Leakage Detection Methods for Roof Membranes

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ABSTRACT

It can be difficult to localize a leak in a roof system, because the water can be transported a long distance in the roof construction. There are some different methods that can be used to detect or localize leaks from the outside. Six such methods were compared and tested on different roofing materials and substrates.

Each of the methods tested offers some improvement compared with visual inspections. The methods were more or less suitable depending on the construction of the structure and type of roof membrane. Different recommended approaches are given for leakage detection and quality control.

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1. INTRODUCTION

Leaks in low-slope roof systems with roof membranes can be difficult to localize. A leak indication on the inside of a building does not have to correspond with a leak in the roofing surface in the immediate surroundings because leaking water can be transported considerable distances.

Typically, leakage detection is performed by visual inspection. A method to detect the leakage from the outside can be useful in both quality-control and field inspections of roof systems. If a hole or leak could be located before leakage occurred or caused damages, substantial financial benefits could be achieved.

There are a number of available methods to locate leaks, but they are often only designed for a particular purpose or material. In this project, various methods were compared and evaluated through application on roof systems with different substrates.

2. AIM OF THE STUDY

The aim of this project was to evaluate a number of leakage-detection methods regarding reliability and usability. This was conducted by applying different leakage-detection methods on four test roof systems. To be able to do the evaluation, equipment for some methods had to be developed and fabricated. Complete equipment was bought for one of the methods.

3. EXPERIMENTAL

Depending on the kind of leakage and construction type, different leak-detection methods can be anticipated to be more or less useful. The possibilities for detection of leakage in various roof constructions are also probably varying with different methods. The following six different methods were applied to the four test roof systems:

1. Pressure-box method
2. Tracer-gas-box method
3. Smoke method
4. Overflow method
5. Humidity-detection method
6. Potential-difference method

3.1 Roof systems

The four different test roof systems were built in a laboratory. The roof systems were flat with parapets and equipped with drains and details for protruding pipes. The plan of these roof systems is shown in Figure 1. All four roof systems were equipped with single-ply SBS as a roof membrane. These roof membranes with details were installed by a professional roofing worker. The roofing worker also prepared the membranes with predefined defects during installation. The following substrates were used for the test roof systems:

Roof 1 Lightweight concrete
Roof 2 Wood
Roof 3 Expanded polystyrene on corrugated sheet metal
Roof 4 Mineral wool on corrugated sheet metal

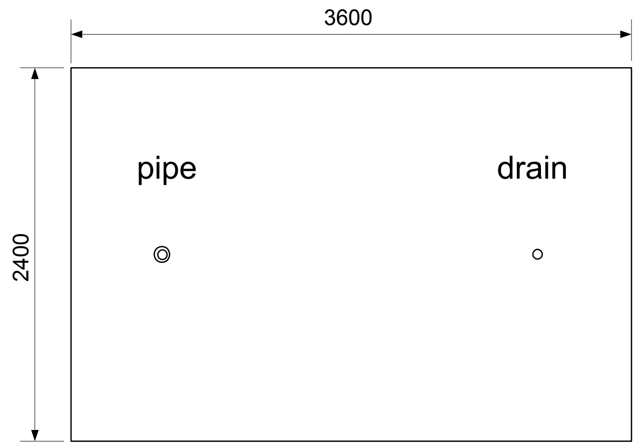

Figure 1: The layout of the test roof systems (dimensions in mm).

3.1.1 Roof 1

The lightweight aerated concrete had a thickness of 150 mm (5.9 inches), and the roof membrane was mechanically attached.

3.1.2 Roof 2

The wood used for roof No. 2 was tongue and-groove timber with a sawn face with a thickness of 22 mm (0.87 inches). Before the roof membrane was installed, the wood was covered with underlay felt to which the roof membrane was fully bonded.

3.1.3 Roof 3

The roof membrane was mechanically attached to the corrugated sheet metal. The thickness of the expanded polystyrene was 100 mm (3.9 inches).

3.1.4 Roof 4

As with roof No. 3, the membrane was mechanically attached. The thickness of the mineral wool was 145 mm (5.7 inches).

3.2 Testing Methods

3.2.1 Pressure box

To verify the watertightness of waterproofing layers in bathrooms, this method is applied according to the description in a Swedish standard (SS 92 36 21) [1]. In this project, the method was adapted for roofing applications through development of the equipment. One adjustment is that the negative pressure in the pressure box has to be reduced and monitored to avoid the risk of tearing the membrane off.

The pressure-box method is accomplished by mounting a transparent box on the surface that is going to be tested. To receive good connection with the surface, the box is equipped with rubber sealing strips around the perimeter. The box is also equipped with a nipple and manometer to monitor the pressure in the box (the equipment is shown in Figure 2). Before testing, the surface is covered with a special leak-detection fluid (e.g. soap water), which forms foam when penetrated by airflow. During the test, negative pressure is applied to the box, and if there are any leaks in the area covered by the box, foam is formed and the leaks are easily detected. The time for the bubbles to form is typically less than 30 seconds.

Figure 2: Equipment used for the pressure-box method.

If soapy water is used, the temperature has to be above the freezing point. However, other leak-detection fluids (as used in the refrigerating industry) have freezing points below all normal outdoor temperatures.

3.2.2 Tracer-gas box

With special detectors, a tracer gas can be detected above the surface of a roof membrane to indicate punctures through material. Of course, the tracer gas has to be introduced under the roofing material in some way. A tracer gas is a gas that is not typically found in surrounding air in that concentration. An example of a tracer gas is nitrous oxide.

This method had not before been applied on roof membranes. Equipment for the method (shown in Figure 4) had to be developed. The detection device consisted of a pressure box, air pump and tracer-gas detector. Negative pressure in the box was produced by an air pump. The negative pressure in the box was used to increase the gas flow through possible punctures in the material and to shorten the response time of the gas detector. The pressure box was of the same type as in the previously described pressure-box method.

Figure 3: One of the test roof systems taken outside for testing.

In the laboratory tests, the constructed test roof systems were sealed on the edges and beneath with plastic sheeting to make a tight box with the roofing material as the upper side (See Figure 3). The tracer gas nitrous oxide was introduced in this box. After a while, when the gas was supposed to be rather evenly spread in the formed box, a detecting device was used to search for leakage on the surface.

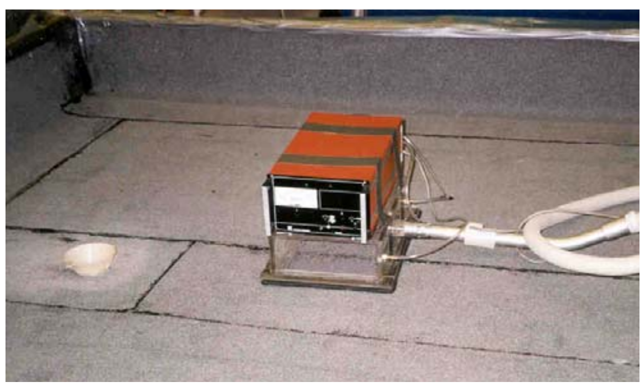

Figure 4: Pressure box with tracer-gas detector and connected air pump.

The possibility to use this method on real houses depends on the construction under the roof. If there are inhabitants in the building, maximum gas concentrations are 500 PPM due to the sanitary limit value [2].

3.2.3 Smoke

Smoke is pumped in under the surface that is going to be examined, and larger leaks where smoke penetrates the roof membrane are detected effortlessly.

A form of this method is used in Sweden to test the tightness of roof systems covered with mechanically attached bituminous roof membranes. The method is carried out by pumping air mixed with smoke under a roof system's surface. The overpressure from the air mixed with smoke is supposed to raise the surface and reveal if the material is tight and correctly attached to the roof construction. The equipment is shown in Figure 5.

Figure 5: The equipment used for the smoke method.

3.2.4 Overflow

In the overflow method, a roof system is filled with water and drainage is prohibited. If there is a leak in the surface, the water will pass through. If no water can be detected in the construction below the roof system and the water level does not fall, the roof system is considered watertight. According to HusAMA [3], the method is carried out by subjecting a roof system to at least 60 mm (2.4 inches) of water for three days after an ocular inspection. The roof system should then be monitored for six days.

This method is mostly used on terrace slabs or reversed roof systems before they are covered with concrete, asphalt or something similar. Prerequisites for the method are a roof system with internal drainage and temperatures above freezing. The method is also called the flood test [4].

3.2.5 Humidity detection

If a roof system is suspected to have leaks, this method can be performed after a rainfall. The water on the roof system's surface will penetrate through the membrane and accumulate in the substrate. When the surface has dried, a nondestructive moisture detector of capacitive type (see Figure 6) is used to find humid areas under the roof membrane. A humid spot under the membrane indicates a leak. During the dry season when a roof system is not watered down naturally by rain, a roofing professional can sprinkle the roof. This method can also be combined with the overflow method.

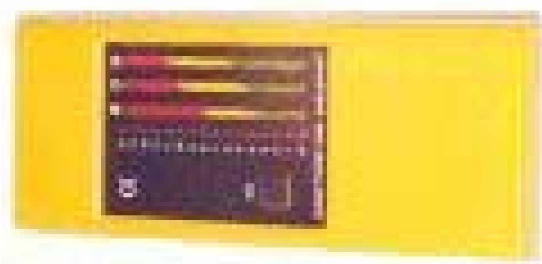

Figure 6: One of the nondestructive moisture detectors used.

3.2.6 Potential difference

This method is useful for detecting leaks on larger roof areas, provided the membrane is an electrical insulator. This method utilizes the insulation property in combination with the fact that water is a relatively good electrical conductor. In the United Kingdom, the method is called the electrical earth leakage technique [4].

If there is continuous water passage from the surface through a leak and a material below, the water passage can act as an electrical conductor. When applying a current on this water passage, the leak can be detected.

The prerequisites for this method are:

- The roofing material must be an electrical isolator
- The roof system's surface must be wet or moist during measurements
- There has to be a continuous water passage through the leak
- There must be a possibility to connect the construction below the surface, which is in electrical contact with the water leak, with the positive pole of the equipment.

These prerequisites are possible to obtain even on ballasted roof systems or roof systems covered with soil or gravel. The roof system should have a primary or secondary load-carrying structure made of steel or reinforced concrete that the protruding water can reach to easily close the electric circuit. If the substrate under the roofing material is wood, the positive pole has to be connected directly to the intruding water because dry wood is a good insulator. The equipment can be used on warm and cold roof systems.

The method is usable on roofing materials that are good electric insulators. Bituminous roofing materials and PVC coverings are suitable, but EPDM membranes, which contain carbon black, are generally not suitable due to their typically all-too-high electric conductivity. The method can also be used on membranes in other applications, such as swimming pools.

Figure 7: The equipment used for the potential-difference method on one of the test roof systems.

In this project, the equipment used for the potential-difference method was manufactured by a company in Germany. The equipment consists of a pulse generator, which produces pulses with amplitudes of 40 V. The pulse generator's positive pole is connected to the roofing construction or floor structure. This can be done, in most cases, by the earth connector in the wall plug or radiator system. Otherwise, the connection can be made directly to the intruding water on the inside. The negative pole of this equipment consists of an aluminum wire woven into a string (i.e., a string of the same type used around enclosed pastures). This uninsulated electric wire is laid in a loop around the roofing area that is going to be tested, as shown in Figure 7. A voltage field appears on the roofing material between the electric wire and leak. With the help of a potentiometer connected to two electrodes (as shown in Figure 8), the differences in the potential in this field are measured, and the position of the leak can be found quickly. Figure 9 shows how to systematically move the electrodes connected to the potentiometer to find the leaks. When there is a shift in the direction of the field at the third point, one approximate direction to the leak is found. Following measurements are done perpendicular to the ones done earlier. By the second time the field changes direction, the leak is found.

Figure 8: The potentiometer with the attached electrodes.

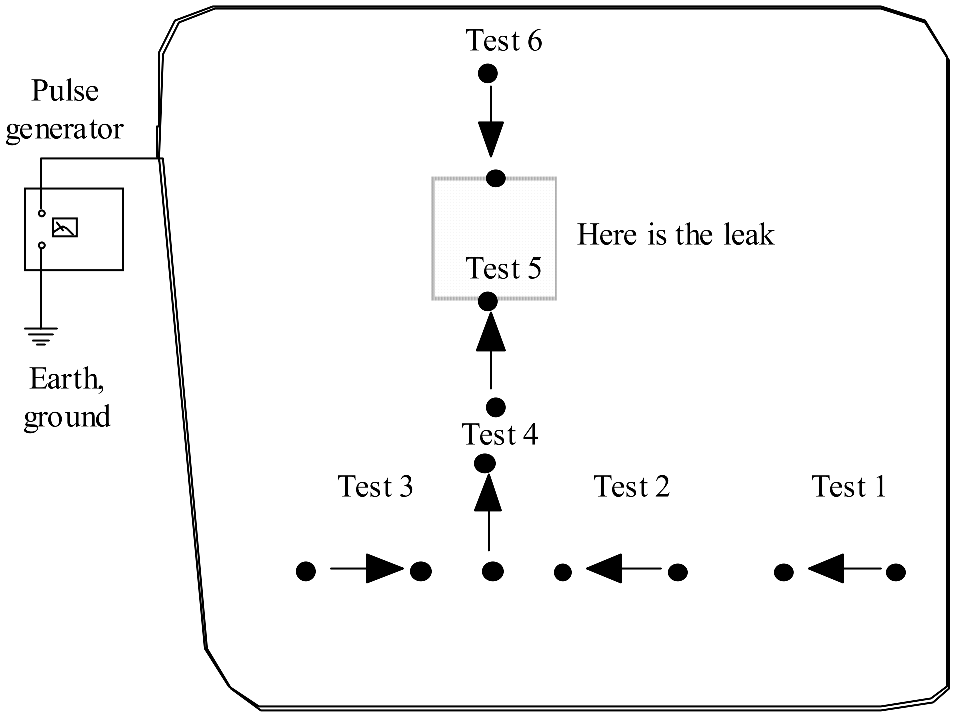

Figure 9: An example on how to perform a leak detection with the potential-difference method. The dots represent the position of the electrodes, and the arrows describe the field direction according to the potentiometer. Each test takes approximately 10 seconds to perform. All the measurements are done within the loop of electric wire.

4. RESULTS AND DISCUSSION

The measurements conducted show that certain combinations of leakage-detection methods and roofing materials are preferable because they are easier to perform than others. Each of the methods tested offer some improvement compared with visual inspections, which is the method usually performed.

4.1 Pressure-box method

According to the Swedish Standard SS 92 36 21 [1], the air pump shall be able to produce a negative pressure of at least 20 kPa (2.9 psi). Because a negative pressure of only 2 to 3 kPa (0.3 to 0.4 psi) is sometimes sufficient to tear off fully bonded membranes, a maximum negative pressure of 1 kPa (0.15 psi) was set when using this method during the study.

The method was found to detect leaks accurately and worked with all four substrates. The size of the pressure box limits the detection. A box that is too large is too heavy to operate and transport up on to roofs while a small box makes the detection process more time consuming.

A drawback of this method is that it is time consuming if larger areas need to be tested. As with the tracer-gas method, if there are no indications where the leak is, the whole roof has to be tested bit by bit.

4.2 Tracer-gas-box method

When using this method, the location of a leak can be found, but only as accurately as down to the area enclosed by the he pressure box. When a hole is detected, the area inside the pressure box has to be visually inspected to find the leak. If no defect can be seen, the previously described pressure-box method has to be used. To change to the pressure-box method is easily made by spraying on leak-detection fluid and adjusts the pressure.

This method is most suitable to use on mechanically attached membranes where the tracer gas can be distributed under the membrane. The size of the pressure box limits the detection. A box that is too large is too heavy to operate and transport on to roofs, while a small box makes the detection process time consuming. If there are no indications where the leak is on a roof, the whole roof has to be tested bit by bit.

4.3 Smoke method

This method is most suitable on mechanically attached roof systems with nonpermeable substrates because a prerequisite for this method is that it is possible to produce a positive pressure below the membrane. The smoke method works best with newly installed roof systems because roof membranes seem to stick to the substrate after a while and prevent the smoke from spreading evenly.

When using this method, the overpressure has to be monitored to eliminate the risk of tearing the membrane off.

The visual effect of the smoke was found to be dependent on the light conditions. If the surface is poorly illuminated, the smoke does not produce enough contrast to make it visible. A certain drawback of the system is that it is not completely nondestructive. A hole has to be made in the roofing material to let the smoke in. A professional roofing contractor has to be present to patch the hole after the test. The advantage of the method is that rather large areas can be searched at each time.

Of the mechanically attached roof systems in the laboratory measurements, this method worked best on the roof system with a substrate of lightweight concrete. With the other two mechanically attached roof systems, it was hard to achieve the required pressure under the membrane.

4.4 Humidity-detection method

In field measurements, the humidity-detection method can be used to detect parts of the roof system for more detailed inspections using the pressure-box method. It can also be used with visual inspection. The disadvantage of this method is that added humidity can take a long time to dry out. If the leak is rather large or has been present a long time, the substrate can already be wet in large parts of the area.

In the laboratory measurements, this method was executed last to avoid interference with the other methods. It was hard to detect holes with this method during these measurements, especially on roof No. 2, which had an underlay felt under the roof membrane.

4.5 Overflow method

An advantage of the overflow method is the limited equipment needed. All that is required is a stopper that suits the drain and some kind of water supply.

A drawback of this method is that the possible leaking water can cause damage to the building. According to measurements conducted at the department [6], the water-flow rate, through a 1.8-mm (0.07-inch) hole in a single-ply membrane, can vary between 0.3 to 1.6 l/h (0.011 to 0.057 ft^3/h), depending on the substrate. These amounts of water may seem rather troublesome, but they only correspond to a decrease in the water level of 0.003 to 0.016 mm/h (0,00012 to 0,00063 inches/h) if the roof has an area of 100 m^2 (1076 ft^2). Over three days, the prescribed time in HusAMA [3], the water level will only decrease 0.2 to 1.1 mm (0.008 to 0.043 inches) if evaporation is disregarded. The conclusion is that either the holes have to be rather large or the test area has to be small to detect a decrease in the water level.

Correctly used, this method can indicate a leak in a roof system but not pinpoint its exact location. It is advised that this method be used with the humidity-detection method or potential-difference method.

4.6 Potential-difference method

This method has been tested previously in the United Kingdom [4] with its roof system constructions but without a comparison with other methods. In this study, the potential-difference method was used on roof system constructions commonly used in Sweden and compared with other leak-detection methods.

Under the condition that it is possible to apply an electrical potential over the membrane, the method works quite efficiently. When used properly, the accuracy of the method allows the user to position the leak within centimeters.

The method is particularly useful on a roof system where the leak has been going on for quite some time and substrate and structure have been wet down. If the roof system's surface is dry, the water flow from a garden hose is enough to create a thin water film over the surface.

This method is not typically suitable as a quality-assurance method because a newly installed roof system typically does not contain a sufficient amount of water. On the other hand, after a test with the overflow method, a new roof system will be well-prepared for this method. The method is quite practicable to use during repair work to verify that all leaks have been repaired.

A drawback of this method is that can be difficult to perform if there are many details on the roof system connected to the ground. A benefit of the method is its independence regarding weather [4] because rain will not disturb the test contrary to some other methods. The method has proven to be a practical alternative to the overflow test, which also was shown in the United Kingdom [4].

5. CONCLUSION

Six methods have been tested and compared on exposed roof membranes. The smoke method was the most visual method, but it has its drawbacks by not being nondestructive and able to detect the smallest holes. The potential-difference method was clearly the fastest of the nondestructive methods but requires the surface to be wet and does not work well with certain substrates. The pressure-box method, on the other hand, works on all surfaces and substrates with good accuracy but is time consuming. The overflow method is a rough method and can cause damage if there is a leak present. The humidity-detection method is also a rough method and can only indicate holes and not detect them. The tracer-gas method seems promising but has to be further developed before it can match other methods.

For quality control or after of roof membrane installation, three methods are recommended to detect leaks. When it is possible to produce a positive pressure under a membrane, the smoke method can be used. As a sample-test procedure, the pressure-box method is suitable. If an overflow test is planned, it should be supplemented with the potential-difference method or at least humidity detection.

For leakage detection on low-slope roof systems with roof membranes, more than one procedure can be used. If the roof membrane can act as an electrical insulator, the best approach is the potential-difference method. With other types of roofing material, and when the potential-difference method is not available, the pressure-box method is recommended. In combination with the pressure-box method, the humidity-detection method is suitable to narrow down the areas that are going to be inspected in more detail. The pressure-box method can also be used with the potential-difference method to verify the indications.

6. ACKNOWLEDGEMENT

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