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LABORATORY TESTING OF PAVEMENT CRACK SEALANTS

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ABSTRACT

Crack sealing is a practical, cost-effective technology for maintaining asphalt pavement. Because crack sealants are important, development of improved materials is under way around the world. However, before any new sealant is brought to the market, it must be rigorously tested either in the field or in the laboratory. Evaluation in the field is usually very costly and there is no guarantee that one or two years of monitoring and assessment will expose the true characteristics of a new material. On the contrary, however, good laboratory equipment can cut the time of testing and evaluation to months or even days, depending on the number of variables considered.

The performance of a pavement crack sealant in the field depends mostly on traffic load (frequency, type of vehicles, tire pressures and type, location), climate (temperature, precipitation, global location) and its application (routing, use of hot lance, quality control). This paper describes the new laboratory equipment used in this study, the testing program and the results obtained. It is expected that this new technology will assist road transportation agencies to decide which sealant available on the market is best suited for their road networks under specific traffic and climatic conditions.

1. INTRODUCTION

Crack sealing is practical, cost-effective technology for maintaining asphalt concrete (AC) pavement. Any new technique or material should undergo rigorous field evaluation. Such an evaluation must either be carried out as a long-term project, or as an accelerated test before being brought into use. Usually there is no time for long-term performance evaluation and accelerated field tests are prohibitively expensive, Ref. 1 & 2. The only practical alternative is laboratory testing, Ref. 3.

Current crack-sealing techniques are generally not satisfactory. The development of a satisfactory technique is difficult because there are many variables affecting sealant performance. All of these factors are important and each must be assessed before any crack-sealing materials and rehabilitation techniques are selected. These factors are:

- sealant characteristics (e.g., adhesiveness, extensibility, strength and durability), Ref. 4,
- design (e.g., forms of cracks, type of routing), Ref. 5,6 & 7,

- sealant application (e.g., temperature of sealant and of AC at the time of pouring), Ref. 8,
- quality of workmanship, Ref. 8,
- traffic conditions and climatic conditions at the site, Ref. 9, etc.

2. TESTING EQUIPMENT AND SET-UP

The Construction Material Testing System (CMTS) developed at IRC, is basically a testing table consisting of two halves: one half can move horizontally while the other half moves vertically, thereby providing combined static and dynamic horizontal tensile and vertical shear stresses under displacement and load control conditions. Figure 1 schematically shows the concept of CMTS and Figure 2 is a photograph of the CMTS in an environmental chamber, with the sample prepared for testing. Figure 3 shows a new attachment to the CMTS allowing testing of three samples at the same time. The movement of both halves of the table is facilitated by a closed-loop servo-hydraulic system. Temperatures can be varied in the environmental chamber from -40°C to +40°C.

A high-speed PC-based data-acquisition system monitors the load cells, displacement transducers and temperature sensors. Data-processing computer programs are used for data analysis and graphical output of the test results. In addition, crack initiation, development and propagation are continuously observed and recorded using photo and video cameras.

3. SAMPLE PREPARATION

For the purpose of obtaining test samples a short 3-m x 15-m experimental road section was constructed on the campus of the NRCC. Prior to the placement of the asphalt, the site consisting of old AC was cleaned and then covered with a thin layer of sand. The purpose of the sand layer was to seal small existing cracks and to even out some irregularities. At the same time, the thin layer of sand prevented the new asphalt from adhering to the old, thus allowing for easy removal of asphalt slab samples from the site. A standard Ministry of Transportation of Ontario (MTO) HL-3 asphalt mix was used for constructing a 75-mm thick layer.

The road section was cut into 300-mm x 300-mm samples with a diamond saw simulating cracks in the pavement. All samples were cut in such a way that each "crack" was always perpendicular to the direction of the compaction. Subsequently, routs were cut along the "crack" lines. A standard road router, utilizing carbide-tipped blades, was provided by the MTO. The AC slabs were cleaned, carefully lifted and supported by plywood plates and transported to the laboratory. Each half of the sample was then glued to a split steel plate, which was held together by two steel handles fastened to the side of the plate. Samples were then thoroughly cleaned in the laboratory and later dried. In the Series I the routs were heated by an air gun with a high air flow of 350-400°C until the temperature of the AC surface reached approximately 100°C to 120°C. In Series II the routs were heated by an automatically controlled movable flame lance at different speeds and at approximately 1000°C. The crack below the rout (i.e. the space between two asphalt slabs) was then filled with sand, so that the hot sealant would penetrate and fill the space of the rout only to a depth of 10-12 mm. A commercial sealant was then poured into the rout. After the sealant had cooled, the sand was removed from the crack prior to testing.

In Series I, approximately 350 - 400 grams of sealant were required for a 40 x 15 x 300 mm rout. Two sealants were used in this series. They are referred to below as A (harder sealant) and B (softer, more flexible and more plastic sealant). The following average heating temperatures for pouring sealants recommended by the manufacturers were used:

Sealant A	180°C	(175 - 185 °C manufacturer A)
Sealant B	197°C	(190 - 205 °C manufacturer B)

In Series II three sets of samples were prepared under the following conditions: 1) no heating - sealant C, 2) moderate heating - sealant D and 3) high heating - sealant E. Moderate and high heating were achieved by fast and slow speed of the fire lance, respectively. In order to better (visually) observe the generation and propagation of cracking, the sealant and the surrounding area of the AC were sprayed with a bright white paint. After this preparation process, the sample glued on the steel plates was positioned on the table and both plates were fixed to the table. The final product ready for testing is shown in Figure 2.

4. TESTING PROGRAM

Originally, we carried out a large number of tests under various constant cold temperatures; these however, did not lead to completely conclusive results, because lack of definite and visible crack development. In addition, since the peak of the time (equivalent to displacement) versus load curve, Figure 3, does not really represent failure, the evaluation of the results was almost impossible. The "failure load" does not really represents cracking, as most of the time no visible crack occurred. However, a crack could have occurred inside the interface between the AC and the sealant, or inside the sealant material itself. Nevertheless, the tensile force/stress was transferred to the other part of this interface surface, preventing from pinpointing actual crack allocation, if any.

The above problem led to a change in the original testing procedure from one of using constant temperature to one where the temperature in the testing chamber was gradually changing. After a number of trials, the best procedure was found to be one where the temperature was cooling from -20°C to -40°C. The testing of the two different types of sealants A and B (developed by two different manufacturers), whose identities can not be released, immediately showed conclusive results. Based on this and the discussion above, the influence of the following variables on sealant adhesiveness, extensibility, strength, and durability, was investigated in this study using the following test and thermal chamber conditions:

a) combination of constant horizontal strain with the repetitive vertical shear in the sealant,
b) cooling chamber/sample temperature condition during testing.

5. RESULTS

Two testing SERIES were carried out based on different preparations of rout:

I) Two different sealants, A and B, were tested using a hot air lance at 400 °C,

II) Three different sealants, C, D and E, were tested using a flame lance at 1000°C.

Based on the success in the past, i.e. when conclusive results where obtained by changing temperature in the testing chamber (described above), two test series were performed under the following conditions:

1) starting temperature was -30°C, with cooling down to -40°C,
2) test began with immediate horizontal and vertical repetitive displacement, and
3) all tests were carried out for cooling only.

5.1 SERIES I - Tests based on utilizing a hot air lance at 400°C until the surface of the rout reached 100°C - 120°C.

The numerical results of all the tests in this series are presented in Table 1 The average peak load for sealant A was almost twice as high as for sealant B. The displacement (at peak load) was much less for A than for sealant B. The energy at the peak and at the end of the test is considerably higher for A then for sealant B. After the peak load was reached, the A load decreased sharply, indicating failure, while the B load stayed more or less constant up to the end of the test. After the first sharp drop in load, the A sample became slightly stiffer, owing to the decreasing temperature in the chamber. Therefore the loading curve shows a small increase up to approximately 12 to 15 mm of the crack widening. The B samples continued to hold the same load. This difference in behaviour can be also observed in Figure 4, which shows all tested samples under approximately the same thermal conditions. Moreover, it was visually observed during testing, that all A samples failed in cohesion while all B samples showed no signs of failure, Figure 4. It was observed during the testing that the lowest temperature in the chamber did not reach -40°C as planned, but fluctuated between -34°C and -38°C.

Since all the A samples failed in the same way, only one photograph, Figure 5, is presented here. It represents the same cohesion failure of all the A samples under cooling testing conditions. On the contrary, Figure 6 shows that none of the B sealant samples failed under the same thermal and loading conditions. These results indicate that if a sealant can keep its material characteristics and, in particular, flexibility and elasticity, even in very cold temperatures, it will most likely out-perform other less elasto-plastic sealants.

5.2 **SERIES II** - flame lance - 1000°C, no heat, medium heat and high heat.

Based on the obtained overall results shown in Figure 4 and results for moduli in Table 2, the following observations can be made (results are classified according to the performance of individual sealants and according to the level of lance temperature as classified above):

<u>Sealant C</u>: (Elastic Modulus = 179.2) This sealant started to debond at approximately 17% of the rout elongation and can be qualified as a fast debonding material with very high brittleness characteristics. The best performance was achieved without heating, followed by use of normal heating, while the overheating led to the worst results.

<u>Sealant D</u> (Elastic Modulus = 191.1) A slow debonding damage process is the property of this sealant. Initial debonding occurred after about 20% of the rout elongation. Over heating or no heating made no difference until 80% of the rout elongation occurred. Also, for this sealant heating the rout did not bring any considerable benefit and therefore in the field heating would not be necessary. The best results were obtained when normal heating was used, followed by overheating and no heating.

<u>Sealant E</u> (Elastic Modulus = 160.1) This sealant, practically speaking did not debond. All samples started to debond only at ~ 100 % of the rout elongation and therefore comparison of results after this point would have no meaning. Therefore, there would be no need to heat the rout, if this sealant were used in practice.

It must be mentioned that the results obtained were influenced not only by the thermal properties of the sealants, but also by the thermal characteristics of the sealant / bitumen / aggregate interface. It seems, however, that sealant E is able to adhere firmly to the surface of the rout, whether it was heated or not. Sealant C performed better without heating the rout, while sealant D showed a slight advantage when normal heating was used.

As far as the elastic moduli results are concerned, Table 2 demonstrates similar performance results as those (Sealant Debonding) shown in Fig Y (except when sealants C and D are compared). The overall mean elastic modulus for sealant E is significantly lower than the modulus for C and D materials. It is quite obvious that the sealant E is softer and more flexible, even during the cold temperature testing.

The mean elastic modulus for sealant C was considerably lower than the modulus for sealant D. Because sealant C becomes extremely brittle (as described below), this negative characteristic overshadows its otherwise good elasto-plastic property. Therefore, even though the mean elastic modulus for sealant D is significantly higher then that for sealant C, sealant D is a better material for use in cold climates.

Another interesting behavior (brittleness) was observed during the testing of sealant C samples. As described above, the three samples were tested at the same time. The results demonstrate that at the low temperature this material becomes extremely brittle. That is, if one of the samples (out of three) starts to fail (i.e. debond in a fraction of a second), this impulse is transferred to the other two samples, which then fail immediately after. It should be noted that all three samples (tested at the same time) are functionally independent and yet even a micro impulse was transferred to the neighboring sample. Nevertheless, if the results for the three samples that failed at the same instant were considered as only one test (15 samples), it is quite clear that such an extremely brittle material will perform poorly in the field.

6. DISCUSSION

Based on the results carried out on 5 samples for sealants A and B and 15 samples for each other sealant (E, D, C - put in the order of their field expected performance) one can conclude that:

1) this type of testing is capable of determining which of the sealants available on the market would be the most suitable for a particular region, traffic and climatic conditions,

2) that heating of the rout leads to no significant improvement in their performance under tested conditions.

However, what does make an immense difference is the type of sealant tested. In our opinion, the best type of sealant for field application out of the types we tested would be one similar to B and E, followed by A and D. The C type of sealant, which is highly prone to becoming brittle, should be avoided for application in cold climate areas.

Other useful information could be obtained from the following suggested future tests, based on three different pouring temperature limits: 1) below the specified low limit, 2) at the averaged specified limits and 3) at the higher temperature then the specified upper limit. Such results would be very important for comparison of laboratory tests and actual field practice, i.e. the field quality control.

7. CONCLUSIONS AND RECOMMENDATIONS

A testing procedure based on combined horizontal strain and vertical repetitive shear loading under decreasing temperature conditions accelerated the laboratory evaluation of crack sealants, indicating a good possibility of solving this important problem.

The results of this investigation indicate that <u>relatively</u> softer, more flexible and plastic materials may perform better in the field than stiffer, less flexible and less plastic materials. This conclusion, however, must be proven through further research investigations.

In conclusion, we believe that this work may lead to a test procedure that will be useful not only to road transportation agencies but also to industries developing new sealant materials. The final goal of the author and his colleagues is to develop testing equipment and a procedure for performance testing of sealants that would be acceptable to the American Society for Testing and Materials - ASTM.

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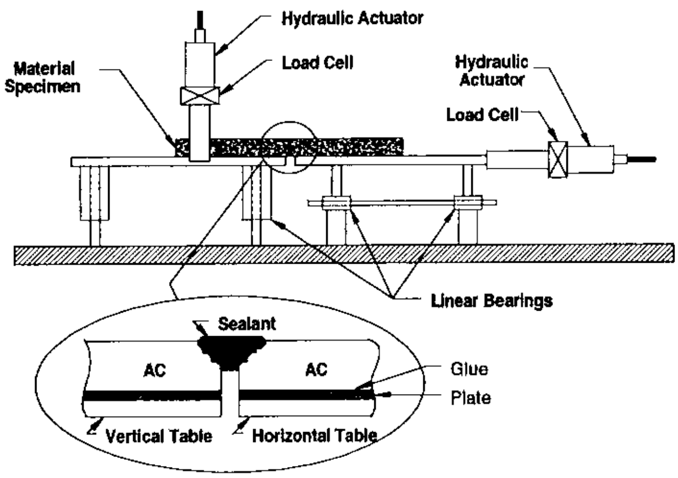

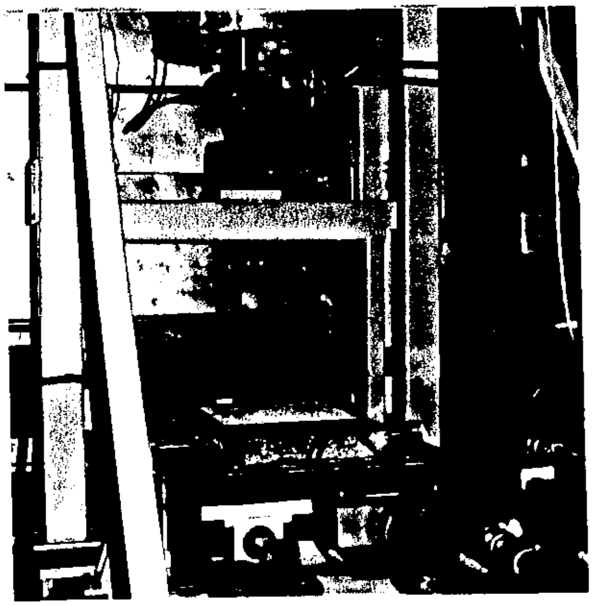

Fig.1 - Concept of CMTS

Fig.2 - CMTS in environment chamber
Sample ready for testing

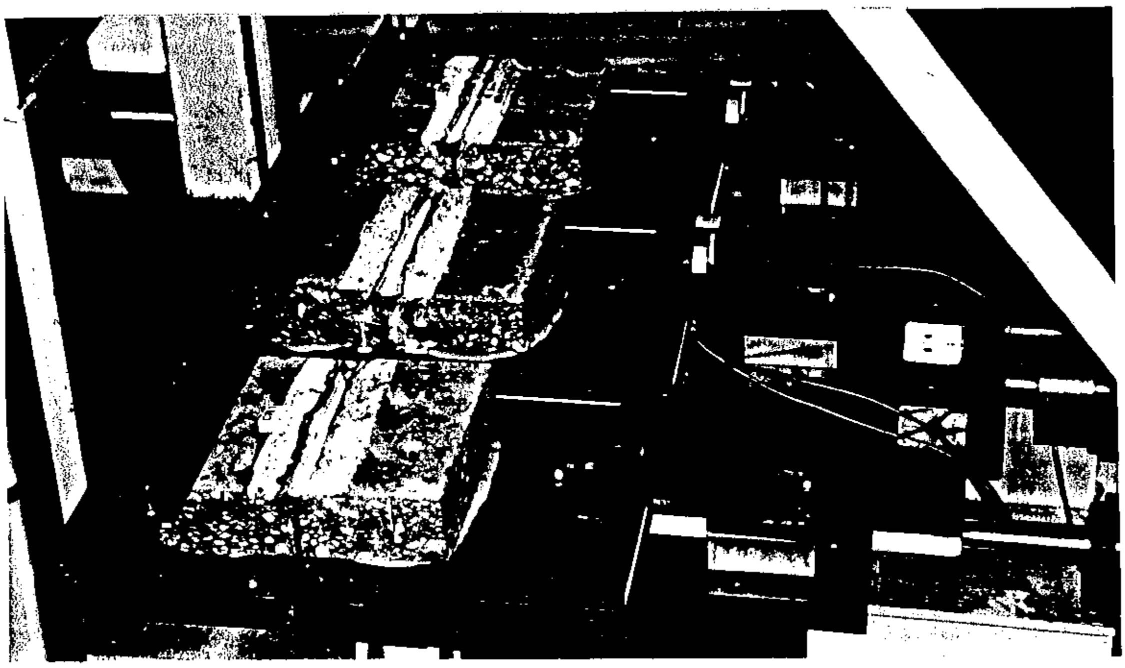

Fig.3 - New testing attachment for testing three samples at the same time

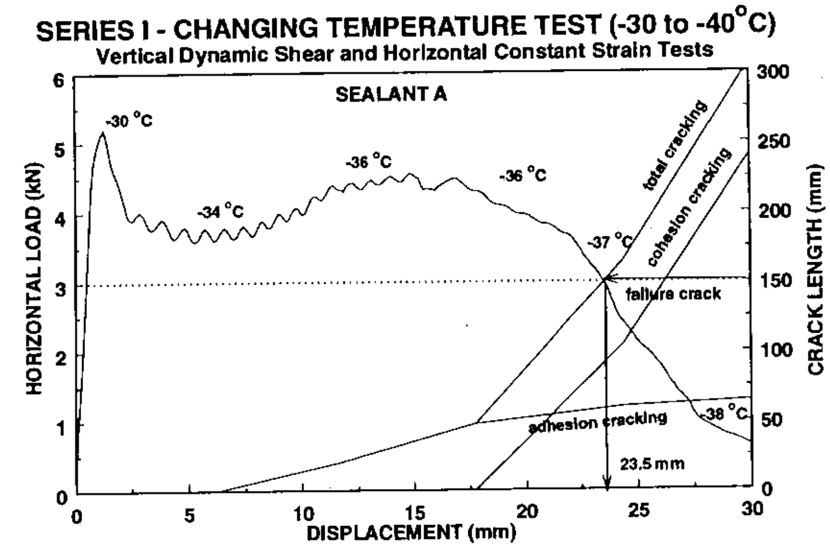

Fig.4 - Series I: Individual curve of sample 0256

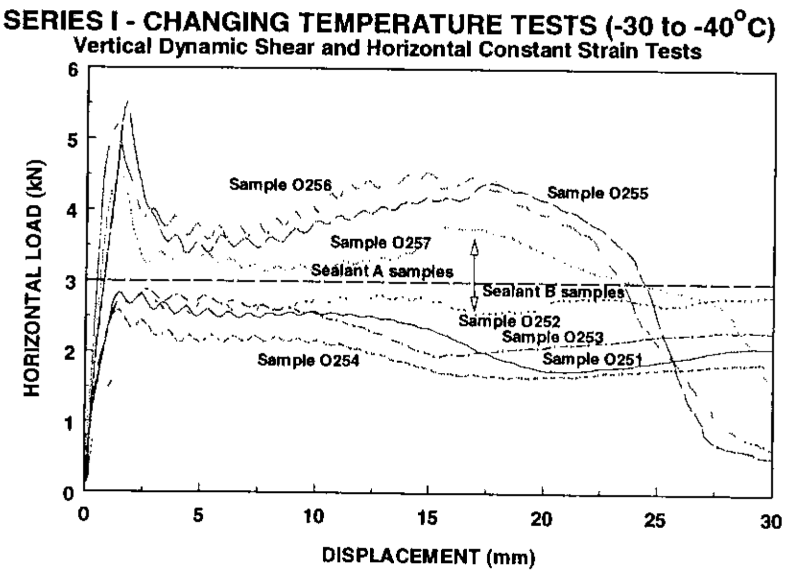

Fig.5 - Series I: Results for all tests (Sealants A & B)

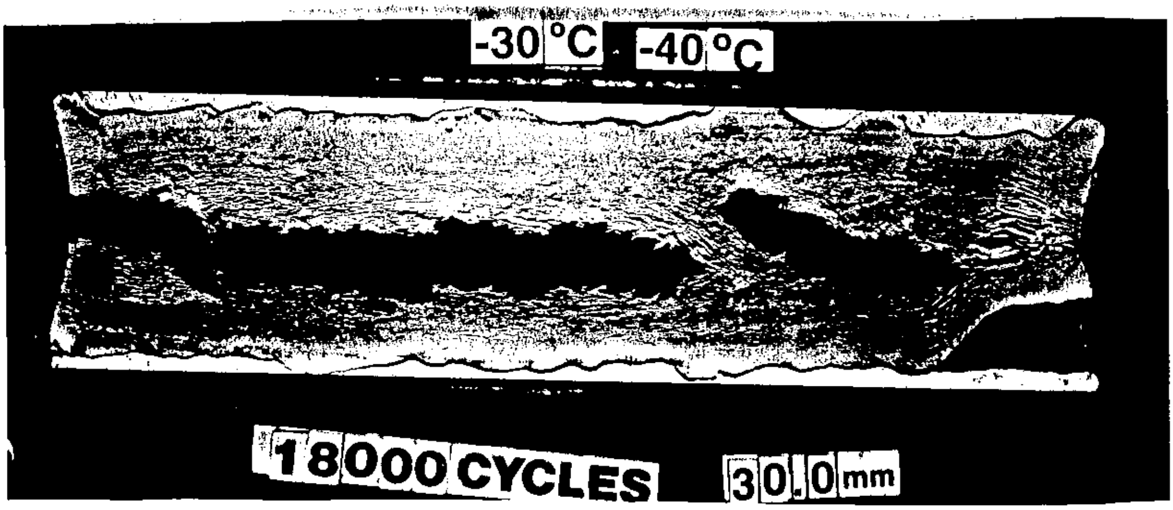

Fig. 6 - Series I: Cohesion/adhesion failure (Sealant A)

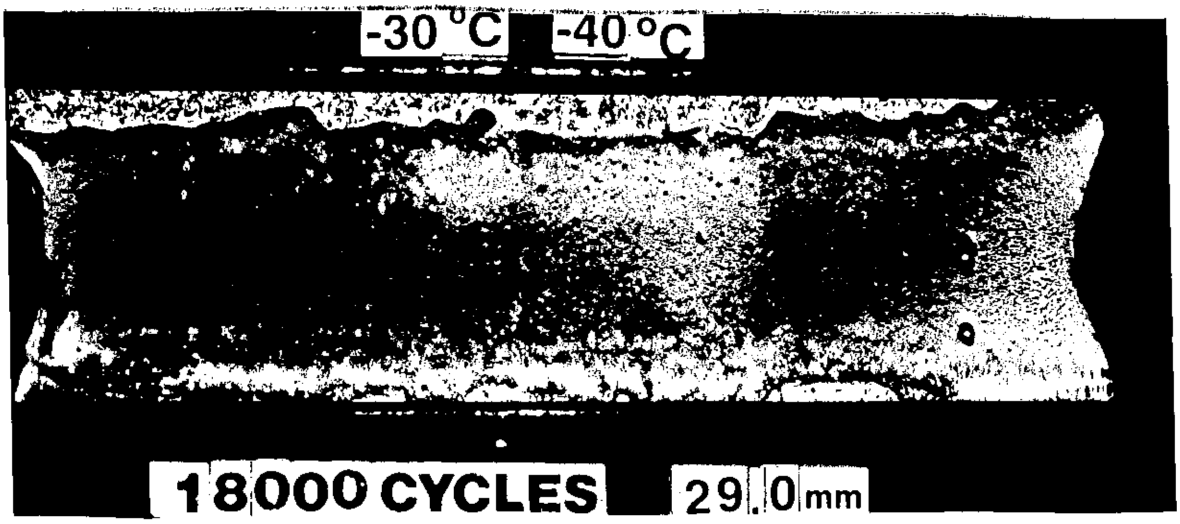

Fig.7 - Series I: No visible failure (Sealant B)

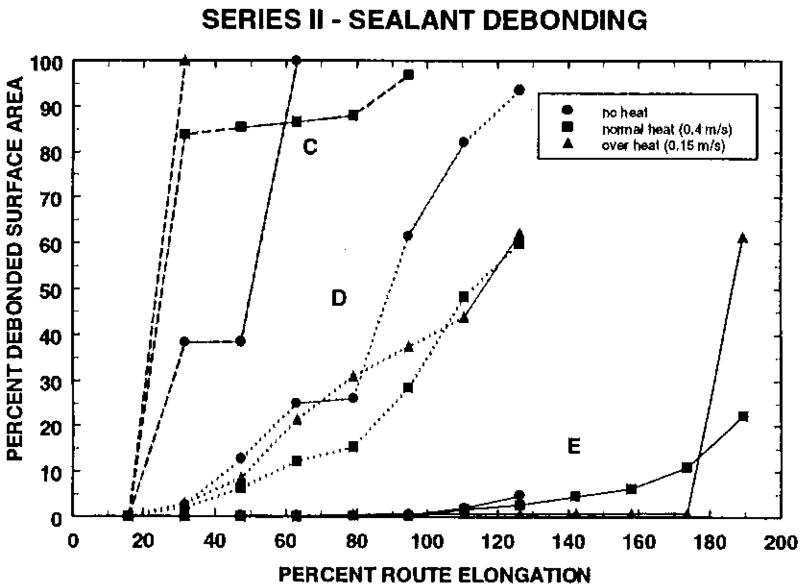

Fig.8 - Series II: Overall test result for three sealants at three rout heating conditions: moderate, medium and high