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NON-DESTRUCTIVE TESTING (NDT)

PART - 4

WATER LEAKAGE DETECTION IN BUILDINGS & WATERPROOFING MEMBRANE INTEGRITY TESTING

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A Not-for-Profit Knowledge Centre

From the Editor's Desk

Concealed water leaks in buildings can originate from many sources such as air conditioning units, cold-water chillers, water supply and drainage lines, and clogged drains, etc. Water leakage from external sources may result through damaged skylights or windows, cracks in external walls and roof terraces, separation cracks, construction errors, failure in waterproofing systems, failure in sealants provided at the junctions of window frames and masonry or even built-up condensation drips. With water-related damages in buildings rising, it becomes very difficult for remedial waterproofing without any proper diagnosis of the exact location of the leakage or the source of the leakage. Tracing the leakage by any trial and error method or by a conventional flooding test/spray test not only becomes time consuming, but is not always successful, as such tests only check the ingress of moisture/water, which may not happen during the test and may arise due to defects or discontinuity in a waterproofing system. Further, the leakage issue may be compounded where the roof terraces have an overburden as in the case of a roof garden or a vegetative roof system. With advances in the materials and systems used in waterproofing, people are now being given 20-25 years warranty on their waterproofing systems. However, the actual challenges faced by the contractor or the owner is the measurement of the performance of the waterproofing system, or monitoring the performance of such a guaranteed system over a long period of time. Here, these advanced non-destructive instruments become very handy for detecting and pinpointing water leakages. Looking at this grey area, where hardly any application of advanced non-destructive instruments are being carried out in practical fields, we scanned through some modern techniques and instruments that are being used in India and abroad for leakage detection for the general understanding of applicators/contractors so that proper remedial action can be taken.

Some of the major equipment used to locate leaks on building envelopes includes thermal imaging, electronic field vector mapping (EFVM), acoustic data loggers, correlators and humidity sensors, etc. However, out of these, thermal imaging and electronic field vector mapping are most suitable for leakage detection.

Although thermal imaging has been used by many consultants for building diagnosis, its application in leakage detection is limited only to a few trained professionals. The most important criteria of thermography are the interpretations of the thermal images taken at different times where ambient temperature changes affect the type of thermal images at the same location. Hence understanding the science of infrared radiation of different surfaces subjected to temperature changes is important, and with the help of passive and active thermography, one can interpret the images and identify the source of leakages. Hence though the process is simple, it can become complex unless one understands it completely. Improper understanding may lead to unsuccessful diagnosis of leakage issues, which is what is happening in most cases.

Amongst all the water leakage detection equipments the most accurate is EFVM which can pinpoint the leakage source and can be used for quality control & quality assurance in a membrane waterproofing system thus helping in warranty assurance.

Though the most common application for water leak detection is under raised floors, water can also come from a roof that leaks. Wherever costly equipments are installed, or at data centres, one can install a water leak sensing system by a cable in the ceiling above the data room and suspend the cable from the water pipes of concern, as well as under the raised floor.

Also, facilities and equipment that use water-cooled technology have started to add intelligent cable sensors to provide early warning of leaks that could potentially avoid costly equipment damage and downtime. The cable is installed around the supply and return water lines to continuously monitor for leaks. As a result, they are able to pinpoint the exact location of a leak when it occurs and protect the equipment by triggering an alarm before water reaches the equipment. Leak detection solutions can also be useful in monitoring any area where condensation can build up and cause the growth of mold.

The present issue of ReBuild mainly discuses infrared thermography and EFVM methods for water leakage detection along with some case studies to create awareness about quality control & quality assurance in waterproofing industries.

Advanced Techniques and Instruments for Water Leakage Detection in Buildings

[Source: http://www.findaleak.co.uk/water-leak-repair.html]

1.0 Introduction

One of the most common problems faced by a house owner is dampness, seepages, leakages and resulting damages. Often, difficulties in finding the source of the leakages and seepages lead to unsuccessful remedial measures, mental agonies and eventually even financial losses. With the advent of advanced non-destructive testing methods it is possible to pinpoint the exact location of a leakage, and the same technique can be used during the installation of a waterproofing membrane or during any remedial treatment.

2.0 Leakage Tracing

The most vital aspect of inspection will be the detection of moisture penetration or possible sources of it. One can more readily trace a leak with water itself so one can simulate a leak by applying water to the suspected leak source. It is important to verify that the leak is indeed coming from the roof and not from another source. Inevitably, any moisture that enters a building from overhead is immediately considered a roof leak, but it might be something entirely different: condensation from piping, poorly insulated roof decks, uninsulated equipment or leaks in overhead sprinkler and drain lines, failed window seals, etc. Uncovering a moisture source not associated with the integrity of the roof membrane or flashings can save an owner valuable time and money as well as improve the credibility of the contractor, manufacturer or consultant involved. Material discolourations and deformations (stretching, blistering, gurgling, etc.) also aid in leak tracing.

Once the leak's location inside the building has been determined, the job of hunting down the water's point of entry on the roof's surface begins. Roof leaks won't always be found directly above the point where water is dripping from the ceiling. The water may be traveling some distance within the roof system or along the deck flutes or other components before it finds an opening into the building. It is possible, however, to backtrack from the inside leak to the point of entry on the roof's surface by following the route the water is most likely to take. If the leak's source can't be found close to the leak on the inside, the investigator should begin examining roof surfaces that are higher than the area directly above the leak. Possible sources include curbs, walls, drains, gravel stops, scuppers or air handling units near the interior leak. New base flashings on retrofit roofs should be examined to see that they have not been carried up beyond the old counter flashing and secured to the wall with a termination bar. Metal copings, especially flat copings, deserve special attention. Rusting may be a problem if the joints are exposed to wind-driven water. Sagging, open flashings are frequently found to be the leak's point of entry. Base flashings are also common sources of problems such as punctures, especially where there is heavy foot traffic. Opened or separated laps in the base flashing or diagonal wrinkles that have cracked may also allow water to enter. Vertical penetrations such as sill vents could also be suspects. Expansion joints, particularly those that intersect each other or a vertical surface, should also be checked.

2.1 Common sources of leakage from external walls

Apart from sleeves, common sources of leakage in external walls are:

- Deep cracks/crevices penetrating the finishes and the body of the wall.
- Defective concrete found in the wall.
- Defective or loss of external finishes that protect the wall from the direct attack of rain.

2.2 Sources of leakage from bathrooms and kitchens

In bathrooms or kitchens, the source of the leakage must be identified before any repair works can be considered. If it is the loosening of components in the drainage system such as traps under the sink, basin or bathtub, simple fixing can stop the leakage. The usual remedial treatment would be wrapping bathseal tape around the pipes and grouting the gaps with non-shrink grouts. However, if defective water supply pipes are identified as the main problems, licensed plumbers should be engaged to replace the defective parts or overhaul the entire system.

A common cause is defective sealant around the bathtubs, basins, sinks or a defective waterproofing system on the floor. This problem can be easily dealt with by replacement of sealant. However, if there is a "wet floor" habit, the waterproofing system of the floor is put to test. Should the cause be identified as water spilled on to the floor, it is always advisable to reconstruct the entire waterproofing layer instead of patch repair. In balconies where ponding may be frequent due to heavy rain or blockage of drain outlets by rubbish, the waterproofing system has to be sound in order to be a nuisance to the floor below.

3.0 Leakage Testing

The following testing methods are used as part of water leak investigations in buildings. They are also used with new constructions to verify waterproofing. The different types of leak tests are:

3.1 Flood Testing

It is performed on new low-slope horizontal waterproofing installations such as parking garages and plaza decks.

As part of a leak investigation, flood testing is performed on low-slope building roofs. Containment assemblies are sometimes constructed around the horizontal regions to be tested.

3.2 Leakage Mapping

As part of a leak investigation, leakage mapping can be performed on window joints and other suspect frames. A special nozzle and 0.20 to 0.24 Mpa of dynamic water pressure are applied 300 mm from each 1.5 m joint for 5 minutes.

3.3 ASTM Method of Leakage Testing at Window

ASTM E 1105-08: "Standard Test Method for Field Determination of Water Penetration of installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference."

However ASTM E331 test is by Uniform Static Air Pressure Difference whereas ASTM E547 test is by Cyclic Static Air Pressure Difference.

The air-pressure differences acting across a building envelope vary greatly. These factors should be considered fully prior to specifying the test pressure difference to be used. The field test may be made at the time the window, skylight, curtain-wall, or door assemblies are initially installed and before the interior of the building is finished. At this time, it is generally easier to check the interior surfaces of the assemblies for water penetration and to identify the points of penetration. The major advantage of testing when assemblies are initially installed is that errors in fabrication or installation can be readily discovered and corrections made before the entire wall with its component assemblies is completed at which time the expense of corrective work may be increased many times.

The field test may also be made after the building is completed and in service to determine whether or not reported leakage problems are due to the failure of the installed assemblies to resist water penetration at the specified static air pressure difference.

Weather conditions can affect the static air pressure difference measurements. If wind gusting causes pressure fluctuation to exceed ±10 % from the specified test pressure, the test should not be conducted.

Generally it is more convenient to use an interior mounted pressure chamber from which air is exhausted to obtain a lower pressure on the interior surface of the specimen. A calibrated rack of nozzles is then used to spray water at the proper rate on the exterior surface (Fig. 1).

Under circumstances where it is desirable to use an exterior-mounted pressure chamber, the spray rack must be located in the pressure chamber and air supplied to maintain a higher pressure on the exterior surface. Exterior chambers are difficult to attach readily and seal to exterior surfaces. This test method addresses water penetration through a manufactured assembly. Water that penetrates the assembly, but does not result in a failure as defined herein, may have adverse effects on the performance of contained materials such as sealants and insulating or laminated glass.

Fig. 1: A field leakage test by pipe rack system at window frame

3.4 ASTM Method of Leakage Testing on External Wall

ASTM E2128: "Standard Guide for Evaluating Water Leakage of Building Walls"

This standard describes multiple methods for determining and evaluating causes of water leakage of exterior walls. It is an investigative guide to determine if a buildings drainage capacity of the wall is causing or is likely to cause premature deterioration of a building or its contents. A field leakage test by pipe spray system at external wall is shown in Fig. 2.

Fig. 2: Leakage test by pipe spray system at external wall

The other related standards are ASTM E2556: "Standard specification for vapor permeable flexible sheet water resistive barriers intended for mechanical attachment" and ASTM E783: "Standard Test Method for Field Measurement of Air"

4.0 Leakage Testing by Non-Destructive Testing Methods

Leak testing is the branch of non-destructive testing that concerns the escape or entry of liquids or gases from pressurized or into evacuated components or systems intended to hold these liquids. Leaking fluids (liquid or gas) can penetrate from inside a component or assembly to the outside, or vice versa, as a result of a pressure differential between the two regions or as a result of permeation through a somewhat extended barrier. Leak testing encompasses procedures for one or a combination of the following.

- Locating (detecting and pinpointing) leaks
- Determining the rate of leakage from one leak or from a system
- Monitoring for leakage

Leakage investigation is increasing in importance because of the rising value of, and warranties on, manufactured products and because of the constantly increasing sensitivity of components and systems to external contaminants. Environmental concerns are causing additional emphasis on leak testing and its conduct.

4.1 Equipment/Methods used for leakage detection

The water leak detection system helps to find leaks on pipe work and building envelopes. Some of the major equipment used to locate leaks on building envelopes include Thermal Imaging, Electronic Vector Mapping, Vac Box testing and Trace Gas Injection & sensing etc. Combining these techniques with more traditional techniques such as dye testing, smoke testing, and pressure testing can give an ideal solution for all leak location processes.These techniques for water leak detection can be combined or used in isolation depending on what is constructed over the service or how deep the service lies.

4.2 Acoustic Leak Detection

Acoustic leak detecting instruments (Fig. 3) allow the localization of the lowest consistent noise. It offers automatic noise reduction from intermittent interfering noises, like passing vehicles, people talking, and pedestrian footsteps. This means the source of leaks can be identified a lot quicker.

4.3 Correlator Leak Detection

Leak correlators (Fig. 4) identify the acoustic frequency made by water escaping from a pipe. The correlator uses two sensors placed over the pipe length which detect the noise of the water escaping from the leak and calculates the leak's location by comparing the delay in the signal reaching each sensor.

There are some other equipment/methods by which leakage detection can be made, such as:

- Acoustic data loggers
- Combined acoustic logger & correlator
- Ground penetrating radar
- Salts/Chemistry analysis
- Drain cameras
- Humidity sensors
- Dew point alarms
- Pipe tracing equipment

Fig. 3: Leakage detection by advanced Ground Microphones

Fig. 4: Leakage detection by Digital leakage correlator

5.0 Conclusion

With new construction, verification is achieved if no water leaks into the interior of the structure. With leak investigations, where there may be signs of interior water damage but no actual leaks, infrared (IR) thermography and electrical capacitance (EC) testing such electronic field vector mapping (EVFM) are most suitable in addition to visual inspection to determine whether water penetration is occurring. These two methods have been discussed in detail in subsequent sections.

Infrared Thermography for Detecting Water Leakages – Case Studies

[Source: "http://www.ndtwiki.com/index.php/Leak_Testing"]

1.0 Introduction

The speed of using infrared, and the larger areas covered rapidly by an IR camera, can save time and money by providing a faster, more efficient and more reliable survey. An IR camera can detect moisture located behind interior walls under the right conditions. The temperature difference created by the presence of moisture on the inside surface of a wall will appear differently than the surrounding areas. These techniques for water leak detection can be combined or used in isolation depending on what is constructed over the service or how deep the service lies. Infrared Themography inspection is a powerful and non invasive means of monitoring and diagnosing the conditions of buildings and detecting water leakages (Fig. 1).

Fig. 1: Display on LCD screen of thermal camera

2.0 Fundamental Principles

According to the Fundamental Law of Planck, all objects above absolute zero emit infrared radiation. This radiation only becomes visible to the human eye when the temperature is above 500°C. Infrared monitoring equipment has been developed which can detect infrared emission and visualize it as a visible image. The sensitive range of the detector lies between 2 and 14 microns. The 2–5.6 micron range is generally used to visualize temperatures between 40°C and 2000°C and the 8-14 micron range is used for temperatures between -20°C and ambient temperatures. The thermograms taken with an infrared camera measure the temperature distribution at the surface of the object at the time of the test. It is important to take into consideration that this temperature distribution is the result of a dynamic process. Taking a thermogram of this object at an earlier or later time may result in a very different temperature distribution. This is especially true when the object has been heated or cooled. The detectability of any internal structure such as voids, delaminations or layer thicknesses depends on the physical properties (heat capacity, heat conductivity, density, and emissivity) of the materials of the test object. Naturally any interior 'structure' has an effect on the temperature distribution on the surface. If the temperature changes on the surface there is a delay before the effect of this change occurs below, where a defect such as a void occurs. The longer the time delays before the temperature changes, the greater the depth of the defect below the surface. Generally anything deeper than 10 cm will only show after a long period of time (>1 hr) after the temperature change has occurred. Since the infrared system measures surface temperatures only, the temperatures measured are influenced by three factors: (1) subsurface configuration, (2) surface condition; and (3) environment. As an NDT technique for inspecting concrete, the effect of the subsurface configuration is usually most interesting. All the information revealed by the infrared system relies on the principle that heat cannot be stopped from flowing from warmer to cooler areas, it can only be slowed down by the insulating effects of the material through which it is flowing. Various types of construction materials have different insulating abilities or thermal conductivities. In addition, differing types of concrete defects have different thermal conductivity values. For example, an air void has a lower thermal conductivity than compared to the surrounding concrete. Hence the surface of a section of concrete containing an air void could be expected to have a slightly different temperature from a section of concrete without an air void.

There are three ways of transferring thermal energy from a warmer to a cooler region: (1) conduction; (2) convection; and (3) radiation. Sound concrete should have the least resistance to conduction of heat, and the convection effects should be negligible. The surface appearance, as revealed by the infrared system, should show a uniform temperature over the whole surface examined. However, poor quality concrete contains anomalies such as voids and low density areas which decrease the thermal conductivity of the concrete by reducing the energy conduction properties without substantially increasing the convection effects. In order to have heat energy flow, there must be a heat source. Since concrete testing can involve large areas, the heat source should be both low cost and able to give the concrete surface an even distribution of heat. The sun fulfils both these requirements. Allowing the sun to warm the surface of the concrete areas under test will normally supply the required energy. During night-time hours, the process may be reversed with the warm ground acting as the heat source. For concrete areas not accessible to sunlight, an alternative is to use the heat storage ability of the earth to draw heat from the concrete under test.

3.0 Factors Affecting Temperature Measurement

The first important point to remember is that in order to use infrared thermography, heat must be flowing through the concrete. It does not matter in which direction it flows.

The second important factor to consider when using infrared thermography to measure temperature differentials due to anomalies is the surface condition of the test area. The surface condition has a profound effect upon the ability of the surface to transfer energy by radiation. This ability of a material to radiate energy is measured by the emissivity of the material, which is defined as the ability of the material to radiate energy compared with a perfect blackbody radiator. A blackbody is a hypothetical radiation source, which radiates the maximum energy theoretically possible at a given temperature. The emissivity of a blackbody equals 1.0. The emissivity of a material is strictly a surface property. The emissivity value is higher for rough surfaces and lower for smooth surfaces. For example, rough concrete may have an emissivity of 0.95 while shiny metal may have an emissivity of only 0.05. In practical terms, this means that when using thermographic methods to scan large areas of concrete, the engineer must be aware of differing surface textures caused by such things as broom textured spots, rubber tire tracks, oil spots, or loose sand and dirt on the surface.

The final factor affecting temperature measurement of a concrete surface is the environmental system that surrounds that surface.

Some of the factors that affect surface temperature measurements are:

3.1 Solar Radiation

Testing should be performed during times of the day or night when the solar radiation or lack of solar radiation would produce the most rapid heating or cooling of the concrete surface.

3.2 Cloud Cover

Clouds will reflect infrared radiation, thereby slowing the heat transfer process to the sky. Therefore, night-time testing should be performed during times of little or no cloud cover in order to allow the most efficient transfer of energy out of the concrete.

3.3 Ambient Temperature

This should have a negligible effect on the accuracy of the testing since one important consideration is the rapid heating or cooling of the concrete surface. This parameter will affect the length of time (i.e. the window) during which high contrast temperature measurements can be made. It is also important to consider if water is present. Testing while ground temperatures are less that 0^{o}C should be avoided since ice can form, thereby filling subsurface voids.

3.4 Wind Speed

High gusts of wind have a definite cooling effect and reduce surface temperatures. Measurements should be taken at wind speeds of less than 15 mph (25 km/h).

3.5 Surface Moisture

Moisture tends to disperse the surface heat and mask the temperature differences and thus the subsurface anomalies. Tests should not be performed while the concrete surface is covered with standing water or snow. Once the proper conditions are established for examination, a relatively large area should be selected for calibration purposes. This should encompass both good and bad concrete areas (i.e. areas with voids, delaminations, cracks, or powdery concrete). Each type of anomaly will display a unique temperature pattern depending on the conditions present. If, for example, the examination is performed at night, most anomalies will be between 0.1° and 5°C cooler than the surrounding solid concrete depending on configuration. A daylight survey will show reversed results, i.e. damaged areas will be warmer than the surrounding sound concrete.

4.0 Test Methodology

The leakages and dampness in buildings can quickly and thoroughly be scanned using an infrared camera, identifying problem areas that cannot be seen by the naked eye. Infrared thermography (also called "thermal imaging" or "infrared imaging") is a process by which infrared radiation from an object can be measured or imaged using a special type of digital camera which translates the infrared image of the object (which is not visible to the human eye) into an image on an LCD display (Fig. 1). In many cases the infrared radiation received by the camera corresponds in a fairly straightforward way with the temperature of the surface(s) being imaged. Thermal imaging of building structures and components is useful because it allows a thermographer to visualize temperature differences up to 0.1^{o}C between two different materials or between two different areas of the same material. The area having moisture penetration, dampness, leakages are shown with blue colour images (Fig. 1). The temperature difference of the image establishes the damp areas. Taking digital images of the same spot either by a separate camera or by the same thermal imaging camera with a provision to take digital images will help to identify the spot. Once the source of the leakage is identified, the remedial treatment becomes more successful.

5.0 Case studies

5.1 Bath Room Water Leakage Detection

Survey of one of a villa's bathrooms at Santacruz, Mumbai was conducted to detect water leakages. Accordingly, a thorough thermal image investigation of the bathroom area was also carried out in April 2012. The visual inspection as well as thermal image inspection was carried out internally as well as externally to ascertain the extent of damage and methodology for proposed repair work. The thermograph photos were also taken where more attention was required in respect of identifying the leakage spots for remedial work. The temperature difference of affected areas were noted and analyzed to locate the leakages. The following leakage locations were identified as follows :

- Dampness in the ground floor bathroom slab area coming from 1st floor bathroom (Fig. 2).
- Concealed Nahani trap (Fig. 3) and pipe line have deteriorated which need replacement.

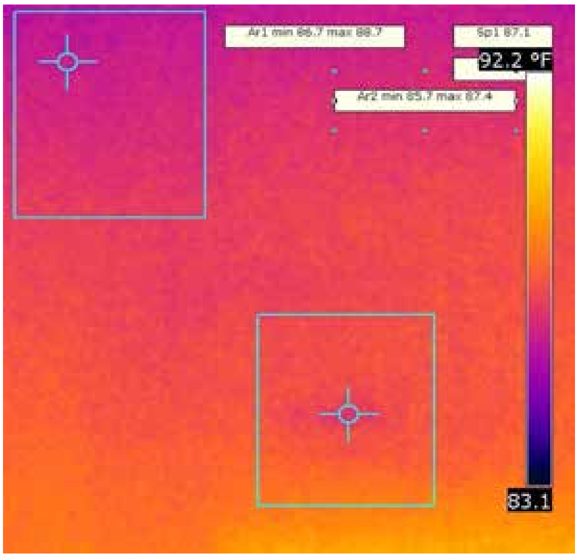


Fig. 2: From ground floor ceiling

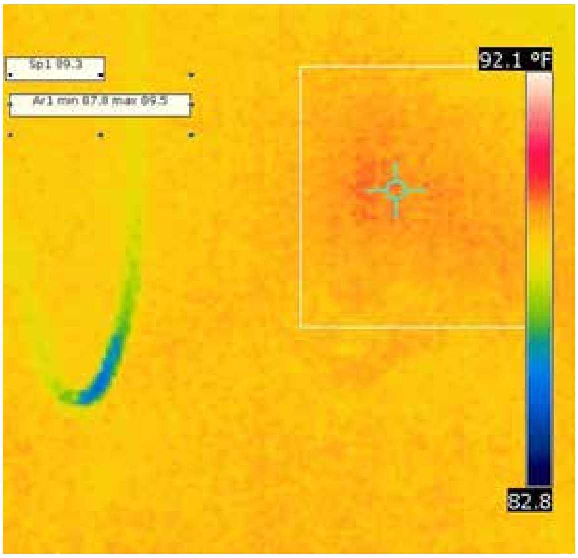


Fig. 3: 1st floor bath room near Nahani trap south wall joint

After locating the leakage spots the remedial treatment was successfully carried out, after which no leakage was observed.

5.2 Leakage Detection of a Roof Ceiling

In a 27-storey posh residential tower in south Mumbai, leakage was occurring at the 12th floor roof slab. It was observed that water was dripping from one point at continuous intervals (Fig. 4).

Fig. 4: Water dripping point and accumulation of water of 12th floor roof ceiling

Some drillings were carried out on ceiling surfaces (Fig. 4) to release the water pressure. The water drop varied between 30 to 50 drops in each 10 minutes interval and increased with heavy rain but decreased without rain. The same water was being accumulated in a larger area and was dripping slowly when there was no rain. At the 13th floor, all the water spread areas such as the deck slab, water fountain, artificial water pond, back side of the fountain, were tested by visual observation, water ponding test and thermal imaging. Except for the deck slab, the other locations were ruled out as causes of the leakage. The deck slab of the 13th floor was double height of 8.4 m, without any facade protection. During the monsoons the rain water was splashing on the deck floor. Though the deck had a provision of water proofing, a leakage occurred due to a failure of the waterproofing at one transition zone of a pillar. After conducting thermal imaging, the exact location point was identified. The digital image and thermal imaging of the same spot is given in Fig. 5 & Fig. 6 respectively.

The remedial waterproofing treatment was carried out after which no leakage has been observed so far.

Fig. 5: View of 13th Floor deck slab floor near pillar

Fig. 6: Infrared thermal imaging showing gap at joints of pillar where water was penetrating

5.3 Leakage Detection of a Jacuzzi

A RCC framed bungalow of plinth area of 25000 sqft having all ultra modern facilities covered with lawns and landscaped gardens in Revas Road, Chondi, Alibaug had some leakage issues. It had a Jacuzzi where water leakage was occurring for which thermal imaging was carried out. After filling the Jacuzzi with full of water it was observed that the level of water was receding slowly. Wet spots were observed at few locations after making empty of Jacuzzi. There were cracks in few locations on the surface of Jacuzzi, which was identified by thermal imaging analysis. The digital and thermal images are shown in Fig. 7 to 12.

The leakages spots were identified in all the thermal images and accordingly remedial treatment was carried out after which no leakage was observed.

Fig. 7: Digital Image of leakage spot

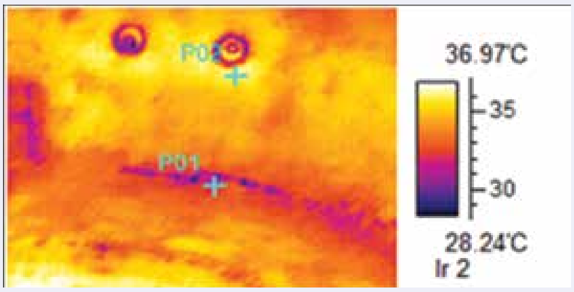


Fig. 8: Temperature :P01- 30.8°C Min.; P02- 36.4°C (Max.)

Fig. 9: Digital Image of leakage spot

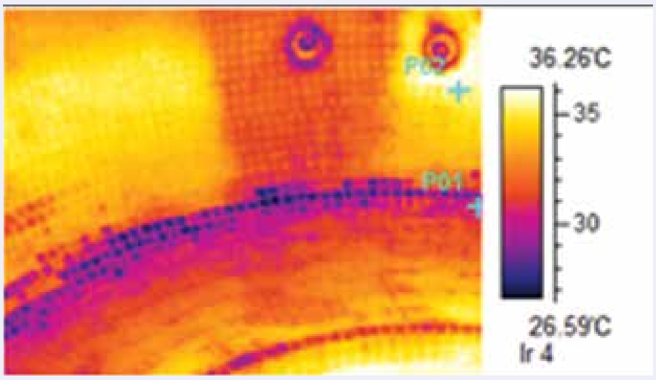


Fig. 10: Temperature : P01- 27.7°C Min.; P02- 36.1°C (Max.)

Fig. 11: Digital Image of leakage spot

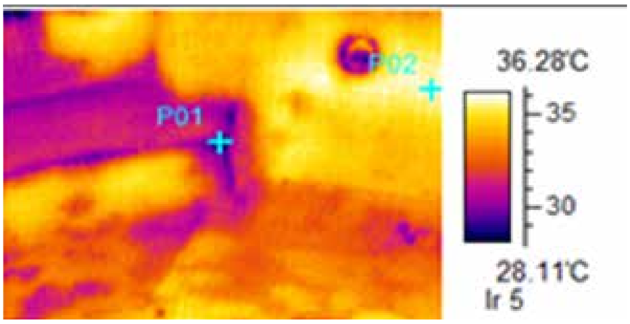


Fig. 12: Temperature : P01- 28.2°C Min.; P02- 36.1°C (Max.)

5.4 Non Invasive Roof Leak Detection

A leakage occurred at the ceiling-wall joint of a residence in year 2003. Water entered the home at the supply duct register and the windows at the front wall of the living room. Water testing indicated the intrusion might have been the transition between the wall and roof. Corrective measures were performed that included replacing the roof flashing as well as the stucco siding of this area. After one year a rainstorm again caused water intrusion within the same area previously noted before flashing and wall stucco replacement. In the absence of infrared thermography the ceiling would have been removed to inspect the roof sheathing for the water intrusion point(s). With infrared thermography it was not necessary to remove contents, wallboard, or erect scaffolding, nor was floor protection necessary.

Visual inspection of the roof exposed two potential water intrusion points, the gutter and chimney areas. The gutter had foam installed at the upper slope of the gutter. Since this was an unusual use of foam, it may have hidden imperfections or water entry points behind the gutter. Water testing was directed at the gutter area to determine if it was a leak site.

5.4.1 Baseline Determination

Following the visual inspection a complete infrared thermographic inspection of the interior of the affected area was performed. This was to provide a reference point of the thermal characteristics of the walls and ceiling of the affected area. Areas that were cooler or showed temperature abnormalities were examined closer with moisture survey equipment that consisted of conductive and dielectric meters. No moisture differences were found in the cooler areas visible in the infrared thermograms.

5.4.2 Water Testing

Water was applied to the roof from a spray rack system for 30 minutes at each location or 15 minutes using the hand held spray applicator (Fig. 13). Fig. 14 shows the positions of the rack system for each 30-minute test. Entire roof surface was divided into number of panels for the spray followed by thermal imaging at ceiling surface of the same location and testing was conducted in each panel. Soon after the spray rack system was moved into another position, water intrusion was found in the ceiling of the residence. During this test no water intrusion was found, indicating no water intrusion points for this area of the roof.

Fig. 13: Images of the spray rack system used to apply water to the roof

Fig. 14: Image of the hand held applicator and its position during the water test of the gutter area as well as the positioning of the spray rack system

5.4.3 Moisture Discovery

During the water application process infrared thermography was used to scan the ceiling surface of the living room. No moisture was detected until the spray rack system reached a particular position. Figure 15 shows the beginnings of the water intrusion as indicated by the cool spot noted by the arrow.

5.4.4 Intrusion Discovery

Once it was determined through water testing where the approximate location of the roof leak was, roof tiles were removed to examine the underlayment and roof sheathing. By following the water visible below the underlayment, the source of the intrusion was found. Two nails were discovered that had been dropped onto the roof sheathing, then covered by the underlayment and having punctured the underlayment. Since the roofing tiles prevent water from entering the underlayment it was important to determine how the water got under the roofing tiles to begin with. Further exploration of the roof revealed a debris dam at the valley of the roof. Roofing codes in the area required the tiles to be installed without a gap at the roof valley. This allowed debris to accumulate in the valley eventually damming the valley causing water to spill over onto the underlayment.

As the roof water test continued, the water intrusion increased, moving to the front wall of the living room.

Fig. 15 indicates the location of the water within the wall as it moves behind the wall, surfacing at the top and bottom of the window. At this point of the test water was dripping from the window header on to the floor of the living room. Water testing continued with the spray rack positions at different locations. As the rack moved away from the valley of the roof the water intrusion decreased, finally stopping with the completion of the water testing.

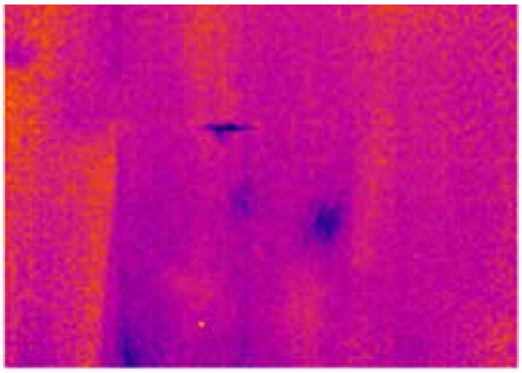


Fig. 15: Thermogram showing the beginnings of the water intrusion

(Source: Non Invasive Roof Leak Detection Using Infrared Thermography by Scott Wood, Four Star Cleaning and Restoration, Inc.)

6.0 Conclusion

The thermal imaging method is the most advanced technique to trace the leakage path. This technology is available in India and is being used by many consultants to detect water leakages as well as many other common defects in buildings.

Membrane Integrity Testing & Electronic Leak Detection by Vector Mapping and Case Studies

[Source: http://leak-detection.com/about-ild/case-studies/case-study]

1.0 Introduction

Electronic Field Vector Mapping (EFVM) is a cutting edge technology that is redefining the art of leak detection and quality assurance in low-slope roofing and waterproofing systems. Vector mapping pinpoints breaches in the roof membrane by tracing the flow of an electric current across the membrane surface. One can get virtually 100% testing on roofing and waterproofing membranes with ELD Fusion®, with an advanced combination of High and Low Voltage Electronic Leak Detection methodologies.

2.0 Importance of Integrity Testing

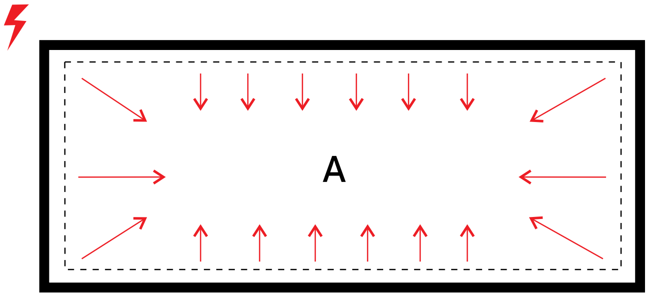
Small punctures, membrane splits or mechanical damage to a waterproofing membrane will result in wet insulation, mold, and costly interior damage. Leaks can go unnoticed and the water exit location might not correspond with the point of entry. Previously, lengthy and costly leak investigations were necessary to locate a membrane breach, especially in protected roof membrane assemblies, garden roofs, or parking and plaza decks. Vector mapping eliminates the dangers and potential damage inherent in traditional flood testing. Unlike the interpretive process of water, flood, infrared, or nuclear testing, vector mapping detects membrane faults directly.

3.0 How Does EFVM Work?

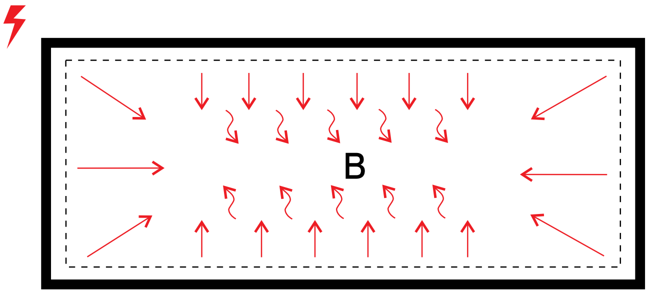
An electric field is created by applying water on the surface of the membrane and using the water as a conductive medium. The EFVM equipment delivers a low voltage pulsating electrical charge between the non-conductive waterproofing membrane and the conductive structural deck. A watertight membrane will isolate the potential difference, while breaches in the membrane will cause an electrical connection to occur. The directional flow of the current is read with a potentiometer to locate the point of entry with pinpoint accuracy.

The vector mapping conductive mediums are created to test non conductive substrates. Three different conductive mediums allow for accurate EFVM testing results:

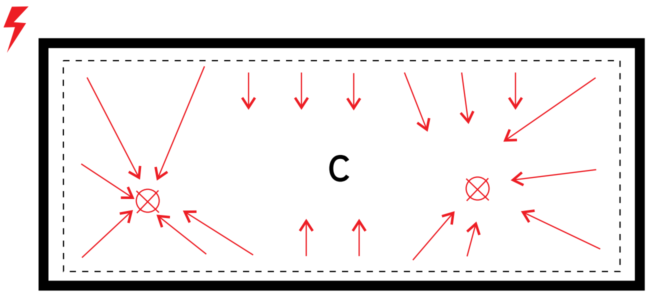
Vector mapping grid (VMG): A welded stainless steel mesh which can be utilized on the fully-adhered systems. This mesh is a non-corrosive material that prevents aging deterioration within the roofing system.



A: Small electrical pulses are directed onto the membrane. The electricity searches for a ground connection



B: If the membrane is watertight, the electricity is isolated and does not find a ground connection



C: If the membrane is not watertight, the electricity makes a ground connection and is pulled toward positive poles.

Vector mapping mesh (VMM): A fine aluminum screen that is utilized in loosely-laid membrane systems.

Vector mapping felt (VMF): A non-abrasive conductive fabric that can be utilized under a loose laid or mechanically fastened roof assembly and embedded into hot liquid membrane systems.

The conductive mediums are placed under the waterproofing material and connect to a contact plate, via a prefabricated cable to the contact box. The Vector-9 conductor wire on top of the membrane delivers direct current tension to the surface. Even in the case of minimal contact with moisture, the system closes the electrical circuit. Moisture penetration can be located quickly and then be cost-effectively repaired.

The test is completed by conducting a visual inspection of all wall junctions, perimeter details, and membrane penetrations. All breaches are numbered to allow for repairs by the waterproofers onsite and are retested to confirm watertightness. A report follows with picture documentation of every breach and a detailed drawing noting the wire placement and breach locations. The various EFVM methods are discussed as follows:

3.1 Low Voltage Method

In low voltage vector mapping (Fig. 1), the surface of the roof membrane is moistened (not flooded) to create an electrically conductive medium.

A conductive wire loop is laid out on the membrane around a section of the area to be tested. One lead from a pulse generator is connected to this wire perimeter. The other lead from the generator is connected to a ground, either the structural deck or a GroundScreen™ conductive mesh installed in the system. Leaks or breaches in the membrane are detected when the electric current flows across the moistened membrane and through the breach to the deck, completing the circuit. The technician uses two probes connected to a receiver to determine the direction of the current flow and to precisely locate the breach (Fig. 1).

Fig. 1: In Low Voltage Vector Mapping (wet testing) the technician uses metal probes on a wet surface to pinpoint membrane breaches

3.2 High Voltage Method

Unlike the low voltage method, high voltage testing is performed on a dry horizontal or vertical surface using a very small current at a relatively high voltage for safe and reliable testing (Fig. 2).

Fig. 2: High Voltage ELD (dry testing) is ideal for testing flashings and other vertical surfaces

One lead from the portable current generator (charger) is grounded to the conductive roof deck (either metal or concrete) or a GroundScreen™. The other lead is attached to a special electrode brush made with highly conductive metal bristles. As the technician "sweeps" the brush electrode over the surface of the roof membrane, electricity will flow through any breach in the membrane.

This completes the circuit between the brush and the ground, and immediately pinpoints the location of the fault. Where there are no breaches, the membrane acts as an insulator and prevents the flow of current to the deck.

3.3 ELD Fusion Method

ELD Fusion combines traditional Low Voltage Vector Mapping (wet testing) on large horizontal areas with High Voltage ELD (dry testing) on vertical surfaces, transitions, and other areas not tested with the low voltage technique (Fig. 3). ELD Fusion gives 100% coverage, and a 100% efficient leak free test.

Fig. 3: ELD Fusion method of membrane integrity testing

3.4 Vector Mapping Benefits

- Pinpoints membrane defects for efficient repairs
- Repairs can be immediately retested
- Most green roofs can be tested with soil overburden in place (low voltage method)
- Less expensive, faster, safer, and more reliable than flood testing
- Sloped roof systems and flashings can be quickly and efficiently tested (high voltage method)
- Enables direct (non-interpretive) detection of membrane breaches
- Wet weather tolerant (low voltage method)

3.5 Vector Mapping Applications

- Insulated and non-insulated low-slope roof systems (excluding metal-coated and carbon black EPDM membranes)
- Ballasted roofs (low voltage) Ponded and flooded roofs (low voltage)
- Green roofs
- Plaza decks
- Quality assurance
- Warranty verification
- Membrane integrity testing
- Pools, parking garages, liners
- Horizontal and vertical waterproofing membranes

3.6 Advantages of EFVM Testing

- Pinpoint accurate, quality-control testing method
- Non-destructive integrity and troubleshooting testing
- Ability to test sloped decks and vertical walls
- Defects can be repaired and retested the same day
- Limited use of water required to conduct test
- Inclement weather will not hinder the test (wet conditions are preferred for electrical flow)
- Overburden installed immediately after the EFVM test
- Eliminates unnecessary removal of overburden to locate a breach when doing a visual inspection
- Membrane can be tested prior to the expiration of the warranty or after traffic has occurred on the membrane

3.7 Limitations of EFVM Testing

- Not capable of testing most black EPDM membranes (ability to test white & grey EPDM)
- Steel-reinforced concrete topping slabs can affect the EFVM readings due to the conductivity of the metal within the topping slab (fiber-reinforced concrete is suggested for retesting capabilities)
- Metal projections protruding through the membrane must be isolated with membrane to allow for retesting

4.0 Case Studies

4.1 EFVM Testing vs. Flood Testing

A hospital project in Cincinnati, Ohio, USA utilized EFVM testing for final watertightness verification of a hot-rubber membrane approximately 25,000 sq. ft. in size. Due to the occupied hospital space below and the elaborate paver system above, ensuring 100% waterproofing was the highest priority. The consultant on the project requested that a flood test and an EFVM test be completed prior to the overburden installation.

Fig. 4: EVFM and flood testing for watertightness

Once the waterproofing was completed, a 48-hour flood test was performed and the area was deemed watertight. A testing agency was called in immediately after the flood test in March 2011 to complete the EFVM testing (Fig. 4). After the EFVM test, over 50 breaches (Fig. 5 & 6) were located within the membrane, which were found to be mainly due to mechanical damage. Unlike a flood test that only shows a membrane's ability to hold water, the EFVM test is a pinpoint-accurate test that confirms watertightness, or, in this case, a test that located potential active leaks.

Fig. 5: Breach no 19 as detected by EFVM test

Fig. 6: Breach no 5 as detected by EFVM test

EFVM testing gives an exact location, making repairs simple and quick without any additional inspections required from the contractor. A report was issued to the roofing contractor listing all breach locations and a plan drawing as well for reference. Once all repairs had been made and retested, all of the overburden was put in place and the plaza deck was completed (Fig. 7).

The Vector-9 conductor wire remained in place to allow for future testing, should any damage occur prior to the expiration of the waterproofing warranty. The same pinpoint testing will be possible through the pavers and miscellaneous vegetation in the future.

Fig. 7: View of plazadeck after the repair with overburden

4.2 EFVM Testing through Overburden

A water treatment plant in Lorton, Virginia, USA was in the process of completing the installation of an 85,000 square foot lid covering a clean water storage tank. During this process, it was discovered that ground water was leaking into the tank. Over $2^{1/2}$ feet of soil was already in place on top of the tank and it would have cost the contractor more than $1 million to locate and repair the breaches, with no guarantee they would have all been found. A testing agency was contacted in hopes that the EFVM test would locate the breaches in a more cost-effective and timely manner.

Fig. 8: Pinpointing the leakage location and further removal of overburden for remedial treatment

Since the vector wire was not installed prior to the dumping of soil, the technician had to weave a temporary wire through the soil around the lid area. Because the soil acted as a conductor, the EFVM test could be conducted and the readings obtained were strong. The technician was able to locate multiple breaches. Once a breach was located, the technician placed numbered landscape flags to allow for excavation of the soil (Fig. 8) and subsequent sheet membrane repair. The contractor made the repairs (Fig. 9) and the areas were retested to confirm watertightness. Since the completion of the test, the fresh water tank has remained free from ground water contamination. A view of overburden after repair and installation of waterproofing system is shown in Fig. 10.

Fig. 9: Remedial waterproofing at leakage point

Fig. 10: View of overburden after repair and installation of waterproofing system

4.3 EFVM Testing on a Vertical Surface

One notable project which contained multiple areas of vertical waterproofing is an indoor botanical garden located in Alberta, Canada. Opened in the late 1970's, the original gardens contained more than 20,000 plants, waterfalls, bridges, ponds and sculptures by local artists, showcased as a permanent art exhibition. In 2008, a renovation of the 100,000 sq. ft. gardens began. One major component of the renovation was the installation of a new cold applied waterproofing membrane for the horizontal and vertical applications, which allowed for a seamless installation throughout the project.

To verify the installation of both horizontal and vertical applications, a testing agency was retained to conduct an EFVM test to ensure a watertight installation. Beginning in late June 2011, began testing the newly-installed waterproofing membrane. The membrane appeared to be intact and watertight, but EFVM testing found areas of damage (Fig. 11) that were not visible to the naked eye. Until the advent of EFVM technology in the mid 1990's, there was never a successful testing method for the verification of vertical waterproofing installations. With millions of square footage of vertical waterproofing being installed every year, a method of vertical testing was conducted and accordingly remedial waterproofing (Fig. 12) was made.

Fig. 11: Breaches identified by vector mapping test on vertical surfaces of the membrane

Fig. 12: Remedial waterproofing at leakage point

4.4 EFVM Testing of Uneven Surfaces

The Kansas City State House was in the process of installing a concrete layer of stairs that had a hot liquid waterproofing membrane. The contractor suggested an EFVM test due to the fact that an 8,000 square foot area was installed the previous year. Although there was no damage visible to the naked eye, the contractor wanted to ensure the area was 100% watertight before the stairs were completed. Flood testing was not an option due to the inability to build dams around the stairs.

The EFVM test discovered numerous breaches. Repairs were not economically viable and the area was reinstalled. The EFVM test was used again to verify the new membrane's integrity and the Vector-9 wire was left in place to allow for future retesting after the concrete was installed.

5.0 Conclusion

The EFVM test method is the most advanced technique and precisely pinpoints the leakage points in a waterproofing system. Though the technology is rarely available in India at present, once introduced, sooner or later, it will be the most preferred system for leakage detection.

The Institute's Activities

Open Programme

Topic : Entrepreneurship in Waterproofing, Structural Protection and Repair of Concrete Structures
Date : 28 July – 8 August 2014
Venue : DFI-SPR, Mumbai

Topic : Diagnosis and Condition Assesment of Concrete Structures – An approach to Repair
Date : 25 – 26 September 2014
Venue : DFI-SPR, Mumbai

Forthcoming Training Programmes

DFI-SPR has scheduled the following training programmes for the upgradation of knowledge base of Practising Engineers, Waterproofing and Repair Contractors, Consultants, Architects, Faculties and Students from Engineering Colleges.

Sr. No.	Date	Venue	Topic	Fees	Details of the topic
1	22 & 23 Jan 2015	DFI - SPR, Andheri (E), Mumbai	Building Maintenance - Waterproofing and General Repair	₹ 4200	• Manifestation of weathering distresses in concrete buildings • Diagnosis and condition assessment • Advance Waterproofing Materials, Systems and Application Methodologies • Understanding cracks - classifications and patterns • General repair techniques and materials • Strategic planning and maintenance of buildings
2	5 & 6 Mar 2015	DFI - SPR, Andheri (E), Mumbai	Protection and Repair for Retaining Structures and Treatment Plants	₹ 4200	• Storage tanks and reservoirs (Overhead and Underground) • Swimming pools – elevated and ground level • Treatment plants – effluent / chemical • Basements and Foundations • Joints – design and treatments in retaining structures • Protection measures against ingress / loss of materials • Specialized coatings and repair measures • Case studies

Corporate Training Programme

In addition to the above scheduled programmes, we do organize separate corporate training programmes on specific topics as per the needs of the customer.

Distance Education Programme

"Certificate Course in Waterproofing & Repairs of Buildings"

One year distance education course commences from April 2015

Eligibility

- Diploma in any branch of Engineering
- Non- Engineering Graduate with 2 years work experience in construction

Programme Fees :

₹ 30000 + Service Tax @ 12.36%

How to Apply :

Application form can be obtained from Dr. Fixit Institute of Structural Protection and Rehabilitation by paying ₹ 250 or Downloaded from our website : www.drfixitinstitute.com and sent along with application fees of ₹ 250. Payment should be made by demand draft in favour of **"Dr. Fixit Institute of Structural Protection and Rehabilitation"** and payble at Mumbai.

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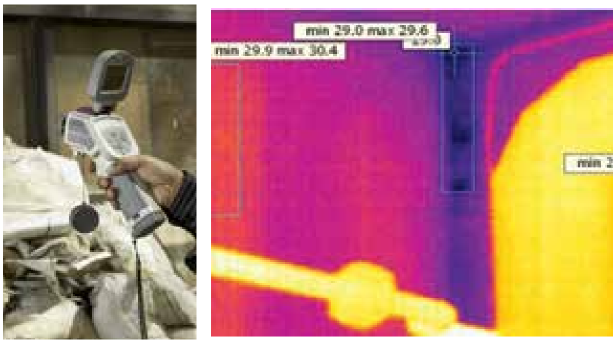
Fire damage assessment of an auditorium building


Corrosion investigation by Galvapulse GP 5000 in a cement plant


Chemical analysis of concrete samples



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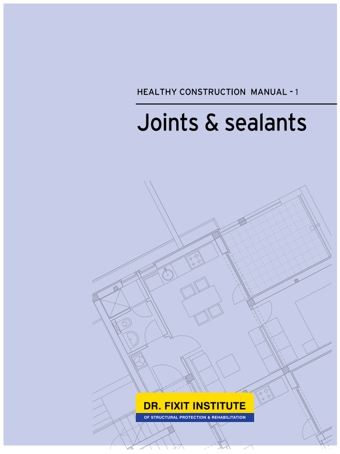
Publications

HEALTHY CONSTRUCTION MANUAL - 1

Joints & Sealants



ISBN 978-81-909802-0-3,

Price : ₹ 300
Postage : ₹ 25 for Mumbai and ₹ 50 for outside
Pages : 53

The Manual on "Joints and Sealants" covers different types of joints and their need for providing in concrete structures. It explains the movement of joints and how to design such joints at different locations consisting of different materials of cast-in-situ as well as precast constructions. It also provides solutions to seal those joints with different types of sealants and also guides for selection of materials for structures with fluid pressure and industrial floor joints and how to install those sealants including use of water stops / waterbar. The safety, health and environmental aspects are also covered.

HEALTHY CONSTRUCTION MANUAL - 2

Protective Coatings

(For Concrete & Masonry Surfaces)

ISBN 978-81-909802-1-0,

Price : ₹ 400
Postage : ₹ 25 for Mumbai and ₹ 50 for outside
Pages : 104

The Manual on "Protective Coatings for Concrete and Masonry Surfaces" is aimed to guide the practising and maintenance engineers in selecting a suitable protective coating for durability of the concrete and masonry structures and to provide details of method of applications, standards and specifications for executing the jobs at site. The various topics covered: Introduction, Properties and Test Methods, Characteristics Performances of different Coatings, Application, Quality Assurance, Safety, Health & Environment and Preparation of Tender documents including Appendixes, List of Relevant standards, equipment and their function.

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To become a premier national knowledge and skill development centre for capacity enhancement in waterproofing and other areas of repair, restoration and renewal engineering based on sustainable and green technologies.

MISSION

To act as a platform of national and international networking for sharing of knowledge and practices in the fields of waterproofing, repair, restoration, and renewal engineering in the context of life cycle assessment of the built environment for adoption of best practices by the country's construction industry.

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