Presented at the 19th Annual meeting of AEMA 1992, Fort Lauderdale Florida.

A LABORATORY METHOD FOR DETERMINATING THE RETAINING FORCE OF CHIPPINGS IN SURFACE DRESSINGS.

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Surface dressing (chip sealing) is a well established, economical and highly effective method for maintaining the surface of roads. Normal surface dressing consists of spraying a thin film of binder onto the road surface, followed by the application of one or two layers of aggregate chippings. The major part of bitumen emulsions produced in Europe is used for different types of surface dressings. The object of surface dressing is to seal the road surface and to arrest disintegration of the road as well as to provide a skid-resistant surface. In Scandinavia the wear resistance to studded tires is also important.

When using bitumen emulsions for surface dressing the following properties are important:
- Viscosity. It should be low enough to permit spraying with a conventional sprayer but high enough to prevent emulsion run off after application.
- Breaking properties. The binder should give a fast grip of the chippings to minimise disruption of traffic.
- Curing properties. A quick development of a good retaining force is important to decrease problems with flying chippings.
- Binder properties. The binder should give a high retaining force and have a good durability as well as good adhesion to the chipping.

Many of these properties can easily be measured with standard methods according to IP, ASTM, CEN or national standards. There are however very few methods to measure the breaking and curing properties of bitumen emulsions.

The subject of this paper is to present a laboratory method for the determination of the breaking and curing properties of emulsions in surface dressing applications, and to illustrate practical examples of this method. A proposal for how the method can be used in standard specifications is also presented.

SPIN TESTER

The Spin Tester consists of a rotating metal disc which can be spun at variable speed. The disc is located inside a box covered with a lid to protect the surroundings from flying chippings. (Figure 1)

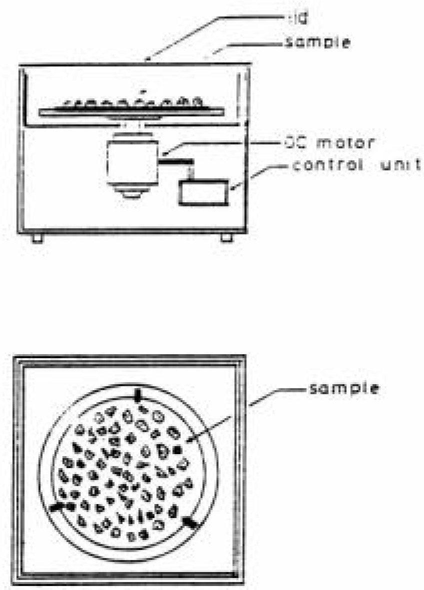
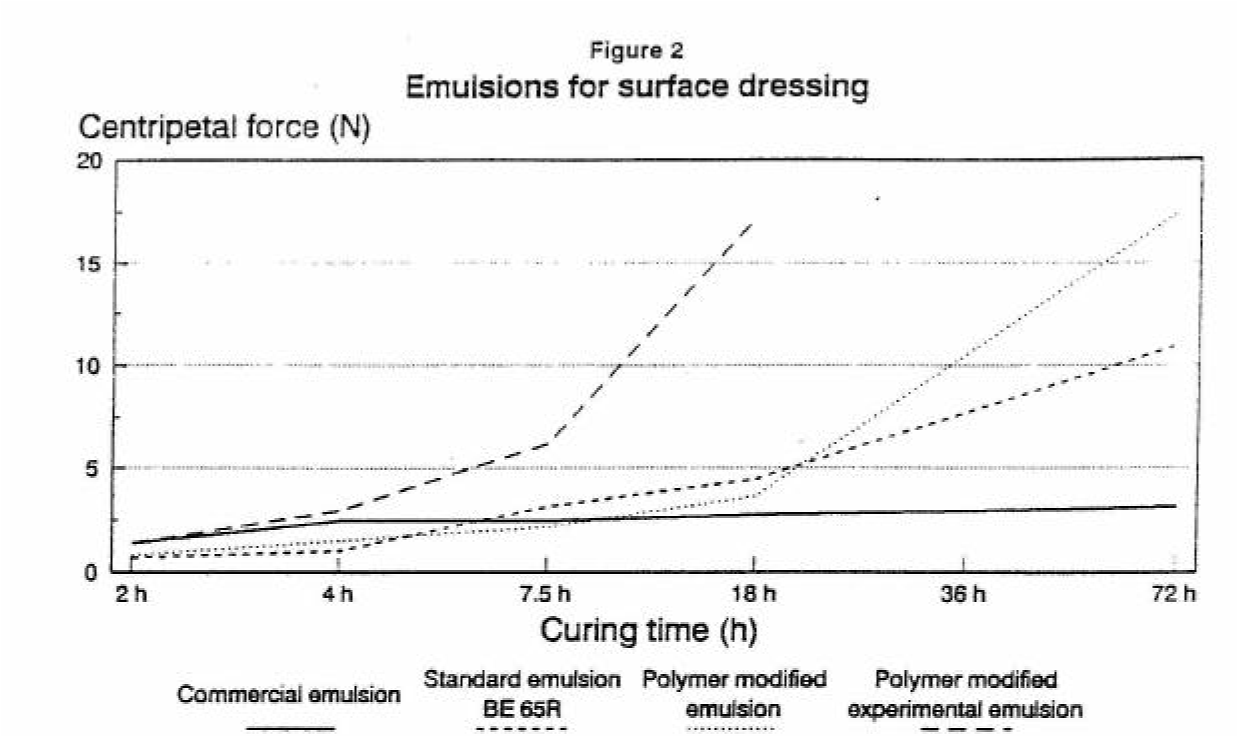


Fig.1: The spin test apparatus.

TEST METHOD

This method is based on a surface dressing made in the laboratory using a piece of roofing felt in the shape of a disc. Roofing felt was selected as the bed for the surface dressing since it embodies the principal components of an asphalt road surface. The felt should be fairly stiff and covered with fine sand or mineral granules. The rim of the disc is covered with a template to keep it clear of emulsion. The test emulsion is poured onto the felt and levelled out with a spatula. The template is removed and carefully selected dry pre-washed chippings are applied directly. The chippings should be as cubical as possible and are therefore harp sieved. After the chippings are applied timing commences. The surface dressings are left to cure for the desired period. They can be cured at ambient temperature in a normal laboratory environment, but since humidity has a large influence on the breaking rate of an emulsion (see below) it is preferred to cure the samples in a carefully controlled humidity environment.



After the desired curing time the surface dressing sample is weighed and mounted on the metal disc of the spin tester. The speed where approximately 50% of the chippings are lost is estimated. The sample is spun for 30 sec and reweighed. If the estimate is correct another two samples are spun. If not, the speed is adjusted and the test repeated. When three discs have been spun at the same speed the average weight loss is used for calculating the retaining force (centripetal force) according to the following formula:

$$F = mv^2/r = 4\pi^2 mr/T^2$$

F = Centripetal force (N)
m = The weight of one chipping (kg)
V = speed (m/s)
r = The surrounding average radius of the remaining chippings on the disc (m)
T = Time of revolution (s)

$$R = r_0 \sqrt{(1-x/M)}$$

r_0 = Radius of surface dressing on the disc (m)
x = Weight loss of disc during spinning
M = Weight of aggregates applied to the disc + 20 g (which is the estimated weight of binder stuck to the aggregates)

The test data is presented in a diagram plotting the centripetal force as a function of curing time.

SURFACE DRESSING EMULSIONS

Several surface dressing emulsions were tested using the spin tester. These included standard emulsions as well as experimental products. The test procedure is presented in Appendix 1. The emulsions show very different breaking behaviours (figure 2). The apparently poor result for a "commercial emulsion" is due to a very soft base binder in the emulsion. The results for "BE 65R" and "Polymer modified emulsion"are in agreement with experience from field tests.

EFFECT OF EMULSIFIER TYPE

It is well known from practical experience, that the type and concentration of emulsifier is very important in determining the breaking behaviour of an emulsion.

a) Cationic

In Europe a high proportion of surface dressing emulsions are manufactured using an alkyl propylene diamine type emulsifier. Figure 3 illustrates the fact that the higher the concentration of this type of emulsifier in the emulsion, the slower the breaking rate of the emulsion.

Table 1

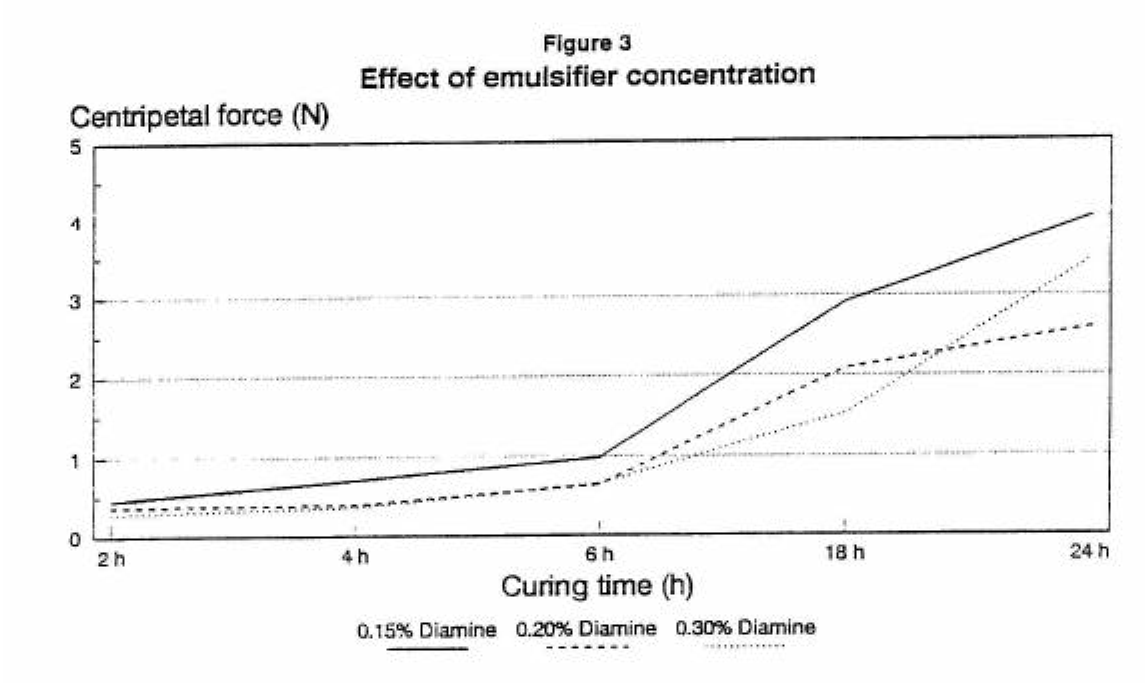
Spin Tester Results for a Curing Period of 18 hours of a Polymer Modified Emulsion and 14 mm Porphyry Aggregate chippings

Emulsifier Type	Retaining Force, (N)
Fatty Diamine	3.48
Amidoamine	5.27
Branched Amine	6.19

The structure of an emulsifier also has a significant effect on the breaking rate of the emulsion. This is especially important for polymer modified emulsions, where the addition of a polymer can extend the breaking rate of the emulsion. The results tabulated in Table 1 show the relationship between the breaking rate of the emulsion and the chemical structure of the emulsifier.

b) Anionic

A significant portion of surface dressing throughout the world is carried out using anionic emulsions. The breaking mechanism of this type of emulsion is due to the evaporation of water. Figure 4 illustrates the curing behaviour of an anionic emulsion. The curing rate of anionic emulsions can be increased by pre-spraying of a cationic breaking agent on to a road surface, prior to the application of an anionic emulsion (Figure 4)



INFLUENCE OF HUMIDITY

It is understood that humidity is a very important factor in the breaking and curing of bitumen emulsions. To investigate this effect a standard emulsion for surface dressing (BE 65R) was tested using the spin tester at three different humidities.

Figure 5 illustrates that a high humidity delays the breaking of an emulsion considerably. It can be concluded that the curing of the spin test samples should take place in an environment with a constant humidity, and that samples cured at different humidities cannot be compared.

INFLUENCE OF AGGREGATE

From figure 6 it can be concluded that the different aggregates tested show almost identical development of centripetal force in the spin tester during the first 8 hours. The small variations at longer curing times is probably due to minor variations in humidity during the tests.
Initial results indicate that the retaining force of an aqqreqate chipping is independent of its actual size, (Figure 7). Further studies are envisaged to investigate this conclusion.

INFLUENCE OF OTHER ENVIRONMENTAL FACTORS

There are other environmental factors than humidity which could influence the breaking speed of emulsions used for surface dressing. Two very obvious factors are wind velocity and temperature. Some tests have been made using the spin tester to investigate the importance of these factors.

From figure 8 it can be concluded that a wind over the road surface increases the breaking speed of the emulsions but a stronger wind does not seem to increase it further.

Figure 4

Anionic emulsions + 14mm porphyry chippings

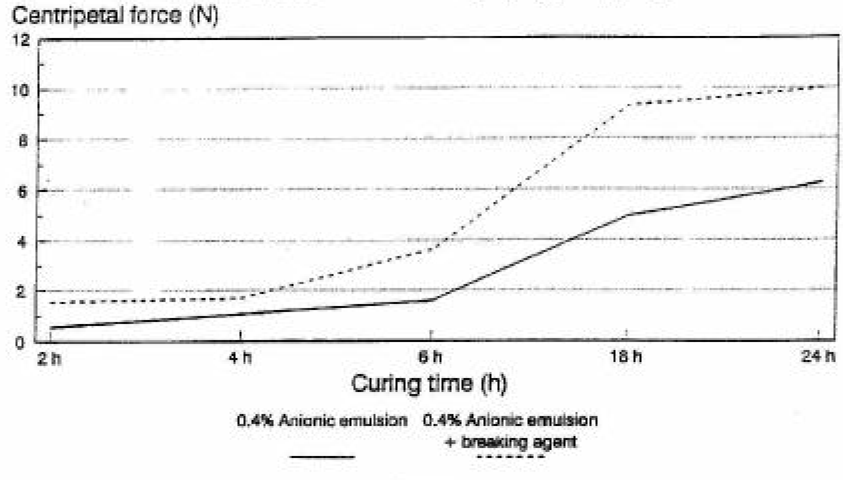


Figure 5

Different humidities

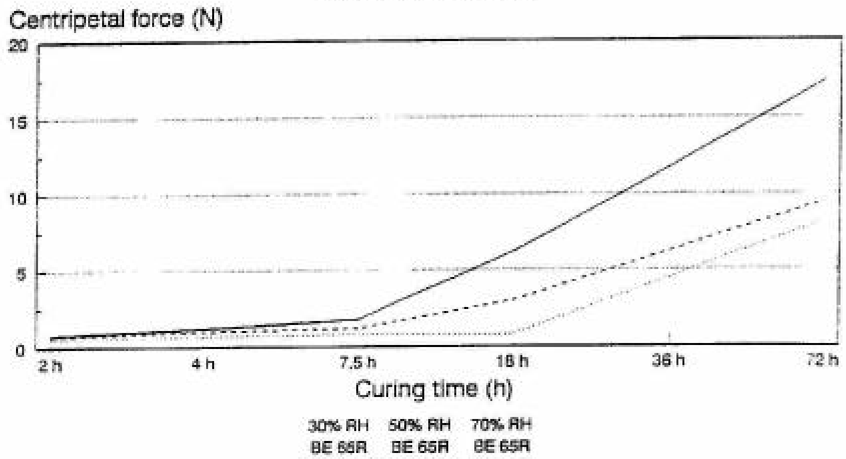
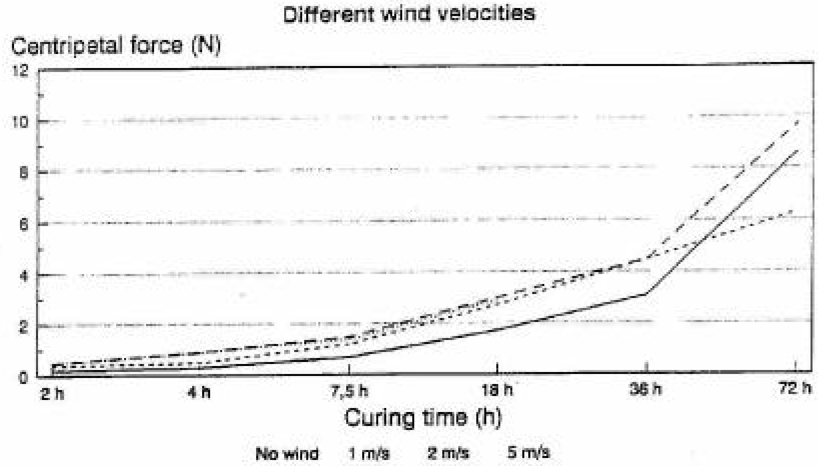


Figure 6

Different wind velocities



Relative humidity 30%

Figure 6

Different aggregates

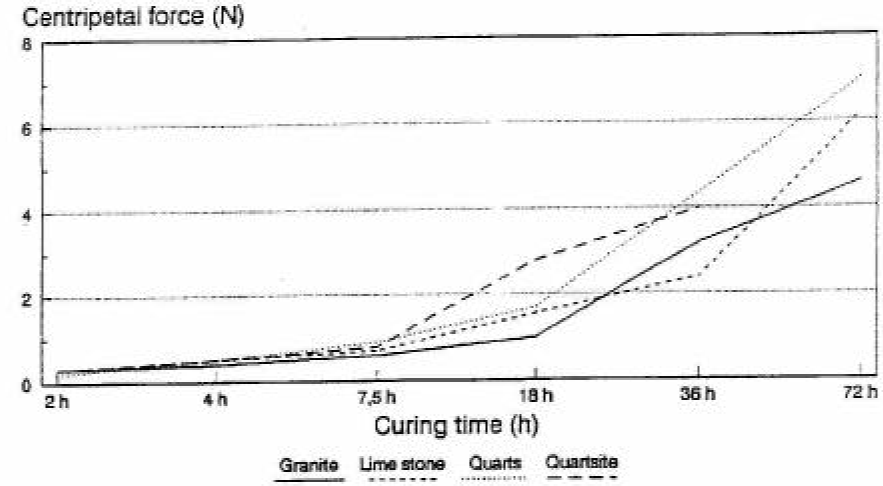
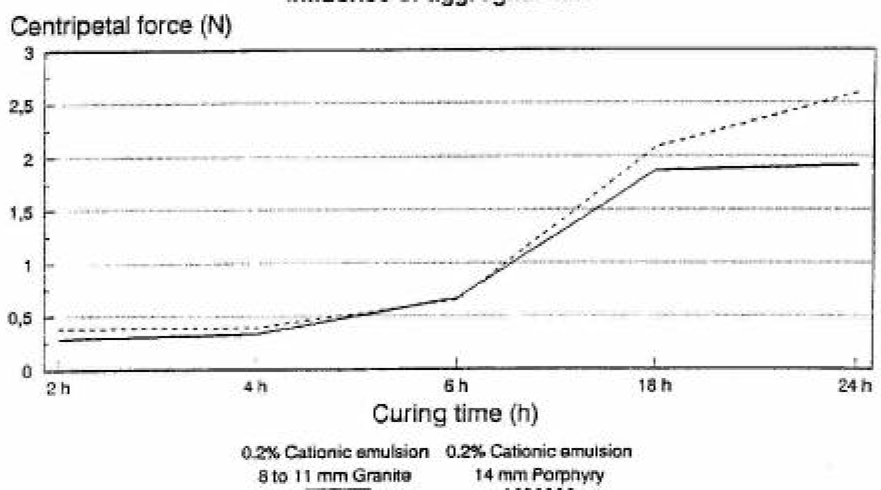


Figure 7

Influence of aggregate size



From figure 9 it can be concluded that temperature does not have any influence on initial emulsion breaking. But further curing is quicker at higher temperatures. It should however be noted that the number of tests and the range of variations is too small to permit any final conclusions.

However it can be concluded that none of these factors is of major importance in determining the result of the spin tester.

RETAINING FORCE BEFORE BRUSH SWEEPING

When making surface dressings it is important to remove loose chippings as soon as possible to minimise damage due to flying chippings. This removal can be done in many different ways.

One common machine is a kind of "vacuum cleaner" which sucks the loose chippings for reuse. In Sweden the most common technique is to brush sweep the road and to leave excess chippings along the road. When this technique is used there is a strong demand to have an emulsion which will permit sweeping as soon as possible, To evaluate the necessary retaining force as measured by the spin tester for permitting sweeping of the road, the following field test was carried out

The Spin Tester was located at a surface dressing site. The roofing felt discs were placed on the road and covered with emulsion by the sprayer. After application of the chippings the discs were removed from the road and left to cure at the road side. After the desired curing time intervals they were tested with the Spin Tester. At the same time test sweeping of the road was attempted. The chippings were 8 - 12 mm granite. The climatic conditions were, temperature (20 - 24^{0}C) and relative humidity (50 - 60%).

The retaining force after different curing times is shown in Figure 10. The raod was considered to be satisfactory for sweeping after 5 hours. The reatining force at that time was approximately 2 N.

SPIN TESTER AS A STANDARD METHOD

The Spin Tester has been used for several years in Nynas's laboratories as a tool for the development of bitumen emulsions for surface dressing. Our experience is that it has proven to be a good test for estimating the breaking behaviour of emulsions. It is however too time consuming and laborious to be a standard test since 5 samples must be made for each curing time and at least 5 separate curing times are required to get a good plot. In the development work it has been highly beneficial to have the complete plot, since it gives a lot of valuable information regarding the breaking and curing behaviour of the emulsion. If the test should be used in a specification, it must be simplified to permit the definition of a single point.

An example of how such a test could look like is to focus on the retaining force of 2 N and then to specify the maximum breaking time to reach this force in a laboratory environment (20 - 22^{0}C and 55% RH). The number of samples would then be limited to three, which would be tested at one fixed speed which is chosen to be accurate for 2 N. If the retaining force is much higher or lower than 2 N this figure will be unreliable. Values higher than 3 N are given as >3 N and values smaller than 1 N are reported as <1 N.

In practice the specification could look like this:
Breaking: Spin Test should give a force of 2 N within 4 hours.

The test could then be simplified to three spin test samples. After 4h curing time they are tested at a speed of 400 rpm. The retaining force is calculated from the mean value from the three samples. If the force is higher than 2 N the sample is approved and if it is lower than 2 N it has failed.

Figure 9

Different temperatures

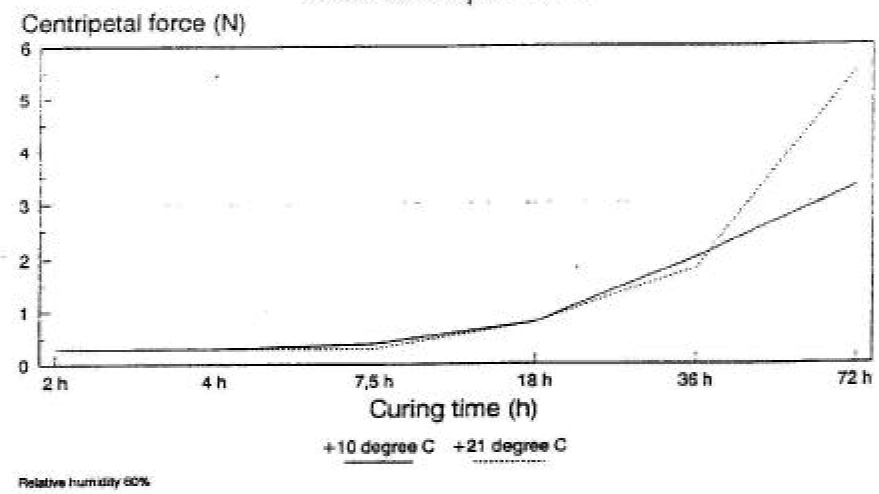
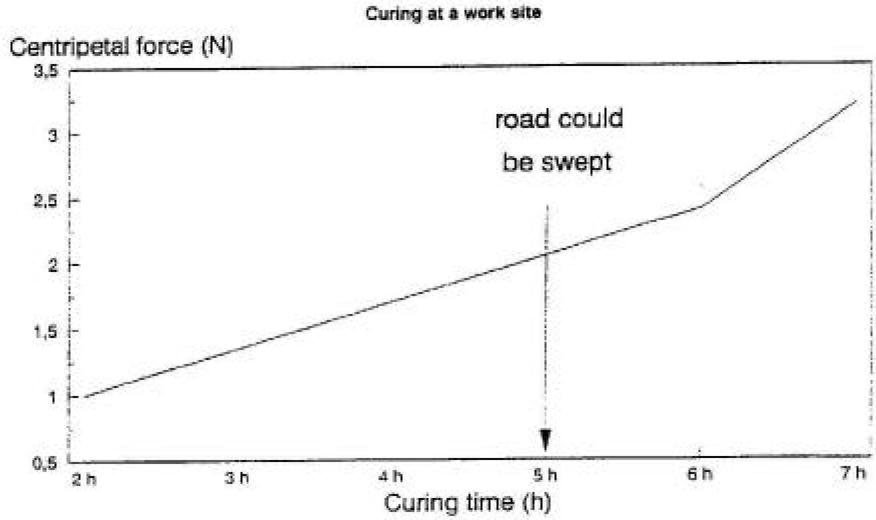


Figure 10

Curing at a work site



CONCLUSION

The Spin Test is a method for evaluating the breaking behaviour of emulsions for surface dressing. It measures the retaining force for chippings on a laboratory made surface dressing sample. This retaining force has been found to be dependent on humidity and the type and concentration of emulsifier, but independent of temperature, wind velocity and aggregate type and size. It has shown a good correlation with field tests and has proven to be a very good test for evaluating emulsions with high performance. The method is well suited to be a standard test for determining the breaking speed of surface dressing emulsions.

Appendix 1 :Spin Test Procedure Bo Sillen 1992-01-16

The following procedure is a standard procedure for spin test performed at Nynas's laboratory in Nynashamn.

MATERIAL

The aggregates used is a 11.2-16 mm fraction of granite from Farsta. The aggregates are washed and harp sieved before use. They are applied dry.

The spin test discs are made from asphalted roofing board SAL 4000 which are cut out to discs with a diameter of 260 mm.

The bitumen emulsions are homogenized by stirring before used. They are applied at 60^0C.

PROCEDURE

Five test discs should be prepared for each curing time. Two samples are used to find the right speed and three samples for testing.

1. A test disc is covered with a template to give a emulsion layer with a diameter of 230 mm.

2. 87 g of bitumen emulsion are poured onto the disc and levelled with a rake to give an even thickness all over the disc.

3. The template is removed and 430 g of chippings are immediately spread out in one layer as regularly as possible on the emulsion.

4. The samples are left to cure for the desired time at controlled humidity.

5. After the curing the disc is weighed with an accuracy of 0.1 g.

6. The disc is mounted on the steel plate in the Spin Tester and spun for 30 5.

7. The disc is detached and weighed. If the loss of chippings is approximately 50 % two more discs are tested.

8. The centripetal force, F (N), is calculated according to the standard formula:

   $F = c \times n^2 \times r$ where

   c = constant depending on aggregate weight etc.
   ($c = 5.374 \times 10^{-7}$)
   n = revolutions per minute
   r = radius of the remaining chippings, (mm)

$r = 115 \times \sqrt{(1-x:450)}$

x = reduction of weight (g) after the centrifugation
450 = 430 g chippings + 20 g binder

9. The result is reported as centripetal force after a certain curing time. The report should also contain the relative humidity during the curing of the samples.