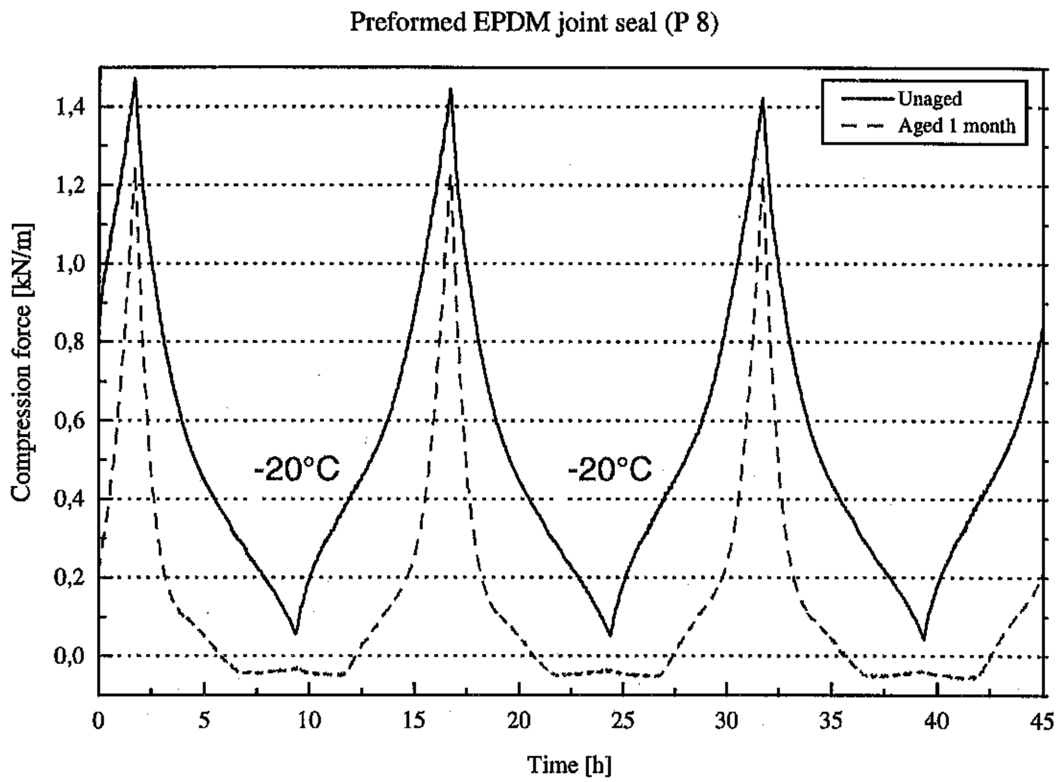

Figure 6. Preformed EPDM joint seal for a nominal joint width of 8 mm with the working range of -1,0 to +3,5 mm. Average value graph from three test pieces.

4.2 Field studies

SP has performed field inspection of preformed joint seals installed in roads in Sweden during a program for survey of joint sealants in roads and air fields. These inspections are reported in detail [8].

One preformed solid EPDM seal and one foamed polyurethane seal was visually examined in this program. The EPDM joint seal, which was installed in 1993, seemed to function well and had no signs of damage. The foamed polyurethane seal had no signs of damage but it fitted so loosely that it is doubtful if it seals a joint in an adequate way.

5 Summary and conclusions

Joint seals intended for use in construction joints in roads and airfields were examined in respect to their performance, within a wide range of temperature. Attention was paid to very slow movements in joints and to compression set of materials. Three EPDM seals were used.

A test procedure was developed for the evaluation of performance of joint seals. The seals were subjected to changing temperature and synchronised movement of the joint. 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, was recorded continuously. A seal was judged as not functioning well when the expansion force was reduced to zero.

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 comparison between various seals is difficult in this project as the manufacturers have specified various working ranges. Apart from that, only one EPDM seal (H 15) functioned well even at -30 °C. The other two EPDM seals (P 20 and P 8) hardly managed to function at -20 °C.

The testing of the EPDM joint seals shows that the compression set in the material after ageing is a limiting factor for the function of a seal. Already after 30 days ageing at +70 °C, both P 20 and P 8 ceased to function at -20 °C. H 15 managed 30 days ageing but ceased to function at -30 °C after 60 days ageing. The compression force decreased significantly also at +25 °C after the ageing. The problems with the high set has also been observed in Germany on naturally aged EPDM joint seals.

The results from the investigation show the importance of performing a function test on preformed joint seals, within the entire field of application, in order to verify the properties specified by the manufacturers. The proposed test procedure makes it possible to determine limits in working range and temperature for joint seals. The method is also suitable to evaluate the influence of the environmental factors like temperature, liquid chemicals, UV-light, ozone, etc. on the performance of joint seals.

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Procedure description
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Ignacy Jakubowicz

Function test of elastomeric profiles for concrete pavements

Materials Technology
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Function test of elastomeric profiles in concrete pavements

Table of contents

1 SCOPE

The purpose of a joint sealant is to seal a joint against certain environmental factors like water, gravel, dust, etc. As the width of joints is changing with temperature, the profile must be flexible enough to compensate for 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 and to the compression set of the material. This SP-Method describes a function test for elastomer profiles intended for use as joint sealants in construction joints.

2 REFERENCES

The background to this test is a research study carried out at the Swedish National Testing and Research Institute (SP). This work began in 1981 with performance and functional testing of hot and cold applied joint sealants for roads and airfields and concluded in the report denoted SP-Report 1988:23 and in the CEN New Draft Test Method. This research study was, during 1995-1996, extended to comprise preformed elastomeric joint sealants for construction joints. The results of the study are summarised in SP-Report 1996:33.

3 PRINCIPLE

This method is intended to be used as a basis for determination/confirmation of the working range of an elastomer profile in terms of joint movements and fluctuating temperatures. The function test is also used for the evaluation of the effects of compression set on the working range of the product.

4 APPARATUS

The testing apparatus (see figure 1) shall consist of a climatic chamber capable of regulating the temperature between +30 and - 30 °C with the accuracy of ±2 °C. Inside the chamber, a tensile and compression test rig shall be placed having at least three pairs of beam for testing of three specimens simultaneously. The beam-ends shall consist of parallel, flat, highly polished stainless steel plates, between the faces of which the test specimens are compressed. The plates shall be sufficiently rigid to withstand the stress without bending and of sufficient size to ensure that the compressed test specimen is within the area of the plates. The test rig must be motor driven without significant slip or backlash, giving a constant rate of movement. The rate of movement shall be 0,60 mm/h ±10 %. Three load cells shall be connected to an electronic data collection device for measuring and recording of the compression force with the accuracy of ±2 % and the minimum compression force applied to each system.

The testing apparatus shall have the following characteristics:

- shall allow the specimens to be insert conveniently and without disturbing the specimens before, during, or after removal
- shall not be significantly affected by the failure of one or more specimens
- shall be motor driven without slip or significant backlash

- shall be capable of moving the test blocks and specimens smoothly and linearly, so that their alignment is maintained at all times without subjecting them to torsion, bending, shock, or significant vibration
- shall be capable of exerting on each specimen an appropriate compressive force and compressing each specimen uniformly under the specified conditions.

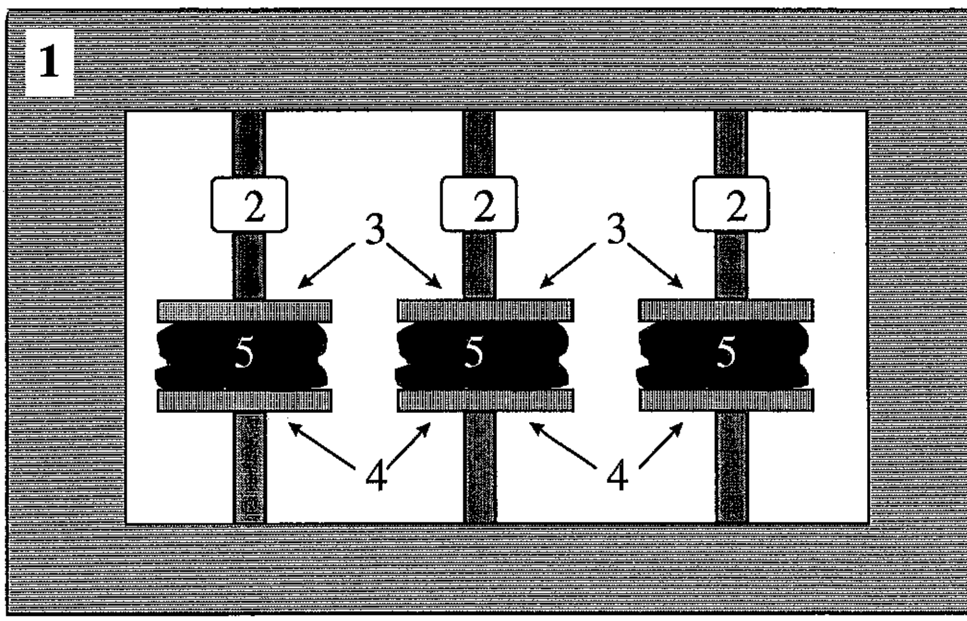

Figure 1. Principle sketch of the testing apparatus

1. Climatic chamber capable of regulating the temperature between +30 and -30 °C.
2. Load cells connected to an electronic data collection device for measuring and recording of the compression force.
3. Stationary beams.
4. Movable beams.
5. Test specimens.

5 TEST SPECIMENS

For each test, joint seals are to be cut into at least three test specimens. The preferable lengths of the specimens are 70 ±1 mm or 100 ±1 mm.

Unless otherwise specified, the test specimens shall be conditioned before testing in the atmosphere specified in the appropriate International Standard relating to the material under test.

6 PROCEDURE

6.1 Function test

The specimens are placed between the beams in the direction of compression of the seal in service and compressed to their nominal joint width ±2 % as specified for the product by the manufacturer. The test is started at 11 ±1°C with the gap between the beams equal to the nominal joint width and settled as zero displacement. The movement of the beams must be synchronised with the change of the temperature in such a way that the minimum width is achieved at the highest temperature (preferably +25 °C) and the maximum width at the lowest temperature (-20 °C or -30 °C), see figure 2. The rate of the deformation shall be 0,60 ±0,06 mm/h.

The ranges of displacement and of temperature shall be specified by the manufacturer or by appropriate regulations. Because of the fixed rate of the deformation, the testing time for a test cycle will vary with the range of displacement. At least three complete test cycles, as shown in figure 2, shall be repeated.

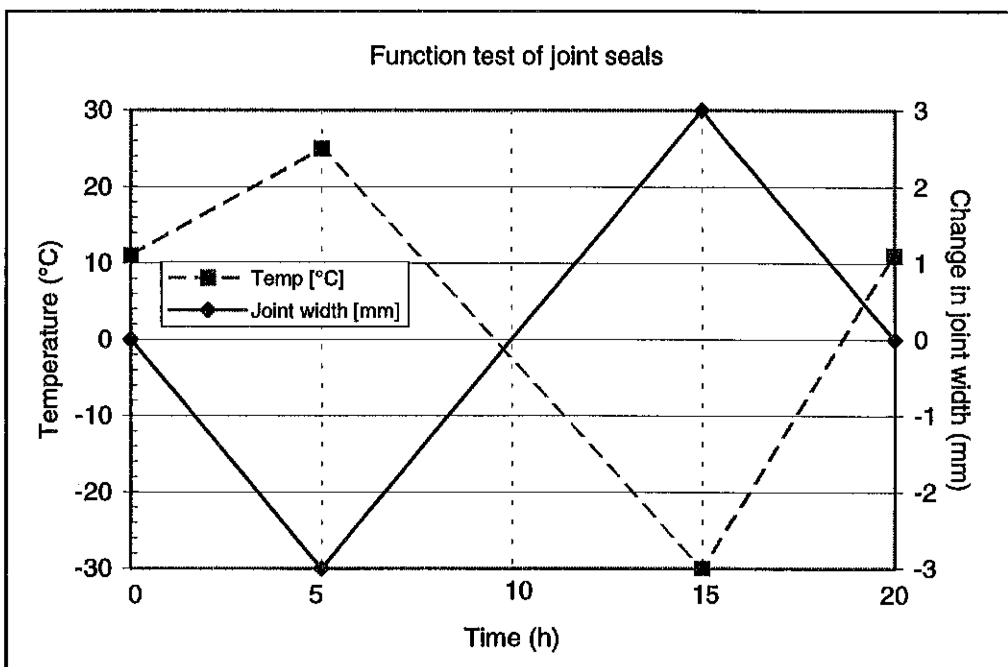

Figure 2. Example of one test cycle. Range of displacement and of temperature shall be specified.

Testing of performance (function test) of the joint seals is based on the measurements of the compression force as a function of temperature and joint width. The results are presented as curves (see figure 3) showing variation of the compression force for the unaged samples and for samples after periods of ageing in compression (see 6.2). The maximum compression force is reached at the minimum joint width (at the highest temperature). At the maximum joint width (the lowest temperature) the compression force reaches the lowest value. A flat curve at this point and a force at zero or below zero indicates that a sealant does not properly seal a joint.

6.2 Accelerated ageing in compression

The test is intended to measure the ability of elastomer profiles to retain their elastic properties after prolonged compression at constant strain.

The specimens are placed between the pairs of plates together with the requisite spacers. The bolts are tighten so that the plates are drawn together uniformly until they are in contact with the spacers. The applied compression shall be the nominal width ±2 % as specified for the product by the manufacturer. The assembly is then introduced into an oven which shall operate at 70 ±1°C. The preferable duration of test is 30 days periods. Other duration and temperature of test can be chosen in accordance with ISO 815. Upon completion of the test the assembly is removed from the oven and placed in the testing apparatus. The bolts are loosen, the requisite spacers are removed and the function test is repeated.

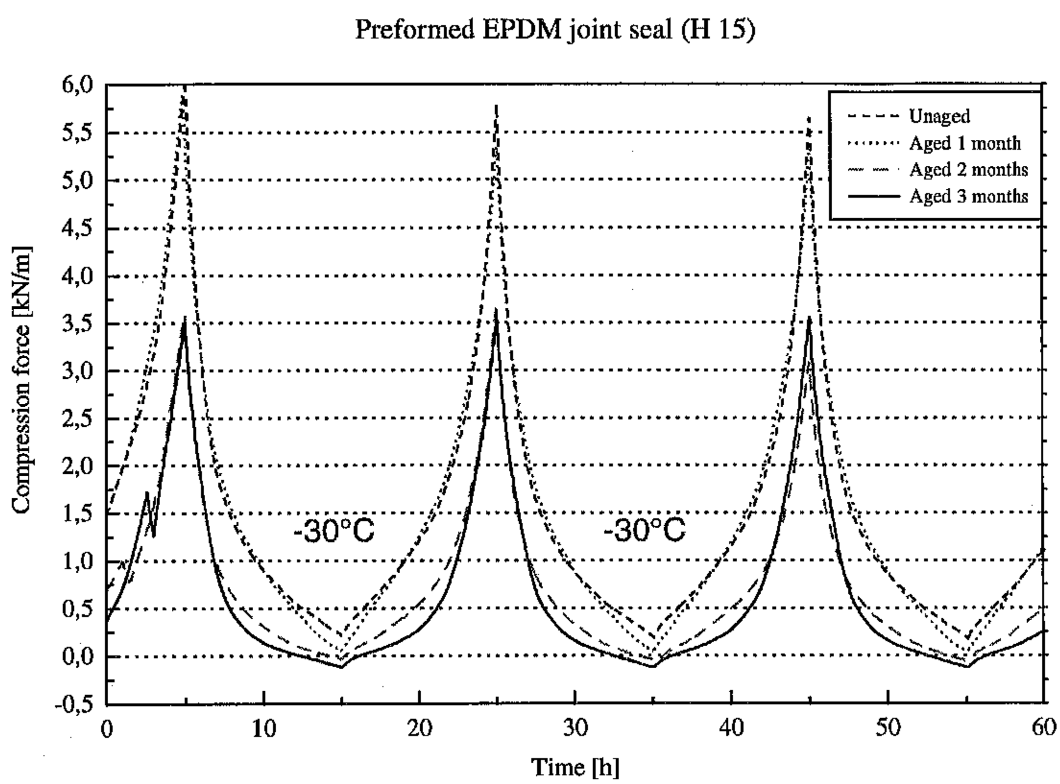

Figure 3. Example of a function test of a profile. The results are presented as curves showing variation of the compression force for an unaged sample and for the same sample after periods of 30 days compression set at 70 °C.

7 TEST REPORT

The test report shall include the following information :

a) description of the profile tested
b) reference to this test method
c) nominal joint width as specified by manufacturer
d) range of displacement and temperature
e) number of test cycles and test specimens tested
f) duration and temperature of compression set
g) maximum compression force at the highest temperature as a mean value
h) minimum compression force at the lowest temperature as a mean value
i) information if results indicate that sealant can properly seal a joint or not for the range of displacement and temperature used in test
j) any deviation from this method.