INFILTRATION OF WATER THROUGH CONCRETE BLOCK PAVEMENTS

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Summary.
It is well known that water penetrating a Concrete Block Pavement can cause severe damage at an early stage. Therefore the determination of the infiltration rate has become a very interesting parameter and a lot of effort has been put into the development of usable equipments for the tests.

In this paper a new Infiltrometer is introduced which take care of evaporation of the liquid to be infiltrated, keep the water pressure on the pavement at a constant level and makes it possible to carry out standardized infiltration tests.

The tests made during the work illustrate that the use of Trass-lime mixed with ordinary joint gravel and water may result in an impermeable joint. The tests shows furthermore that these joints may get permeable after some time. Pavements used for storage may be less permeable than trafficked pavements due to filling of air pores with organic materials. The average infiltration rate measured on pavements with joints filled with joint gravel was approx. 10 l/sec/hectare or 4 mm/h.

Introduction.

This paper represents a part of a Master Thesis Work, carried out at the Technical University of Denmark, concerning determination of water infiltration through Concrete Block Pavements (CBP) with a new equipment. The inspiration to the development of this new equipment and the tests came from the Danish Road Institute and the company SF-STEN A/S, Denmark. The main purpose of the paper is to present the new equipment for determination of the water infiltration through existing CBP and to illustrate relations between infiltration rate and the age of the CBP, the traffic loads, the joint width and joint materials.

During tests, J. Knapton, England, has observed that water penetrating a CBP can cause severe damage at an early stage [1]. Furthermore the use of CBP on filling stations can lead to pollution of the underground if the pavement is permeable. These tests was made in the laboratory [2].

Description of the equipment for infiltration tests.

The tests were carried out with the equipment showed in fig. 1. Part of the equipment is used by geologists to find water infiltration through soil. To make it usable for infiltration tests on CBP it has undergone some modifications. The equipment is called an Infiltrometer.

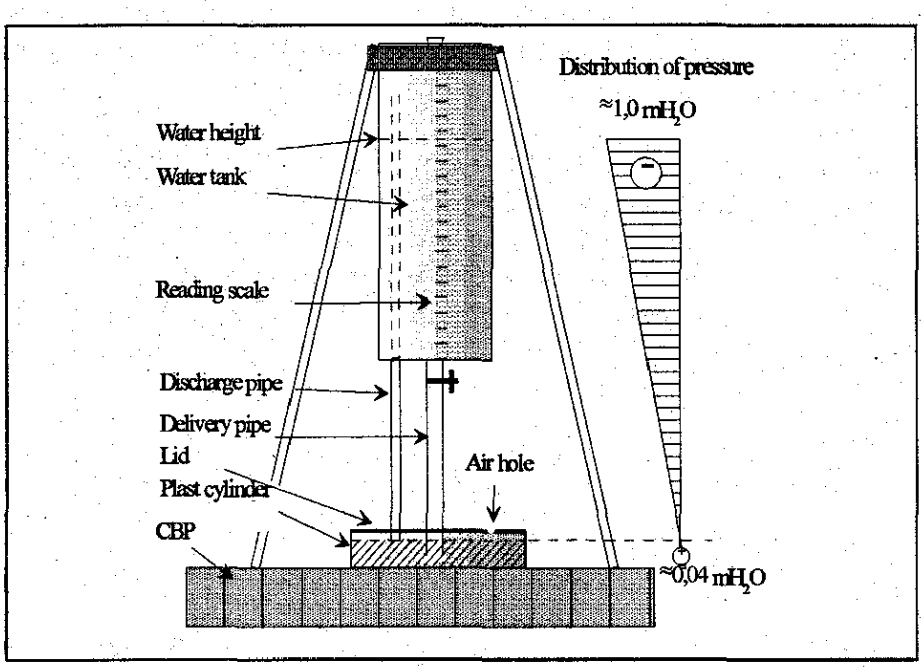

Fig. 1: *Sketch of the Infiltrometer.*

The Infiltrometer consists of a water tank carried by a tripod stand and a plastic cylinder placed on the CBP. The two parts is connected to each other by a discharge pipe and a delivery pipe.

The water tank delivers the water to the plastic cylinder continuously as the water infiltrate through the CBP.

The delivery pipe has a tap, which makes it possible to stop the water delivery to the plastic cylinder. This is e.g. done when filling the water tank before the test starts. After the water tank is filled with water it must be closed with a cork in the top so the Infiltrometer becomes a closed circuit.

The plastic cylinder is sealed to the CBP by the use of silicone mass and become water-resistant if the sealing is carried out carefully. The cylinder covers an area of 0.07 m^2. To avoid evaporation the cylinder has a lid. In the lid is made an air hole to neutralized the vacuum in the water tank when filling the plastic cylinder, and vacuum in the plastic cylinder during the test.

When the tap is opened and the water is allowed to fill the plastic cylinder the vacuum in the water tank is neutralized by the air hole. When the surface of the water in the plastic cylinder reaches the discharge pipe the water tank is no more allowed to neutralize the vacuum through the air hole and the water delivery from the water tank stops.

The plastic cylinder now contains the water which is allowed to infiltrate through the CBP. As the water infiltrate through the CBP and the discharge pipe gets free of the water, air is sucked into the water tank through the air hole. Thereby the vacuum in the water tank is neutralized and the water is allowed to flow through the delivery pipe to the plastic cylinder until water again coats the discharge pipe. Because of the surface tension of the water in the plastic cylinder, the water from the water tank is delivered in small doses when the water meniscus at the discharge pipe is broken by the vacuum in the water tank. But the delivery of water is almost continuos.

Description of the measuring procedure.

The tests were started by opening the tap on the water tank after which the plastic cylinder was filled. When the water reached the discharge pipe a stopwatch was started and the water level was read on the water tank. Afterwards the water level was read every 15 minutes. This interval seemed reasonable and made it possible to determine the time of all the water deliveries quit accurate. An exact determination of the time of the delivery would require a constant survey of the tests during all 5 to 7 hours a test lasted.

A picture of a test carried out with the Infiltrometer is shown on figure 2. It's carried out on a pavement of SF-blocks.

When the test was finished the plastic cylinder was removed and the length and width of the joint was measured. The joint materials was visually evaluated afterwards. The result of the

tests was the quantum of water left in the water tank to a given time. Afterwards the quantum of water infiltrating the pavement could be calculated and the rate of the infiltration could be found.

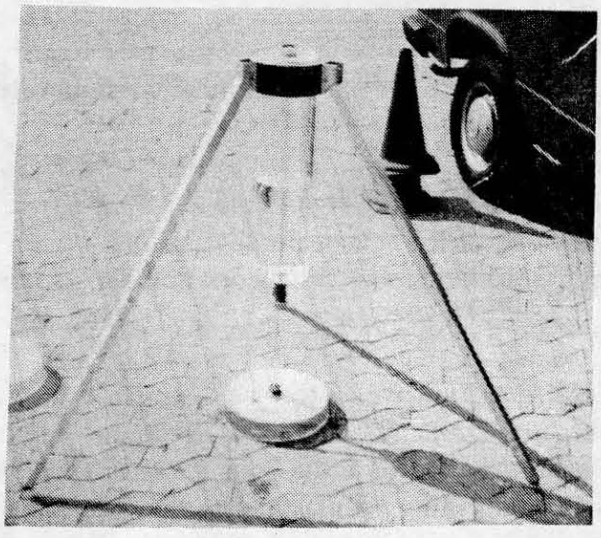

Fig. 2: Photograph of the Infiltrometer.

The test areas.

The tests was carried out on pavements at the area of SF-STEN A/S, Denmark. The chosen areas represented pavements with ages from 14 days to 25 years. The pavements had also been exposed to different kinds of load; both static and dynamic load. The areas was used as driving area for fork-lift trucks or storage of Concrete Blocks. All the pavements was sf-blocks on a base of gravel except for test point no. 16 where the pavement was Coloc-blocks. The joint materials consisted of either ordinary joint gravel or joint gravel mixed with Trass-lime and water. The last type is assumed giving an impermeable pavement and is therefore used on filling stations in Denmark.

Test point number	Joint material	Age	Joint length / cm		Joint width / mm	
1	gravel	23 year	101	97	4,0	3,9
3	Sand, humus and moss on the top	25 year	113		3,0	
4	Sand and humus	25 year	116		2,6	
5	gravel	5 year	105		2,0	
6	gravel	5 year	108		2,8	
15	Trass-lime	14 days	117		3,0	
16	Trass-lime	14 days	108		2,8	
18	Trass-lime	15 year	104		3,4	
19	gravel	15 year	112		3,1	

Table 1: Characteristics of the test points

The gravel used in the joints had fractions between 0 - 8 mm. The joint length is the length covered by the plastic cylinder during the test. The width of the joint is a weighted average of all the joints spacings and was measured with a calliper gauge.

Results from the infiltration tests.

Some of the test points were placed on newly laid Concrete Block Pavement with joints filled with joint gravel. The infiltration tests on these pavements showed that it is impossible to determine the infiltration on such pavements. The joint gravel in the joints crossed by the cylinder was washed away by the water pressure. The water floated on the pavement and the results from newly laid CBP with joint gravel was therefore useless.

The results from the infiltration tests, carried out on the different test areas, are showed in figure 3. The lines in the chart are functions fitted to the real measuring data. This is due to the variety in the flow at each infiltration test which has been mentioned earlier. As the chart shows, the results differs from test point to test point. These differences will be discussed in the following.

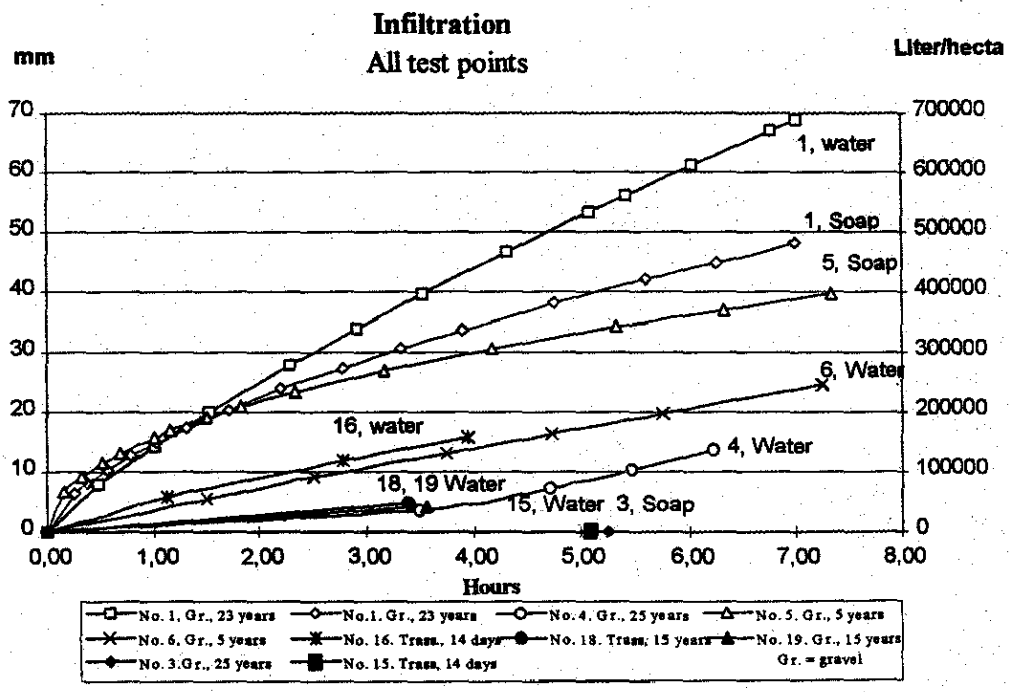

Fig. 3: Infiltration rate in the test points.

Discussion of the difference between using water or soapy water.
The infiltration test on test point no. 1 was done with and without soap added to the water. The two tests took place at a mutual distance of 1 metre and the dimensions of the pavement and the materials are therefore to be considered almost uniform. In the figure the infiltration of the water is obvious higher than the infiltration of the soapy water. It was assumed that the soapy water would give higher infiltration according to the lower surface tension and if more tests were carried out in the area the hypothesis might have been proven.

Discussion of joints with Trass-lime.
In the test points no. 16 and 18 the joints was filled with the hydraulic binder material Trass-lime, mixed with joint gravel and water. No. 16 was a newly laid pavement and no. 18 was 15 year old. The infiltrations were measurable but relative low in the two points. In measuring point no. 15, which also was a newly laid pavement, showed the test no infiltration at all after more than 5 hours. This indicate that a CBP with joints filled with a Trass-lime mixture, can be impermeable if laid carefully. The reason that no. 16 gave more infiltration than the two others was that the sealing around the cylinder was leaking a bit. Test point no. 18 infers that joints filled with Trass-lime might get permeable with time though it is possible that this pavement always has been a bit impermeable. By comparing test point no. 19 which has joints filled with joint gravel instead of Trass-lime and is placed on the same pavement as no. 18 it can be seen that the infiltration is the same. This indicate as well that there are no difference in permeability between the two types of joint materials if the pavements are old and has been exposed to traffic.

Discussion of joint material and traffic load.
The two test points no. 3 and 4, which was placed on the same 25 year old pavement, with a spacing of 30 metre, gave quite different results. No. 3, which primarily are used for storage of Concrete Blocks, showed no infiltration after 5 hours. A visual evaluation showed that the joints contained a large amount of organic materials. If these small particles accumulate in the air pores, the joints will get more and more impermeable with time. In test point no. 4 the test resulted in a little infiltration. The joints in this point was not filled in the same way with organic materials presumable due to the relative high among of truck traffic on the place. The joint of these two test points had the same width and the results indicate that the among of traffic is an important parameter in getting impermeable. At the test points no. 5 and 6 the situation is the same. The points are placed on the same pavement but located in a trafficked area and a storage area. No. 5, which is in the trafficked area, has the highest infiltration and no. 6, in the storage area, is more impermeable with a lower infiltration.

Infiltration velocity.
The results of the infiltration tests are depending on whether the underlying layers are permeable or not. If the layer underneath the bedding sand is impermeable, the infiltration will decrease right after the joint material and the bedding sand are filled with water. If the Concrete Block Pavement is the most impermeable layer the infiltration will keep a constant velocity right after starting the test. Therefore it is very interesting to see the infiltration velocity from the tests which is showed in figure 4.

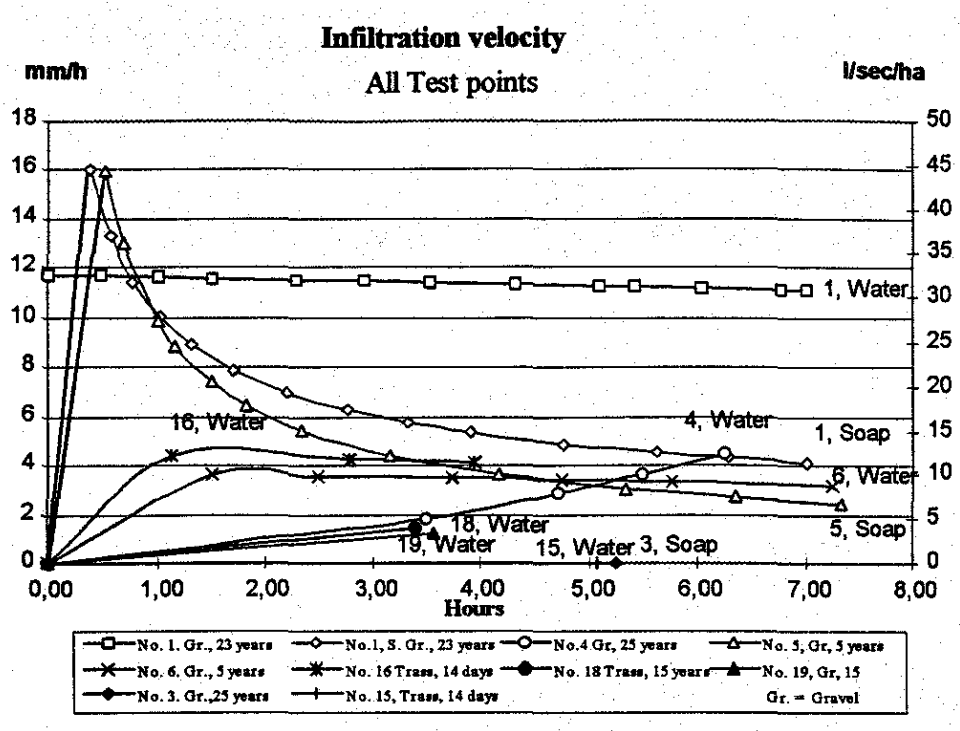

Fig. 4: Infiltration velocity in the test points.

For the majority of the measuring points the infiltration velocity converge at approx. 10 l/sec/hectare which is equivalent to 4 mm/h. The velocity in the first 15 min is probably different from what the figure indicates concerning most of the tests. The assumed flow is like test point no. 4 and 5. These points have a high infiltration velocity in the start and converge to a constant level after some time. Nevertheless, the curves must have the starting point in origo which in the case of the measuring points with few readings, might look a bit strange. Measuring point no. 1 with water has a constant velocity from the start of the test. As mentioned before, this indicate that the underlying layer is more permeable than the concrete block pavement.

Description of possible errors.

This new developed equipment has some advantages compared to other infiltrometers but as any other measuring equipments there are also some possible errors that can occur during a test. These will shortly be described in the following.

The reading of the infiltrated water is done on the water tank with intervals of approx. 15 min. According to the way that the water flows out of the tank, this influence the calculated infiltration velocity. E.g. if a reading has been made and the water refills the plastic cylinder on the pavement right after the reading, this refill is only registered 15 min later. This results in a higher calculated infiltration velocity.

During the infiltration test the water pressure on the pavement varies from +1 mm to - 3 mm related to the given water level at 40 mm in the plastic cylinder. This variation is caused by the surface tension and was tried solved by using soapy water but this did not remove the error.

In the calculation of the infiltrated water it is assumed that the water doesn't infiltrate the pavement which is not covered by the equipment. This means that all the infiltrated water is assumed to spread in the materials right under the Infiltrometer which is obviously not true. To show the quantity of this error an eksample where the water is assumed infiltrated as a hemisphere in the materials has been carried out. This gave that the 8 % of the water was infiltrated to the materials not covered by the Infiltrometer. The error described here is not taken into consideration very often but affect the results of any infiltration test.

An other thing that affect the results is the length and the width of the covered joints. In the tests described in this paper the test points has been carefully chosen by fulfilling some criteria. One of the criteria was that the test points should have identical joint dimensions. Of course this is difficult on old pavements were the traffic has caused horizontal movements and consecutive joint variations. In these tests the results are calibrated so that the determined infiltrations are comparable.

Conclusions.

The tests carried out with the new Infiltrometer shows it´s usability. It is easy to use and the evaporation is kept at an absolute minimum. This makes it possible to carry out tests with volatile liquids. There are no need for manual refilling because of the water tank. The tank has no restriction on the among of water and the tank can be made as big as needed. An important thing in infiltration tests is the variation in the water pressure on the surface of the pavement. The higher water pressure the higher infiltration. By using the Infiltrometer the water pressure is kept at a constant level during the test, due to the continuously refill of water from the water tank. It is though possible to make some further developments on the Infiltrometer so the refill of water is done even more continuos.

With this equipment it is possible to carry out standardized infiltration tests on Concrete Block Pavements.

The results from the tests carried out with the Infiltrometer shows that it is not possible to determine the infiltration on newly laid Concrete Blocks with joints consisting of joint gravel. The results on old CBP with vegetation in the joints showed no sign of infiltration after more than 5 hour. A newly laid pavement with joints filled with Trass-lime mix was impermeable. Another pavement with the same joint material but approx. 15 year old showed moderate

infiltration. This indicate that joints with the Trass-lime mix can be broken down within some time and become permeable.

For the majority of the tests the infiltration velocity was, not surprisingly, highest to begin with and stabilized after some time at approx. 10 l/sec/hectare ~ 4 mm/h.

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