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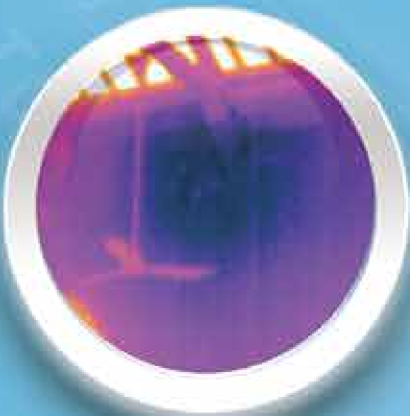
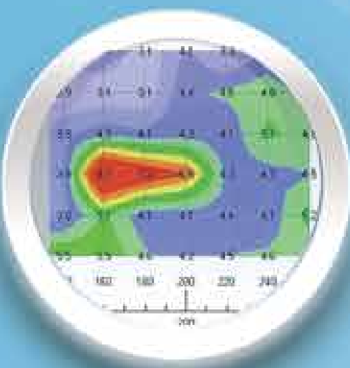


Professional Guide to Water Seepage

Investigation, Diagnosis, Testing & Reporting in Residential Buildings



Prepared by Building Surveying Division, HKIS
www.hkis.org.hk

Professional Guide to

Water Seepage Investigation, Diagnosis, Testing & Reporting

in Residential Buildings

First Edition
2014

Building Surveying Division

The Hong Kong Institute of Surveyors

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Preface

Water seepage problems in buildings have long been a concern for building occupants, owners, and governments worldwide. There are very few guidelines and test procedures for detecting and diagnosing water seepage problems that are applicable to Hong Kong's high-rise, high density built environment. There are also discrepancies in applying the tests and interpreting the results during the course of the investigation and diagnosis. Limited knowledge of building construction and services, time, access, and resources for investigation can prevent a correct diagnosis from being made. A professional guide is, therefore, necessary for the purpose of maintaining high standards and promoting the expertise of professional building surveyors in handling water seepage cases.

This is a guide for professionals. It provides information and advice to professional building surveyors on aspects commonly encountered in the course of detecting and diagnosing water seepage in Hong Kong's buildings. Members should refer to this guide, as it meets a high standard of professional competence. In addition, members should attend and complete a training course designed specifically to highlight the essential features of the guide. Demonstrations of the diagnostic and investigative procedures in the course with reference to real life cases will ensure and enhance members' competence in using this guide. With the adoption of a systematic methodology, more accurate diagnoses and effective rectification works can be achieved. Further, all surveyors must keep their skills and knowledge up to date, which is essential to the professional practice of surveying.

The Building Surveying Division (BSD) of the Hong Kong Institute of Surveyors (HKIS) wishes to express its sincere thanks to all professionals who have contributed to the completion of this series of guides in respect of research, the sharing of practical experiences, and providing relevant cases for study. The BSD has spent every effort to ensure that this professional guide represents the best practices in the industry. Readers are invited to contact the BSD with any suggestion to improve the guides.

Sr Robin LEUNG
BSD Chairman, 2013-2014

CONTENTS

Section 1.0 Introduction

1.1 Purpose of the Professional Guide

This is a comprehensive guide for professional building surveyors who need to identify, detect, and diagnose the problems associated with water seepage in Hong Kong's residential buildings. An investigation of water seepage usually starts with a desk study and visual inspection. This is followed by a systematic and comprehensive investigative and diagnostic procedure and the use of non-destructive tests (NDTs), which have now become essential in almost all water seepage investigations. The focus of this guide is mainly on water seepage in residential apartment buildings, but the diagnostic procedures also apply to all building types and uses.

The scope of this guide covers the planning and methodology of investigation, the diagnostic process, testing methods and reporting.

1.2 Overview

An account of the common water seepage problems and their symptoms and range of causes will be introduced. A systematic desk study, planning, inspection and diagnostic procedure will then be elaborated on with a checklist for practical use. This guide is presented in the following order:

Section 1.0	provides a short introduction to the need for guidance, along with a background and scope covered by the guide.
Section 2.0	provides a brief account on the common water seepage problems and their corresponding symptoms.
Section 3.0	gives a practical guide on the systematic desk study, planning, inspection, diagnosis process for water seepage investigation. A checklist and a flow chart will be used to illustrate the investigative and diagnostic procedures.
Section 4.0	describes five non-destructive tests commonly used in the investigation and diagnosis of water seepage. Their relative merits and de-merits will be highlighted and comparison tables will help the choice of appropriate testing method(s). Highlights the testing standards and certain precautions in carrying out the testing process.
Section 5.0	lists out the scope of investigation, reporting format, and elements reported in typical water seepage investigation cases.

Section 6.0 lists the general references for further reading.

Section 7.0 includes an Appendix on the glossary of terms used.

Section 2.0 Understanding Water Seepage in Residential Buildings

2.1 Common Water Seepage Problems

Water seepage can be one of the most difficult building problems to rectify, yet it is very common in buildings, especially older ones that were poorly-designed and built, and those that are inadequately maintained. In Hong Kong, the office responsible for handling public complaints of water seepage in residential units is the Joint Office (JO) of the Food and Environmental Hygiene Department (FEHD) and Buildings Department (BD). The JO received over 25,000 complaints on water seepage in buildings in 2010. Many of these cases were referred to surveyors in private practice or consultants for investigation. It is, therefore, important that surveyors be competent in determining the scope and nature of the defects, investigative techniques, available tests, and diagnostic procedures.

Although water in liquid form is familiar to all of us, its source and movement, which cause seepage, are often mysterious. Water may come from 'natural' sources like rain and condensation or from water-carrying services like potable water, flush water, or air conditioning chilled water pipes. The movement of water can be horizontal, vertically downwards, or even upwards, as it is aided by gravity or capillary action. Heat and thermal differences can also cause water movement in almost all directions in buildings. As a result, water movements and ramifications can be difficult to trace. Knowledge of construction technology and the properties of water, together with the use of specialised equipment and diagnostic techniques, are essential for investigating the causes of seepage, especially in complicated cases.

2.2 Symptoms and Causes of Water Seepage

The following paragraphs list the most common symptoms found in various building elements and suggest their probable causes. Detailed investigative and diagnostic procedures assisted by suitable tests are necessary for determining the actual cause(s) of the seepage (Section 3.0 – Methodology of Investigation & Diagnosis)

2.2.1 Roofs

Seepage is usually associated with rain and water-carrying services installed on a roof. A detailed review of the design and construction of the premises, as well as a careful analysis of the pattern of dampness and staining on the underside, will give certain hints during the diagnostic process. The most common causes of seepage on roofs are:

a. Poor design with inadequate falls and/or outlets, which causes ponding.
b. Poor workmanship, such as inadequate or defective laps of the sheet roofing membrane, uneven thickness of the liquid membrane, improper curing of the

roofing materials, improper or poor quality dress-ups and tuck-ins over the parapet and plinths/platforms for the service equipment, sharp bends at the corners, etc.

c. Excessive movements of construction joints.
d. Waterproofing layer damaged by the installation or fixing of equipment and the formation of an opening on the roof.
e. Inadequate protection of the waterproofing layer against sunlight and maintenance traffic.
f. Deterioration of the waterproofing layer due to ageing.
g. Leaking or overflowing roof features such as roof gutters, stair hoods, and hatch doors.
h. Rusty and/or damaged sheet steel roofing materials and joints.
i. Cracks along the parapet walls that damage the waterproofing membrane.
j. Improper installation and detailing of outlets and sleeves around the openings through the roof slab.
k. Substandard waterproofing system installed on the roof.

2.2.2 Floors and Ceilings

Water seepage through floor slabs causing damage to ceilings on the floor below are common defects that often lead to disputes between the owners and occupants of different flats. Unless the source of seepage can easily be identified through visual inspection, the use of an appropriate test (see Section 4.0 - Testing Methods) would be necessary to determine the actual source(s) and cause(s). The common causes of seepage on floors and ceilings are:

a. Improperly designed, built, and detailed joints, sealants, or occurrences of cracks in the toilets, bathrooms or kitchens above.
b. Cracks on water closets, bathtubs, shower trays, buried pipes, or drains.
c. Missing or poor quality tanking for the wet areas mentioned above.
d. Waterproofing properties of the tanking that may be damaged by fitting-out works such as the installation of fixtures, sockets, conduits, etc.
e. Deteriorating or defective waterproofing in external features such as balconies, sun shades, or external walls.
f. Flooding due to the blockage of drainage pipes, pipe bursts, or overflow from shower trays or bathtubs.

2.2.3 Internal and External Walls

Seepage along the external wall is usually associated with rain or external pipes that leak. Dampness along the internal walls may be associated with defective buried pipes, especially hot water pipes that are subject to higher frequencies and larger ranges of expansion and contraction. Internal walls adjacent to bathrooms and toilets are also vulnerable to seepage. The most common causes of seepage along walls are:

a. A lack of expansion joints for tiled finishes, which causes excessive stress and cracks or poor workmanship in the tile-fixing process.
b. External wall defects such as honeycombing, spalling concrete, holes left for anchor bolts, debris-filled voids and indents, and excessive movements of external wall components.
c. Defective or deteriorating external wall finishes such as loosened mosaic tiles, poor tile grouting, cracked ceramic tiles, and defective paint surfaces.
d. Anchors of scaffolding and bolt eyes of formwork left without proper seals.
e. Poorly designed and detailed cladding or curtain wall joints, especially openable panes.
f. Common walls between units of pre-fabricated elements or between buildings are vulnerable, especially if the joints on the top level between the buildings are not properly protected.
g. Omitted or inadequately high waterproof layers around shower trays.
h. Defective sealants along the edges of bathtubs, kitchen worktops, and sinks.

2.2.4 Windows

Windows subjected to prevailing winds and rains are particularly vulnerable to seepage during rain storms. Seepage is usually found at the sill level and around window heads, jambs, and openable sashes. It is important that all windows are tested in place for water tightness before handover. The most common causes of seepage in windows are:

a. Excessive gaps left at the concrete structure for installing window frames that are subsequently left without proper filling.
b. Poorly designed, assembled, or deformed window frames and sashes, especially aluminium windows.
c. Rusty steel windows.
d. Omitted water bars and/or weather flashing on window heads and transoms.
e. Defective, deteriorating, or missing gaskets, mastic sealants, and 'O' rings for sashes, louvres, and glass settings.
f. Poorly detailed or inadequately projected window heads, overhangs, or lintels.
g. Omitted water drips and throats on the undersides of lintels.
h. Improperly installed air conditioners.
i. Inward-tilting air conditioning boxes or hoods.
j. Defective sealants around air conditioning units, air ducts, or refrigerant pipelines.

2.2.5 Basements and ground floor

Basements and ground floor slabs are constantly subjected to the pressure of subsoil water or rising dampness. The installation of waterproofing in the form of tanking or a damp-proof membrane is common. The most common causes of seepage in basements and ground floor slabs are:

a. Inadequately thick or defective waterproof tanking and damp-proof membranes due to movements or punctures.
b. Poor quality tanking and damp-proofing materials and workmanship.
c. Deterioration of water stops at construction or movement joints.
d. Backflow due to heavy rainfall or blockage of drains.

2.2.6 Buried or underground drains or pipes

Seepage associated with buried pipes and drains is often difficult to trace. Techniques such as radar or other sonic devices may be utilised during the diagnostic process (see paragraph 4.2 of Section 4.0 - Testing Methods). Water leaking into conduits flows along the piping network from a higher level to a lower level to affect those areas that may be far away from the source. The most common causes of seepage in buried pipes and drains are:

a. Corroded pipes at junctions with floors or walls.
b. Pipes damaged during the construction stage or by construction works in adjacent site(s).
c. Blockage leading to excessive pressure build-up.
d. Intrusion by vermin or plant roots.
e. Differential subsoil movement, which causes pipeline fractures and pipe joint dislocations.
f. Improper installation of junction box(es) or electrical installations in open areas.

2.2.7 Exposed water pipes or drains in pipe ducts

Tracking seepage and repairing internal pipe ducts are difficult. The nuisance caused is tremendous, especially when access to the flat below is necessary. The most common causes of seepage in exposed pipes, drains, and pipe ducts are:

a. Inadequately designed and improperly installed drains, such as the size of pipes being too small, bends being too sharp, pipes being poorly joined and with inadequate falls, etc.
b. The blocking of drains by rubbish or sediment that collects in the system, especially at bends or in traps.
c. An insufficient number or deterioration of brackets against the hammering and breaking of pipes.
d. Mechanical damage to pipes and drains during construction and usage.
e. Inadequate or defective insulation, which leads to the condensation of air-conditioning chilled water or refrigerant pipes.
f. The blocking of open joints such as the hoppers of down pipes by plants or rubbish.
g. Unauthorised additions or alterations and an overloaded drainage system.

2.2.8 Sub-divided flats

Sub-divided flats are common in older buildings. Most have individual toilets that are located far from the flat's original bathroom and toilet. New plumbing and drainage pipes, as well as sanitary fitments, are added and connected to the original system. The most common causes of seepage found in sub-divided flats are:

a. Shower water that is allowed to flood onto the floor directly due to the absence of a proper fall and waterproofing membrane.
b. Poorly assembled sanitary fitments, water supply pipes, and drains.
c. Drainage pipes of inadequate sizes and/or perhaps with improper falls.
d. Inadequate or totally absent falls for converted bathrooms and toilets, along with a lack of a waterproofing membrane for the floors and walls.

Section 3.0 Methodology of Investigation & Diagnosis

3.1 Diagnostic Approach and Investigative Procedures

3.1.1 The professional building surveyor must conduct a preliminary desk study before starting any on-site inspection. This includes the retrieval of building maintenance manuals, approved record plans, photo records, defect and repair histories and their related complaints, and test reports from government departments, if any. The surveyor must conduct a site visit with assistance, if appropriate, as follows:

a. Visually inspect the affected areas to verify the severity of the seepage problem.
b. Interview the complainant to obtain all information related to the seepage (e.g. frequency, duration, symptom, and timing).
c. Use diagnostic equipment (as detailed in Section 4.0 - Testing Methods) to assist in locating and diagnosing the sources of seepage.
d. Visit adjacent flats and/or common areas, when appropriate, and if they are available for you to make further judgements and diagnoses.
e. Find out if there are leaking pipes or fittings.
f. Note any other element (e.g. window, walls, etc.) or factor that could have caused the seepage.

An overview of the diagnostic and repair process is shown in **Figure 3.1.**

3.1.2 The professional building surveyor can adopt the diagnostic procedures elaborated on in the following sections in order to determine the most probable cause(s) of the seepage. All findings, particularly any third party's claims, should be properly recorded.

3.1.3 A **five-stage** investigative and diagnostic approach is recommended **(Figure 3.2)**. A standard investigation kit, including suitable equipment, an inspections checklist, and reporting template, would help the professional building surveyor during the investigative and diagnostic process. The five stages are:

Stage 1 General Appraisal, Desktop Study, and Planning
Stage 2 Detailed on site Survey and Investigation
Stage 3 Analysis of the Survey Findings
Stage 4 Verification and Confirmation by Further Tests
Stage 5 Preparation of a Survey Report

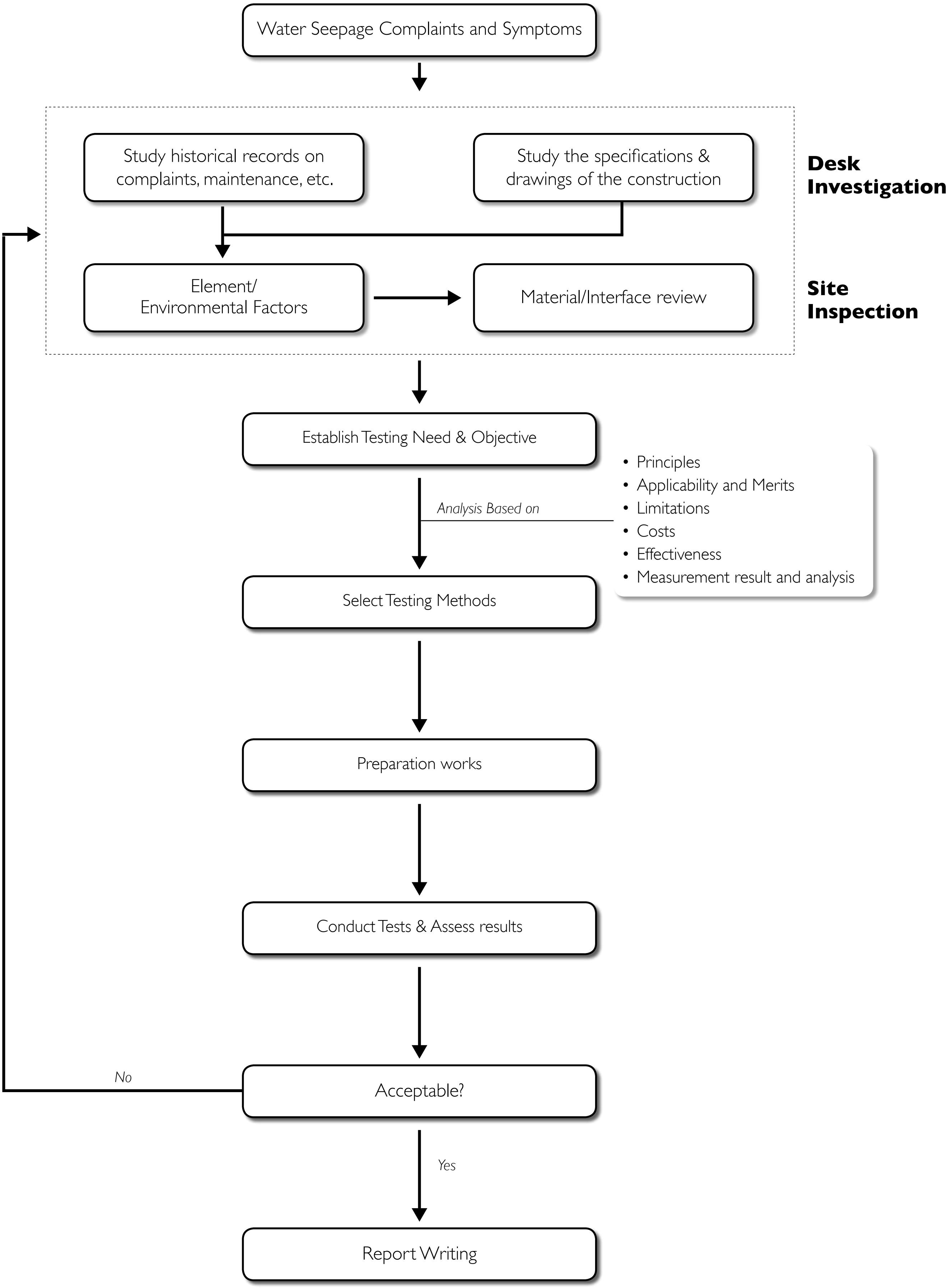

Fig. 3.1 Overview of the diagnosis and reporting process

3.2 Checklist for Diagnosis

The purpose of the following checklist is to help the professional building surveyor gather all relevant information during the course of his/her desktop study, site inspection, and tests. Reference can also be made to Section 5.0 - Reporting on the report format.

<u>Stage 1: General appraisal, desktop study, and planning</u>

3.2.1 A brief discussion of the situation, history, and condition of the water seepage problem with the relevant parties may help the professional building surveyor determine the next stage of work required. The relevant parties include the occupants of the affected premises, the occupants of the upper floor/adjoining premises, the incorporated owners, and the property manager. The findings would help the surveyor prepare the most suitable surveying methodology and equipment in Stage 2.

3.2.2 Carry out the check and detailed planning for the site survey and investigation. The following information will be useful during the process:

a. Age of the building and its construction type and materials
b. Interview with/questioning of the client, management company, etc.
c. Time, period, and pattern of the water seepage observed
d. Association of the weather conditions with the water seepage observed, including a study of weather reports
e. Type of fresh and flushing water supplies, approved and as-built plumbing, drainage, building layout plans, and chilled water piping layout
f. The existence (if any) of subdivided flats or unauthorised building works and their effects
g. Routes and locations of all water-carrying pipes
h. Alterations (if any) to the water pipes, water meters, and drains
i. Renovations, alterations, additions, decorations, and repairs (if any) in the complainant's premises and the adjacent premises, including the common areas.

<u>Stage 2 : Detailed on site survey and investigation</u>

3.2.3 A detailed site inspection is necessary to determine the extent and history of the seepage, the stain pattern, the damage done, etc. Visual inspection is used followed by applying the appropriate tests (if necessary) to collect important data as evidence (see Section 5.0 -Reporting). Inspections should be conducted systematically to both the internal and external parts of the premises with appropriate photographic and other forms of evidence e.g. dimensions.

3.2.4 The professional building surveyor should be equipped with the following commonly used tools and documents:

a. Camera for taking pictures
b. Mirror to inspect the external wall or recessed areas
c. Electric torch for lighting.
d. Tapping rod or hammer for tapping on any suspected defective concrete and/or finishes around the water stain observed
e. Binoculars for viewing the piping and the external wall's condition from a distance
f. Fluorescent dye and UV light
g. Measuring tape and test papers for acids/alkali and urine
h. Approved building plans to ascertain any alteration and unauthorised work
i. Record plans of the plumbing and drainage systems to ascertain the routes of the concealed plumbing and drainage pipes
j. Moisture meter for moisture mapping
k. A checklist of the procedures to avoid omission

Make sure that all equipment and tools have been correctly calibrated.

3.2.5 Record the following information as the basis for further analysis and reporting:

a. Date of inspection(s) or inspection attempt(s).
b. Name, post and qualifications of the professional building surveyor or inspector.
c. Weather conditions
d. Methodology of inspection
   – Visual inspection
   – Moisture mapping
   – Fluorescent dye test
   – Rapid infrared scanning, etc.
e. Areas of inspection
   – Defects as informed by the complainant.
   – All areas at or near the defects, including adjoining rooms, the immediate floor above and external walls.
   – The entire extent of the affected seepage area.
f. Items to be inspected (subject to actual site condition and suspected cause(s) of water seepage)
   – Condensation in those places that may be affected by temperature differences with the adjoining areas
   – Potable water pipes for any continuous water seepage
   – Flow rate of the potable water meters
   – Water heaters for leaks
   – Joints, pipes, and stacks of the drainage pipes for any detachment or damage
   – Pipe ducts via the access panels
   – Drain outlets and sleeves for any gap or damage
   – All plumbing and drainage pipes, if possible
   – All edges and bodies of bathtubs, shower trays, water closets, basins, and sinks for any loosened component or damaged part
   – Windows, air-conditioning holes, and balcony doors for any rain

penetration

  - External walls for any crack, hole, or loosened rendering

g. The timing and duration of the water seepage
  - Detail of the seepage and its duration
h. Existing layout
  - All elements and locations of the possible water seepage sources, such as bathtubs, shower trays, water closets, basins, sinks, and floor drains, should be identified and recorded.
i. Building elements and finishes
  - All building elements and finishes at or near the defect observed must be recorded for reference.
j. Conditions of the defects and findings
  - The status of the water stain (e.g. dry or wet) should be recorded.
  - The corresponding locations of the defects observed in the complainant's premises and the premises where the seepage is suspected to have originated (e.g. dripping water observed from the ceiling of the complainant's premises that may be immediately below the shower tray/ trap of the upper premises)
  - Pattern, direction, smell, colour, levels, branches, etc.
k. Photographic records
  - General view of the premises
  - General views of the suspected sources and causes of the water seepage
  - Close-up photographs of the defects observed, with appropriate scale
l. Analysis
  - An analysis of the water seepage shall be on the basis of a site inspection along with details of the seepage occurrence and duration, extent of the seepage area, government records, and the professional building surveyor's report.
  - Information provided by the complainant (if any), owners, occupants, and property managers must be verified first and considered for reference only.
  - List all possible sources and causes.
  - Rule out impossibilities on the basis of your findings, reasoning, and judgement.
  - If there remains more than one possibility, suggest and/or carry out further tests to verify all possible sources and causes.
  - One simple common test is to note the pattern and timing of the seepage. For example, consider whether the seepage is continuous or periodic or if it is associated with rainy days or after normal bathing, etc.
  - Evaluate the collected evidence objectively to identify the source, cause, and path of the water seepage.
  - Consider to use a scientific 'hypothesis-testing' approach. Basically, the professional building surveyor hypothesizes the most likely source of seepage first. Evidence is collected and analysis conducted to try to 'reject' such a hypothesis. This process is similar to eliminating the possible causes, one by one, with the evidence collected. If the hypothesis cannot be

rejected, then the professional building surveyor has to conclude that this is the most probable cause of the seepage.

m. Conclusion
   - Identify the source, cause, and path of the water seepage.
   - Identify the responsible parties (optional, depending on the engagement of the services).
   - Suggest appropriate repair methods (optional, depending on the engagement of the services).

<u>Stage 3 : Analysis of the survey findings</u>

3.2.6 The survey findings should be analysed to identify the distinctive characteristics of the case and determine the changes that might have contributed to the problem. A process of elimination could then be used to narrow down the likely source(s) of seepage based on the information obtained during Stages 1 and 2.

3.2.7 Whilst visual inspection cannot take an investigation very far, moisture mapping or profiling using a non-destructive technique would provide indicators of moisture paths that are invisible to the naked eye.

3.2.8 If the sources or causes are identified, the surveyor can prepare the survey report, as elaborated on in Stage 5. However, if nothing is clearly established, the surveyor should conduct further tests to verify all possibilities against the suspected items and confirm the judgement in Stage 4.

<u>Stage 4 : Verification and confirmation through further tests</u>

3.2.9 The professional building surveyor may consider carrying out additional tests if it is still not possible to arrive at a conclusion. Tests such as ponding, the spray or dye test, a thermographic scan, and/or other scientific techniques are common for obtaining more evidence to support the diagnosis.

3.2.10 One simple common test is to distinguish between fresh water, soiled water, waste water, and flushing water. The differences in the chemical properties of these types of water are highlighted: fresh water is neutral, soiled water contains urine, waste water is sometimes soapy (alkaline), and flushing water can be acidic (if sea water is used). By applying a pH indicator (such as litmus paper or phenolphthalein indicator) and a urine test paper to sample the leaked water/damp surface, one can eliminate certain causes of the seepage.

3.2.11 If the source of the seepage still cannot be identified, it may be necessary to use more advanced and precise test equipment, including destructive tests, which may require specialist application and interpretation.

<u>Stage 5 : Preparation of the survey report</u>

3.2.12 Survey findings should be summarized in a professional report form together with recommendations for remedial action. The objectives of the investigation and report have to be clarified at the onset of the report.

3.2.13 The methodology and scope of the investigation, details of measurement by the laboratory, or on-site NDTs are usually presented in the form of tables or figures, with an interpretation of the results. Photographic records and annotated floor plans must be used for illustration. The limitations of the investigation, diagnosis, and conclusion must be clearly stated.

3.2.14 The report must also state all assumptions, hypotheses, and attachments with calibration certificates, laboratory reports, etc., if appropriate. Declarations may also have to be made.

3.3 A Practical Flow Chart of the Investigative and Diagnostic Procedures

Figure 3.2 is a summary of the investigative and diagnostic approach for a typical case.

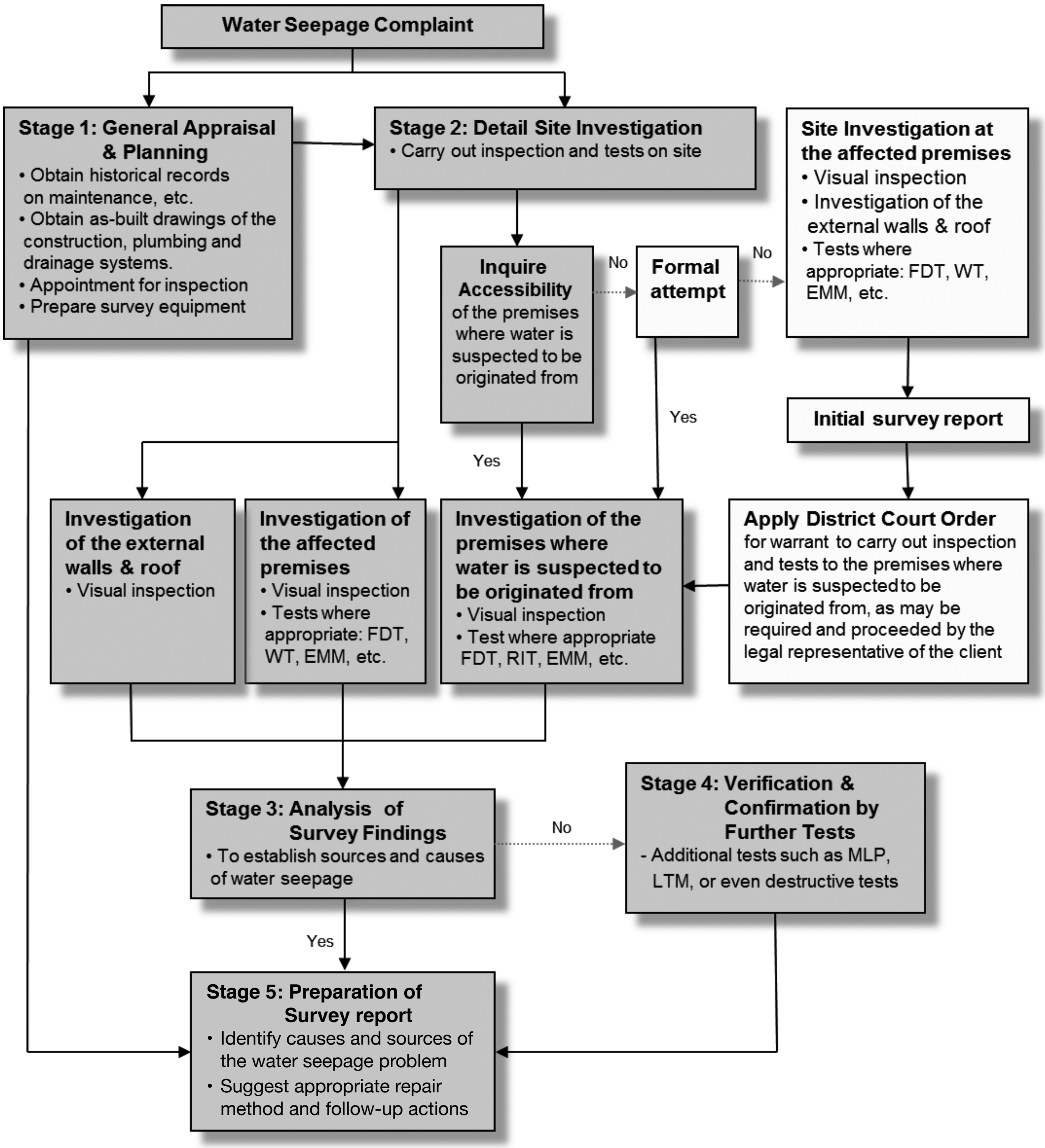

Fig. 3.2 Summary of the Five-Stage Approach to Investigation and Diagnosis

Legend: **EMM**: Electrical Moisture Meter, **FDT**: Fluorescent Dye Test, **LTM**: Leak Tracing Method, **MLD**: Mircowave Leakage Detection, **RIT**: Rapid Infrared Thermographic Scan, **WT**: Water Test

Section 4.0 Testing Methods

4.1 Considerations for Non-Destructive Test Selection

4.1.1 Possible non-destructive technologies

Table 4.1 gives a brief account of the possible technologies that apply to the investigative process. Testing instruments cannot, by themselves, diagnose the cause of dampness. They only provide indications of dampness and present measured data in graphical or table form to assist the professional building surveyor's analyses to determine the cause and source of water seepage. These tests are, therefore, parts of a system for diagnosis, the other parts of which are the knowledge and experiences of building professionals.

Table 4.1 Possible non-destructive technologies or equipment applicable to water seepage investigation

Item	Possible Technology or equipment	Principle
1	Close-Circuit Television (CCTV)	Examines the image or video obtained from within the pipework.
2	Dye or Chemical tracer Test	Examines the seepage water for dye or chemical tracers.
3	Electrical Capacitance	Measures the changes in the electrical impedance of the object. The wetter the material, the greater the response.
4	Electrical Earth Leakage	Traces the measurable currents across the roof surface in thepresence of an applied electric field.
5	Electrical Resistance	Applies voltage across two points and measures the current/electrical resistance.
6	Humidity Sensors	Measures the relative humidity of the air space/ moisturecondition of the building materials.
7	Microwave Leakage Detection	Measures the dielectric constant of the material to evaluate the free moisture content.
8	Nuclear Moisture Meter	Uses a radioactive source to count the hydrogen atoms in a material
9	Nuclear Magnetic Resonance	Uses a nuclear magnetic resonance spectrometer to detect the hydrogen nuclei in a material.
10	Pressure Test	Builds up pressure within a pipework system and observes any pressure drop on pressure meter.
11	Radar	Compares the radar travel time to locate the moist area that exhibits a longer travel time.
12	Rapid Infrared Thermographic Scan	Compares the thermal difference in the seepage area before and after the water spray test
13	Ultrasonic sound sensor	Generates ultrasonic sound to detect air paths, which may also be water paths, through a building element.

Ancillary investigations and tests may be required in conjunction with the above non-destructive technologies. Please refer to these tests listed in Appendix 7.2.

4.1.2 Important factors to consider when choosing a testing method

Close communication between the concerned parties, including clients, government departments, and consultants, and tighter monitoring of the handling procedures and progress are essential. Different causes of seepage in different elements warrant different repair methods. Before remedial works are specified, it is of paramount importance to properly diagnose the root cause(s) of the water seepage. Rectification works must be done to stop the seepage at the source.

Different testing methods can and will produce different results. It is important that all tests be applied in a prudent manner and in accordance with the manufacturer's instructions and specifications. **Tables 4.2 to 4.4** in paragraph 4.3.2 illustrate the applicability of each of the five commonly-used NDTs for various building elements, materials, and fitments. The advantages, potential pitfalls, and limitations of each test must be known to ensure that the most effective procedure is used in each case. Experience has shown that in order to be successful, every choice of test has to include the following criteria:

a. A clear understanding of the potential testing problems
b. Proper supervision and verification of the competence of the operators
c. Adequate reference standards
d. Practical test specifications, method statements, and calibration
e. Detailed inspection records
f. Proper inspection and test timing
g. Safe use of the test equipment;
h. Adequate samples and data sets
i. Establishment of reference benchmarks for comparison purposes

Each method or type of equipment has its strengths and weaknesses. The professional building surveyor must fully understand the testing theories and evaluate the merits and limitations of each option, in respect of individual case, based on:

a. **Ease of use:** including size, expertise, interpretation;
b. **Accuracy:** whether numerical values or just a profile of dampness of the affected area is required;
c. **Time required:** preparation time, duration of test, deferred confirmation until laboratory report is available;
d. **Nuisance / inconvenient to the occupier:** while some tests are non-destructive, there may be cleaning works which follow certain tests;
e. **Potential damage to the property:** certain tests, (e.g. the florescent dye test or an electrical moisture meter) may cause minor damage to the finishes of the properties being tested;

f. **Availability and cost of application:** are the equipment and operator readily available, and what is the cost compared to that for alternative test(s);
g. **Safety to the application:** safety to be ensured for both the professional building surveyor/operator and all the properties concerned;
h. **Appropriateness:** the test must be decided on and applied after a thorough consideration of all known facts;
i. **Forms of data collected:** image captured, video record, or numerical values measured;
j. Location and type of dampness: the location and type of dampness may limit the choice of tests due to space restriction (please refer to Section 2.0); and
k. Method, material and type of construction: these must be determined and clarified during the initial planning stage before any test is proposed (please refer to Section 3.0).

4.2 Application of Non-Destructive Tests

The essential feature of an NDT is that its process produces no harmful effects on the materials, structure, and serviceability of any facility being tested. It is important for professional building surveyors to understand the principles of various NDTs and master the correct way to use scientific equipment and methods to diagnose seepage. Only the five most commonly-used tests are elaborated on below: 1) the Fluorescent Dye Test (FDT), 2) the Rapid Infrared Thermographic Scan (RIT), 3) the Electrical Moisture Meter (EMM), 4) the Leak Tracing Method (LTM), and 5) Microwave Leakage Detection (MLD).

4.2.1 Fluorescent Dye Test (FDT)

Dye-testing is a common tool for confirming the origin of internal water seepage. The Joint Office and FEHD have made use of colour dye tests to trace the source(s) of water seepage. Colour dye, in the form of a liquid solution or tablet, is easily available and a low-cost option for the Joint Office. However, cases of stained sanitary fitments and/or finishes have created resentment and made some owners reluctant to cooperate. Different coloured dyes can be added to different sources at once to confirm the source during an examination, but this sometimes leads to confusion. Samples may also need to be collected and tested in laboratories before a conclusion can be reached. Nowadays, FDTs that make use of colourless solutions have gained in popularity not only with the Joint Office, but in private practice as well.

Photo 1 – Color dyes

Principles

In this test, a dye solution is applied to the suspected source of the problem and the moisture found in the damp area is examined after a suitable time interval for the presence of this dye. Dyes commonly used nowadays are fluorescent (i.e., they glow under UV light), so examination with a UV lamp in dark conditions is needed. We recommend that the test should be used to confirm seepage once the primary suspected source has been identified and that only one dye be used.

Application

The use of chemicals that are flammable or toxic is not recommended. The test should be performed in an area with no open flame or spark. The tested parts should be clean, dry, and free of foreign objects and coatings (e.g. solid contaminants, oil, and grease) that could conceal surface defects or cause false indications. The detailed setup, preparations, and application are elaborated on in Appendix 7.3.

If a fluorescent dye is used, skilled operators of a UV lamp are required to perform the test under the supervision of a professional building surveyor with relevant experience. Adhere strictly to the manufacturer's recommended procedures, including diluting the dye solutions to their required concentrations. A bright glow will pinpoint the precise location of a leak. Corrections may be necessary for different species and materials. When different locations are tested, dyes of different colours shall be used for each location. The sequence of tests should be properly arranged in order to avoid overriding the colours, which may affect the interpretation of the results. Dripping and water stain marks can be seen during a daylight examination with a UV lamp. The result is positive if the fluorescent dye is visible in the alleged leak. The evidence can be recorded qualitatively by taking photographs of the affected area. In certain cases, the dye may not be seen within a short period of time. Sufficient time should be allowed for it to seep through the alleged leak path. It may last for over a day or even a week.

However, the dye test is not always successful. A failure to record its presence in the damp zone cannot be taken as definite evidence against the suspected source. However, a positive test confirmed by the laboratory is firm proof of the source.

Photo 2 – Fluorescent dye test

Photo 3 – Inspection kits

Effectiveness

Advantages

- Proven to find multiple, intermittent, and even small leaks that are undetectable by any other method.
- On site, portable, and reliable
- Economical
- Easy to use with less required knowledge of high technology

Pitfalls during application

- Size and type of the defect, texture of the surface, and penetrative properties will affect the accuracy of the test results.
- False indications from shallow scratches and/or smearing.
- Qualitative indication of the presence of cracks without a quantitative indication of water content.
- Can be dirty and involves chemical and consumable re-agents.
- Manpower-intensive with a lower technology content.
- Not readily comparable to other high-technology, non-destructive testing methods.
- Chance of inadequate flushing water or incomplete dye powder dissolution used.
- Absorption or filtration of dye solutions along the cracks can result in the dye being unable to reach the damp zone.
- Insufficient time allowed between the addition of the dye and its sampling in the damp zone.
- Certain dyes may become unstable in alkaline conditions if the test is carried out in contact with cementitious materials.
- Unsightly stains may remain if excessively strong solutions are employed, sometimes in unexpected locations.

Limitations

- Only applies to those paths affected by water seepage through gravity or capillary action.
- Good for slabs with holes, cracks, or small interconnecting pores only.
- Weak in showing the colouring effect without surface cracks, such as embedded waterproofing membrane defects.
- Surface decontamination and cleaning required.
- Sensitive to micro-cracks >1 mm width.

4.2.2 Rapid Infrared Thermographic Scan (RIT)

The thermographic inspection measures the heat that radiates from a surface. From the variations in the radiation detected, the presence of moisture may be inferred. It is a non-contact technique and particularly useful for showing and recording moisture contours on surfaces and their subsequent changes over a period of time.

Infrared thermograph (thermoscan) cameras equipped with recording devices that are sensitive to infrared radiation should be used. The equipment should be calibrated onsite before performing the infrared scan. Any moisture present on a surface can be qualitatively confirmed. The temperature difference should be clearly demonstrated by variations in the colour of the digital images of the parts of the structure examined. The process is essentially comparative and should not be considered capable of giving absolute values of moisture. It is a method that can detect variations in moisture content from a distance.

Photo 4 – Infrared Camera

Photo 5 – Infrared Camera (Another model)

Principles

Thermographic inspection measures the heat being radiated by a surface. When applied to seepage detection and diagnosis, as the damp areas are cooler which radiate less heat than adjacent areas, the thermo sensor will be able to differentiate these areas in the form of variations in colours of the image captured.

Application

Thermographic inspection can be applied to concrete, brickwork, blockwork, masonry, timber, and paint finishes. The test is inappropriate for impervious or reflective materials (e.g. metals, tile finishes, and thermoplastics). A handy thermoscan camera with a relatively lower resolution (0.1oC, thermo image of 320x240 pixels) is useful for a first scan, which provides an overall picture of the locations and areas likely to be affected by seepage. A more sophisticated, bulkier, and more expensive thermoscan camera with a higher resolution (0.03oC, thermo image of 640x480 pixels) is useful for detailed measurements, mapping, and monitoring.

A direct line of sight to the tested object and an appropriate viewing distance and angle are necessary. A skilled operator is required to perform and operate the camera to ensure that the optimal images taken strictly adhere to the manufacturer's recommended procedures. Interpretation of the images also requires experienced personnel.

The scanning inspection and results would be most discernible during the cooling-down phase of the building element. There may be distortion due to thermal noise from the air between the surface and the camera. Data may be collected in continuous video format or as a series of photographs. Since the thermal differences sought are often very small, data from digital stills may be processed by specialised software to provide further off-site analysis along with a graphics package to display or print the results. The specification and calibration record of the equipment shall be submitted to the project officer for approval and inspection.

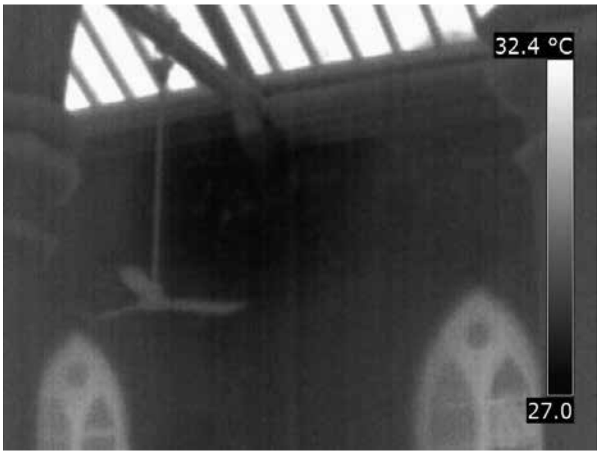

Photo 6 – Infrared Thermography

Effectiveness

Advantages

- Temperature data are obtained in real time.
- An on-site investigative method that is good for locating defects with poor accessibility
- Instant response enables the rapid scanning of large areas.
- Visual/Graphical reference is available.
- Light and portable equipment

Potential Pitfalls during application

- Thermal image difference due to defects (e.g. spalling and rust stains) or features other than moisture (e.g. hot water pipes or electrical conduits) may lead to incorrect diagnoses. Professional knowledge of building construction is required to avoid misinterpreting the results.
- Solar reflections, air-conditioners, heaters, cold and hot objects, etc., which may affect the validity of the test, must be noted.
- Reflections may cause false results. When a suspected seepage area is detected, move the camera around the location and view from a different angle. If the "hotspot" still shows up, it is likely to be an area of seepage and not a reflection.
- Device is sensitive to the ambient thermal environment and wind.

Limitations of the method

- Only responds to surface emissions.
- Only indicates the presence of moisture, but is unable to tell the source(s).
- Limited use in re-entrants, lightwells, and horizontal areas.
- Not suitable for reflective surfaces such as metals or standing water.
- May require night time work for optimum imaging conditions.

- Incapable of giving absolute measurements of moisture content; can only give qualitative data.
- Images must be interpreted by experienced professionals.
- Surveys often need to be planned around weather, time of the day, and cyclic thermal events.
- Need extra care to eliminate physical causes other than moisture before a valid conclusion is reached.

4.2.3 Electrical Moisture Meter (EMM)

An electrical moisture meter (EMM) is a traditional conductive type of meter that measures moisture levels in affected areas. An EMM is one of the most frequently used gadgets for tracing the source(s) of water seepage. There are two types of EMM; one is an electrical resistance (conductance) meter (ERM), or protimeter; the other is an electrical capacitance (dielectric) meter (ECM). The former usually comes with pins that puncture the test surface and measure the resistance between the two pins to a general depth of 3mm. The latter is usually pinless and measures the dielectric constant of the test material, which changes with the moisture content to a depth of up to 20mm. Since an EMM is portable and individual measurements can be made in just a few seconds, it is quick and straightforward to use as a first scanning tool in the investigative process.

Photo 7 – Moisture Meter

Principles

An ERM tests the electrical conductivity of an object between the electrode probes. A certain amount of voltage is applied across two points on the surface of the object. The current flow is measured which varies inversely with the electrical resistance. For a given material, the relationship between resistance and moisture content can be accurately established, thereby allowing its moisture content to be determined. This is a proven technique for estimating the moisture content in timber and a useful tool for detecting dampness in masonry and concrete with caution. Generally, the wetter an object, the lower is its resistance and the higher is its conductivity.

An ECM creates a harmless electrical field in the material directly beneath the transmitter/receiver electrodes contained in or linked to the meter and measures the response. The wetter the material, the greater is the impedance. Conductivity plates are placed on the surface of the material. The readings obtained measure the fringe capacitance of the sensor, which is influenced by the moisture content. Hence, the surface being examined is not marked by needle probes.

Application

A moisture meter is handy and easy to operate, but knowledge of the equipment/ reading and construction details is essential. Experience in interpreting the readings and recognising erroneous ones are essential for a correct diagnosis.

A systematic approach should be adopted for measurement. Testing is carried out at appropriate intervals or grids. A probe may have to be inserted into the test material. All measurements must be recorded on a standardised proforma. All suspected or visually damp/problematic surfaces should be measured with moisture meters to confirm the presence of abnormal dampness.

An EMM is usually sensitive to plaster, brick/block, timber, roof, and floor felts and insulation materials. It is useful for cement and gypsum-based screeds, concrete, ceramic tiles, glass fiber, glass-reinforced plastic, paints, varnishes, etc. Different scales may apply to different test materials. Corrections are necessary for different species and materials.

Measurements should be referenced to other surfaces within the flats. Ambient temperatures need to be recorded to make the calibration of the readings easier. The surfaces of the equipment and test objects must be kept dry and free of contaminants and salts.

Any moisture content obtained can reflect moisture gradient and contour. Temperature compensations and adjustments should be made with reference to the calibrated temperature (usually 20°C). Users should refer to the manufacturers' instructions for operational details.

Surface coating thickness and materials can influence the meter readings. It is a good practice to take several readings and average them out. The accuracy of the results depends on the different contact degrees between the probe and test material, temperature, density, pH value, pressure, etc.

Effectiveness

Advantages

- Hand held, portable, quick reading and easy to operate
- Mainly non-destructive except that pin holes may be left on the testing object. Non-pin type dielectric moisture meters make use of surface electrodes that do not puncture the material surface.
- Capable of plotting moisture gradient and contour
- Mapping of the defective area's moisture content is possible.

Potential Pitfalls during application

- Some EMMs are calibrated for wood testing. Selection of the correct test mode of is required.
- Test that involve conductive materials will give invalid results
- Readings may be affected by the density of materials, aggregate size, smoothness of the measuring surface, surrounding temperatures, surface contaminants, hand pressure on electrodes, and contact area between the electrode and the testing material.

Limitations of method

- Pin holes are left on the surface of the test object (electrical resistance meter)
- For materials other than timber, scaling and calibration may be required
- Not suitable for measuring hard surfaces such as marble or fair-faced concrete.
- Surface should be dry and free of contaminants and/or salts
- Generally measures dampness near the surface. Certain models may be able to measure dampness in concrete to a depth of about 20mm, hence eliminating the possible influence of surface condensation.
- Usage prohibited in electrical conductive materials

4.2.4 Leak Tracing Method (LTM)

Principles

This method combines the principles of the "Electrical Capacitance and Resistance Meter" and the "Electrical Earth Leakage Technique," in which water passing through leaks on floors or other waterproofing layers can carry an electric current and form a path.

The instrument measures the electrical conductivity of the material between the two electrodes. The readings depend on the resistance of the material to electrical conduction. For building materials (e.g. concrete and cement mor tar screeding), resistance decreases as moisture content increases. Normally, dry plaster, concrete, and brick contain so little moisture that it cannot be detected by any ERM. Moisture has good conductivity and a moisture meter will detect the water paths between two electrodes. If the meter indicates the presence of an electric current between two parts of a building, that may be the path of the leak and should allow one to trace the origin of the moisture.

Like the moisture mapping method, data can be collected to show the ranges of the damp area. The meter readings can show the pattern of dampness and, hence, the path of the leak may be found and recorded.

Photo 8 – Leak Tracing Equipment

Application

The appropriate moisture meter is used first to identify the initial location of seepage. Use the moisture meter to measure several readings at a certain distance surrounding the water patch in order to plot a diagram and contour of the pattern of water seepage. Then attach an electrode of the electrical resistance meter to the part of the ceiling (in the lower flat) that is wet. Another operator must hold the other electrode in the upper flat/adjacent unit/external wall. The operator will search, check, and attach the electrode to various parts of the wall/floor/exposed pipe in the suspected area of the leak in the upper flat. If the meter indicates "red" or "wet," then the material is wet between the two points of contact and this is the path of the leak.

Effectiveness

Advantages

- Highly applicable, as long as the water path exists and is continuous;
- Can trace the path and source of water seepage directly;
- Save cost, time and labour;
- Immediate reading in seconds; no waiting time or the necessity to leave instrument on site;
- Non-destructive; no need to take samples or to damage the material or element being tested in any way.

Potential Pitfalls during application

- This test is likely to be affected by earthing and metal conductors (e.g. exposed conduits and metal bars). However, some insulation may exist to neutralise this effect, such as dry concrete that encapsulates the reinforcement, copper pipes that are normally protected by plastic coating, and flush water pipes that are normally made of UPVC.

Limitations of method

- This test can only be carried out near windows/external walls/openings so that one of the electrodes can be connected to a cable to reach the upper premises and/or area of the suspected water leak.
- The distance between the water source and the wet patch should not be far, as the effective length of the cable (within 10m) limits the distance of the detection.

4.2.5 Mircowave Leakage Detection (MLD)

Principles

A microwave moisture meter is used to evaluate "free" moisture content by measuring the dielectric constant of the material being tested. This meter gives instant measurements of moisture content to a certain depth of a material. However, this technique is still relatively new, so time and costs may need to be expended to allow users to familiarise themselves with it. The initial cost of this instrument is much higher than that of most other equipment. But the meter is light, small, portable, and very easy to use. In addition, that no direct electrical contact with the material being tested is necessary is another advantage of using the microwave moisture meter.

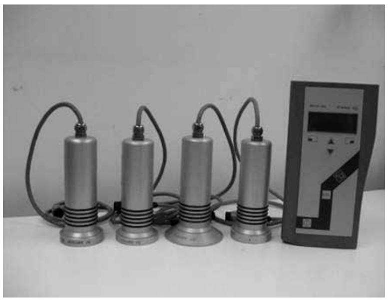

Photo 9 – Microwave Device

Applications

The microwave leakage detection method applies to most porous materials, such as concrete, sand, gravel, and pipes. It cannot be used on certain materials like ceramics and metal. Materials such as reinforced concrete have to be tested and the results interpreted with caution, as the steel reinforcements may affect their accuracy. The instrument surface should be kept dry and measurements made at appropriate intervals and plans.

Skilled operators are required to perform and operate this instrument to ensure that optimal readings are taken with strict adherence to the manufacturer's recommended procedures. Interpretation of the data in the form of the wet weight moisture so taken also requires experienced personnel. There is microwave equipment with various sensitivities. Probes may be able to detect free moisture for up to 110mm from the surface.

Results should be checked for consistency. No special calibration is required from the user. The presence of surface dampness can result in high readings. Metal content in the material (e.g. embedded metal pipes and conduits) may affect the accuracy of the results. The instrument is not sensitive to density variations in the material.

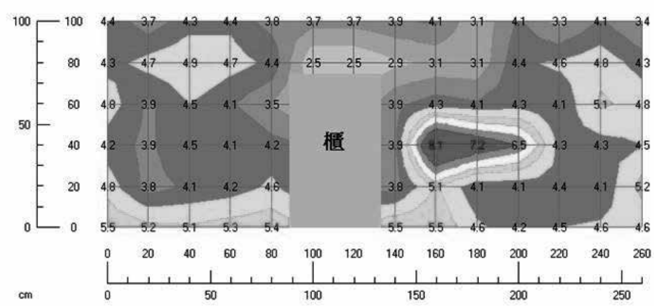

Photo 10 – Microwave Diagram

Effectiveness

Advantages

- Is non-destructive, in-situ, and delivers instant measurements with quantitative readings.
- Is independent of temperature, pressure, particle size, etc.
- Is independent of the material's density and less susceptible to surface impurities such as salt.
- High measuring sensitivity
- Allows for heterogeneous samples and samples that have encapsulated moisture
- Reliable and relatively precise

Potential Pitfalls during application

- Errors may occur with certain ceramics
- The presence of metals in the tested material (e.g. concrete reinforcement) can give false readings
- Water near the surface of the test object will heavily affect the readings.
- Can only be used to measure damp areas along a wall or on a floor.

Limitations of method

- Attention should be paid to the interpretation of the readings when applied to elements that contain metal or ceramics.
- Surface of the test object should be kept dry and flat.
- Test surface must be open to the application of sensors.

4.3 Use of Appropriate Technologies

4.3.1 Care on choice and interpretation of the tests

There is no universal water seepage testing method or equipment applicable to all situations. Only by thoroughly understanding the basic principles of each detection and diagnostic technique can one choose the appropriate test. By carefully considering and applying the appropriate detection and testing technique and adhering to the five-stage investigation and diagnostic approach (see Section 3.0), one should be able to identify the real cause(s) and source(s) of a leak.

Obviously, the application of different tests or techniques can and will produce different results. However, the choice of method, procedure, and interpretation of the results require the skill, experience, and judgment of specially trained professionals with ample knowledge of building construction, building services, and local construction practices. This is why this professional guide was published. professionals, with ample background knowledge of building construction, building services, and local construction practice. This is why this professional guide is published.

4.3.2 Which method to use?

Certainly the incorrect use of a technique can lead to a wasted effort, confusion over the possible causes of a leak, and even the unfair dismissal of the technique. Tests must be intelligently applied. To be effective, their advantages and limitations must be known beforehand to ensure that the most effective procedure is used in each case. For example, an EMM and FDT are common procedures, but their limitations are not fully acknowledged. On the other hand the FDT, RIT, and LTM are considered affordable in terms of operational and maintenance costs.

Linking Testing Methods by Element, Materials and Fitments

Table 4.2 to **4.3** summarise the applicability of the different testing methods to various situations. Please note that the applicability scores of each method vis-à-vis the respective elements are general assessments based on typical situations. The professional building surveyor's judgment, together with the manufacturer's advice on the capabilities and limitations of each method and instrument, must be considered before you decide on a particular method.

Table 4.2 Applicability of different testing methods

Item	Element, materials and fitments	Testing Methods					
		FDT	RIT	ERM	ECM	LTM	MLD
A	Exterior						
1.	Roof/ podium						
a.	Membrane without concrete layer	3	2	1	3	2	3
b.	Membrane with concrete layer	3	2	1	3	2	3
c.	Floor finishes – canton tile/ light weight concrete tile/ ceramic tile/ mosaic tile	3	2	1	3	2	3
2	Terrace/ balcony/ verandah						
a.	Floor finishes – ceramic tile/ mosaic tile/ marble tile/ granite tile	2	2	1	3	2	3
3	External wall						
a.	Mosaic tiles/ ceramic tiles/ paints	1	2	1	2	2	1
b.	Aluminum Cladding	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
c.	Planters	3	2	1	2	2	2
d.	Projections – A/C support frame, drying rack/ canopy/ cage/ flower rack	1	2	1	1	1	1
B	Interior						
4	Ceiling						
a.	Concrete slab	N.A.	2	3	3	3	3
b.	Plaster	N.A.	2	3	3	3	3
c.	Ceiling finishes – paint/ wall paper/ ceramic tile etc	N.A.	2	3	3	3	3
5	False ceiling						
a.	Acoustic panel	N.A.	3	2	2	2	2
b.	Gypsum board	N.A.	3	2	2	2	2
6	Wall						
a.	Concrete substrate	N.A.	2	2	2	2	2
b.	Brick substrate	N.A.	2	2	2	2	2
c.	Plaster	N.A.	2	2	2	2	2
d.	Wall finishes – paint/ wall paper/ ceramic tile/ marble tile/ granite tile etc.	N.A.	2	2	2	2	2
7	Wall opening						
a.	Window	N.A.	2	3	3	3	3
b.	Door	N.A.	1	3	3	3	3
c.	A/C hood/ exhaust fan	N.A.	2	3	3	3	3
8	Floor						
a.	Concrete substrate	3	2	1	3	1	3
b.	Floor finishes: ceramic tile/ mosaic tile/ timber parquet/ carpet/ marble tile/ granite tile	3	2	3	2	2	1
9	Sanitary fitment						
a.	Bathtub	3	2	1	1	1	1
b.	Shower tray	3	2	1	1	1	1
c.	Basin/ sink	3	2	1	1	1	1
d.	Outlet of waste water drainpipe	3	2	1	1	1	1

Legend:

FDT: Fluorescent Dye Test **RIT:** Rapid Infra-red Thermographic Scan **ERM:** Electrical Resistance Meter **ECM:** Electrical Capacitance Meter **LTM:** Leak Tracing Method **MLD:** Microwave Leakage Detection	**Score 3 – Highly applicable** **Score 2 – Sometimes applicable** **Score 1 – Rarely applicable** **N.A. – Not Applicable**

Table 4.3 Comparison of the applicability of water seepage testing methods

Testing Method	Application (Element)						Material							
	roof	wall	floor	pipes: embedded	pipes: exposed	curtain walls, windows or door	Concrete	Masonry	Brick / Block	Cement-based	Glass	Plastic	Timber	Metal
Fluorescent Dye Test (FDT)	√		√		√		√	√	√	√	√	√		√
Rapid Infrared Thermographic Scan (RIT)	√	√	√	√			√	√	√	√	x	√	√	
Electrical Resistance Meter (ERM)	√	√	√	√			√	√	√	√	x	x	√	
Electrical Capacitance Meter (ECM)	√	√	√				√	√	√	√	x	√	√	
Leak Tracing Method (LTM)	√	√	√		√		√	√	√	√	x	√	√	
Microwave Leakage Detection (MLD)	√	√	√				√	√	√	√	x	√	√	

√ Applicable
X Not applicable

Table 4.4 Evaluations of Water Seepage Testing Methods

Testing Methods	Applicability	Reliability	Ease of Operation	Cost Effectiveness	Responsive-ness	Damage Caused	Standards Available
Fluorescent Dye Test (FDT)	3	2	3	2	1	N/D	Note 1
Rapid Infrared Thermographic Scan (RIT)	2	2	3	2	3	Nil	Note 2
Electrical Resistance Meter (ERM)	3	3	3	3	3	N/D	Note 3
Electrical Capacitance Meter (ECM)	3	3	3	3	3	Nil	Note 4
Leak Tracing Method (LTM)	2	2	2	2	3	Nil	Nil
Microwave Leakage Detection (MLD)	2	3	2	2	2	Nil	Nil

Evaluation score for each aspect:

Score 3 Good
Score 2 Average
Score 1 Not appropriate
N/D Sometimes damage may be caused

Note 1: Fluorescent Dye Test (FDT)

1. ASTM E1417/1417M, 2012 - Standard Practice for Liquid Penetrant Testing,
2. ASTM E1418, 2010 - Standard Practice for Visible Penetrant Testing Using the Water-Washable Process,
3. ASTM E1208, 2010 - Standard Practice for Fluorescent Liquid Penetrant Testing Using the Lipophilic Post-Emulsification Process,
4. ASTM E1209, 2010 - Standard Practice for Fluorescent Liquid Penetrant Testing Using the Water-Washable Process,
5. ASTM E1210, 2010 - Standard Practice for Fluorescent Liquid Penetrant Testing Using the Hydrophilic Post-Emulsification Process,
6. ASTM E1219, 2010 - Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process,
7. ASTM E1220, 2010 - Standard Practice for Visible Penetrant Testing Using Solvent-Removable Process,
8. ASTM D5957-98, 2005 - Standard Guide for Flood Testing Horizontal Waterproofing Installations.

Note 2: Rapid Infrared Thermographic Scan (RIT)

1. Hong Kong Concrete Institute: TM1: 2009 - Detection of Building Surface Defect by Infrared Thermography,
2. ASTM D4788, R2007 - Standard Test Method for measuring delaminations in concrete bridge decks using Infrared Thermography,
3. ASTM C1060 Rev A, 2011 - Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of frame buildings,
4. BS EN 13187, 1999 - Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method,
5. ASTM E1655, 2005 - Standard Practices for Infrared Multivariate Quantitative Analysis (For NIR spectral region through MIR spectral region)

Note 3: Electrical Resistance Meter (ERM)

1. ASTM D7438, 2008 - Standard Practice for Field Calibration and Application of Hand-Held Moisture Meters (For wood or timber),
2. BS EN 13183 Part 2, R2007 - Moisture content of a piece of sawn timber. Estimation by electrical resistance (For wood or timber),
3. ASTM D4444, 2008 - Standard Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters

Note 4: Electrical Capacitance Meter (ECM)

1. ASTM F2659, 2010 - Standard Guide for Preliminary Evaluation of Comparative Moisture Condition of Concrete, Gypsum Cement and Other Floor Slabs and Screeds Using a Non-Destructive Electronic Moisture Meter,
2. ASTM D7438, 2008 - Standard Practice for Field Calibration and Application of Hand-Held Moisture Meters (For wood or timber),
3. BS EN 13183 Part 3, 2005 - Moisture content of a piece of sawn timber. Estimation by capacitance (For wood or timber),
4. ASTM D4444, 2008 - Standard Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters

Use of destructive tests

Although less frequently used in water seepage investigation, destructive tests may be used to clarify certain issues or as a means to confirm certain hypotheses. For example, concrete samples may have to be obtained to verify the cement content, while water samples and pieces of damp plaster may have to be taken to the laboratory to establish the nature of the dampness. The wall area affected may have to be opened up to confirm the presence/absence of a waterproof membrane, etc. However, in such circumstances, the defects might have been caused by or are parts of the inherent construction faults or deficiencies. Sometimes these 'tests' may be applied as part of the corrective actions (repairs) and could be more cost-effective than continuing with the investigation.

4.3.3 Have you found the real source(s) of seepage?

Very often the professional building surveyor may not have eliminated all possible causes of seepage before making a conclusion. For example, a symptom found in a particular element may have several sources of dampness. It is, therefore, important for the professional building surveyor to determine all possible sources of seepage so that a plan for fixing the defect can be specified.

The case for using the FDT to diagnose the real source of dampness is that if the dye appears in the defective area within a certain period of time, the establishment of the cause-and-effect link would be very strong. The same goes for applying the LTM to determine the real source of seepage. Comparatively, the RIT, MLD, and EMM methods cannot establish this link. However, the last three methods are suitable for scanning and/ or mapping of the defective area and can help trace the likely source of seepage.

4.3.4 Seepage from external walls

Seepage from external walls is often associated with rain. Water tests are, therefore, often prescribed to diagnose the source of this dampness. However, the path of a water leak may be very long to the extent that the water spray from the test may not reach the real source of seepage, such as a crack along the external wall or a defective sealant. In that case, visual inspections may help. Whenever a building undergoes a major renovation, it is always good to specify a thorough visual inspection with water test as the scope of works. Of course, techniques such as tapping (for defective external finishes) may also be included.

Experience has shown that the lack of proper treatment of bolt eyes for formworks during construction is a very common defect that induces the seepage of water from external walls. During a site inspection, the professional building surveyor should pay particular attention to these voids to ensure that they have been properly filled. Techniques such as tapping or radar scanning may be able to help confirm the diagnosis.

4.3.5 Difference between scanning and mapping

Scanning is essentially a technique that can be applied quickly and conveniently to defective areas that restrict access from a distance. An RIT is a common technique that conducts a quick and inexpensive 'scan' or picture of an affected area. The picture obtained shows a rough contour of the variations in the moisture content of the affected area, but it is not as fine or detailed as, say, MLD.

Comparatively, mapping means plotting the contours of the moisture contents of the affected areas in a two-dimensional plan in detail. The contours and values of the moisture contents are precise numerical values that are more 'accurate' than scanning and can be monitored, if needed. MLD is a common method applied to produce a 'map' or profile of the moisture content in a defective area.

4.3.6 Reminder

The following should be borne in mind by all professional building surveyors:

- Always consider using diagnostic equipment and instruments to collect objective data and evidence for identifying and confirming the source(s) of water seepage.
- Each case is unique or has some unique features.
- NDTs are often qualitative and may require correlation with destructive tests.
- NDTs cannot work miracles. Skill, experience, and interpretation are needed to select the best testing method and establish the best procedure for a given case.
- Only by accumulating experience and experimenting does one gain confidence in all methods and techniques.
- There is no universal NDT, as each new problem requires a surveyor to determine the most suitable testing method to resolve it.
- Each test has its advantages, potential pitfalls, and limitations.
- In order to perform an effective diagnosis, the professional building surveyor should make use of the latest technology. It is, therefore, imperative that all professional building surveyors keep abreast of the latest technological developments in diagnostic procedures and equipment.

Section 5.0 Reporting

5.1 Scope of reporting

5.1.1 The report must be based on evidence collected by desk study, inspection and the result of appropriate and objective tests, if any. Reference is made to Section 3.0 on the list of actions carried out and recorded during the investigation and diagnosis process.

5.1.2 The following is an example of common headings in a typical water seepage survey report. This list together with elements in **Table 5.1** can be developed into a report template suitable for use in reporting cases of investigation of water seepage under various circumstances and for different purposes, e.g. for record, claims, or litigation.

a. Executive Summary
b. General description of the building and flats inspected
c. The dates of inspection and the number of attempts
d. Names, posts, and qualifications of the professional building surveyor(s)
e. Weather conditions
f. Methodology and equipment used in the inspections
g. Summary of the inspections, including findings
h. Information provided by the relevant parties
i. Type, extent, finish, and seriousness of each defect and finding on site
j. Summary of the tests, including the types conducted, with findings. Details of each test conducted should be appended.
k. Analysis of the cause(s) and source(s) with conclusion
l. Limitations of the investigation
m. Recommendations and remedial actions
n. Illustrations including location plans, the latest floor plans of the subject premises,
o. drainage plans, the patterns of dampness detected, photo-marked plans to show the defects observed, and photographs
p. Inspection forms bearing the signature of the professional building surveyor who
q. carried out the inspection in person may be appended.

5.2 Essential Elements

5.2.1 Detailed descriptions under each heading or focus of the report are in **Table 5.1.**

Table 5.1 Essential elements of a survey report for water seepage

Essential element	Requirement
Title page	• Show the address of the premises investigated • If the report is instructed by a solicitor for legal proceeding, include the case reference and names of the plaintiff(s) and defendant(s). • The report has to be dated and/or include a reference number on the title page for clarity.
Contents	• Give a title for each section/chapter of the report. • Give sub-titles of sections under the main chapter. • Include page numbers where appropriate.
Executive Summary	• If the report is long or the issues investigated are complicated, include an executive summary before the introductory section.
Introduction	• State the terms of reference or purposes of the report and/or instructions given by the client or solicitor. • In case of joint expert report, state and emphasize you have been jointly appointed. • In case of individual independent expert, state who you represent, e.g. plaintiff or defendant. • Confirm that you are qualified to carry out investigation and give comments on areas of your expertise. Include a CV in the appendix. • Provide details of parties involved in the course of preparing the report, such as names of laboratory or site supervisor of tests on site, staff involved in the team of investigation, etc. • Provide background of the case and problem. • State the latest position at the time of preparing the report, e.g. complaints to government departments made. • Date and time of inspection /test • Weather conditions, often with exact temperature and relative humidity as reported by the Hong Kong Observatory. • Depending on the investigation strategy, weather conditions before the inspection may have to be reported.
Description of the unit	• Describe the subject premises or the elements to be investigated, e.g. roof, east-facing wall, etc. • Form and material of construction, finishes, etc. • Age of the premises/building. • Describe the problem in detail, including the extent, history of actions, repair or other works carried out previously.
Information obtained from instructing party	• List out information provided by the client or solicitor. • Information without a proper source should not be used. • Court order should be observed in order to ensure the report meets the order requirements • List out documents/drawings inspected and referred to and individual source, e.g. statement of claims from client, copies of approved plans obtained from the Buildings Department, testimonial from related parties, expert report(s) from the other parties etc. • Better arrange the references list in chronological order.

Accessibility	• Accessibility of the premises or the concerned portion must be clearly stated. • It is often that the suspected origin of water seepage (or the defendant's premises) is not available for inspection or testing. This should be clearly stated. • In case of inspection at high ceiling level or external walls, erection of access platform may be required. • Consider using appropriate non-destructive tests which measurements could be obtained at a distance. This may be the only option if inspection of the concerned portion presents a risk to the professional building surveyor, e.g. a sloping roof, hanging canopy, etc. • State if there has been opening up to facilitate detail inspection.
Methodology	• The methodology of the investigation must be clearly stated. • Desk survey and study of relevant legislations, practice notes, documents, drawings, specifications, correspondence, etc. • Basis of evaluation e.g. standards or practices • Visual inspection to form a holistic view of the scale and scope of the issue. • Appropriate scientific and/or non-destructive tests procedures carried out by you or accredited laboratory, with the name and type of laboratory commissioned. Attach laboratory report(s) where appropriate. • Detailed method statement on the operation and tests undertaken, the brand name, and model/specifications of the test equipment used. • Double check the methodology or information stated in other specialist reports is accurate and correct) • Samples may be obtained for laboratory tests, e.g. roofing materials, water sample, etc. • Record the time, date, environment, and ambient temperature when the test is carried out. • Verbal evidence obtained through face-to-face interview. • State any assumptions. • Method of analysis such as by deduction or elimination, use of statistical procedures, etc.
Observation, survey, diagnosis, findings, and comments	• Elaborate the findings from desk study. This should form the basis for recommended actions that follow. • Describe clearly the observations e.g. location, path, pattern, appearance, color, smell, frequency of dripping, etc. and highlight major issues obtained during the on site survey in detail. • Describe the test results e.g. measurement of moisture contents, moisture mapping after application of microwave leakage detection, etc. • Interpret the result or process the data obtained according to the methodology in a professional manner. • Discuss the implications of the results in relation to the issues to be investigated. • Comment on and diagnosis of the results which deduce the conclusion(s).

Limitations	• State the limitations of the investigation and their implications on the results, e.g. restricted access, tests not carried out, non-availability of witness, etc.
Conclusion	• Summarize the evidence, results and your comments and diagnosis in the form of conclusion(s). • Conclusion must be concise. • Include recommendation if there is a course of follow up actions e.g. further testing.
Caveats	• These are standard clauses which aim to safeguard the interests of the client (confidentiality and exclusivity) and limit the liability of the professional building surveyor in preparation of the report. • The report must be used for specific purpose as stated and only be read and referred to by other professional advisers assisting the client. • The professional building surveyor shall accept no liability if the information supplied by other parties was proved to be inaccurate.
Declarations and Statement of Truth	• If the report is prepared as an expert report to assist the court in trials, a statement of declaration shall be made by the professional building surveyor who sign the report, that the professional building surveyor: ✣ has read the code of conduct set out in Appendix D of the Rules of High Court; ✣ agrees to be bound by it; ✣ understands his/her duty to the Court; and ✣ has complied with and will continue to comply with that duty. • A statement of truth shall also be made, such as *'I believe that the facts stated in this expert report are true and the opinion expressed in it is honestly held.'*
Signature	• The end of the report should bear the full name of the professional building surveyor who carried out the investigation and diagnosis, with qualifications. • The report must be signed in personal capacity and not title of a post in a company.
Curriculum Vitae	• A brief bibliography followed by detail description of working experience and specialism. • Highlight working experience and/or academic achievements relevant to the issues to be investigated.
Records of scientific and/or non-destructive tests	• Present results of the tests in the form of scientific report. • Attach laboratory report(s) where appropriate. • Attach relevant calibration certificates for instruments, where appropriate.

Photographs	• All photographs must be referred to in the main body of the report. • Either insert the photographs in the main body of the report following the relevant reference paragraphs, or put all photographs and illustrations in the appendices with clear references in the main body of the report. • Photographs should be dated, annotated and/or highlighted with pointers where appropriate. • Photographs should be of good quality in terms of exposure, with sharp focus, and adequate level of detail to show the subject matter. • Photographs should be true without any adjustment. • Recommended size is 3 photos per one A4 size paper.
Figures and illustrations	• Figures, graphs, tables, diagrams, etc. are good means of illustration of points put forward in the main body of the report. • It is common to present results of tests and measurements in the form of tables and graphs. • Concepts, methodology, and procedures could be illustrated by flow charts. • Specially drawn diagrams and schematics may help in highlighting points and arguments put forward in the report, e.g. hidden pipe runs, sections, etc.
Location plans, layout plans	• Layout plans are useful in illustrating the locations and pattern of the seepage. • Plans have to be in an appropriate scale to show the seepage locations. Specify 'not to scale' if the plan is just an illustration of the relative positions of certain features and the defects. • Use a key plan or part plan to show the detail if the plan is an excerpt from a large sized plan. • Proper coloring could be used for better illustration • Boundary of inspected areas shall be shown on plan

5.3 Common Findings and Observations

5.3.1 The observations should be discussed in narrative form. Facts must be stated, conditions described, and comments made. Measurements and test results can be presented in the form of tables with values. Graphs and diagrams may be used to illustrate trends. All observations and test results must be clearly presented and thoroughly discussed.

5.3.2 Analyses should be focused and correspond to the objectives of the report. Findings are either deduced by logic or elimination. Both methods are acceptable. It is important that the analyses should represent a holistic view of all the data presented without contradictions. All possibilities and limitations should be explained, not avoided. Based on the symptoms and analyses discussed above, the causes of seepage can be narrowed down and a diagnosis made, which would be the most probable cause of the seepage.

5.3.3 It is important for the findings to be supported by convincing data analyses and arguments. It must be emphasized here that the surveyor's experience, knowledge, and skills (attention to detail) are important attributes that affect his/her accuracy in the application of tests and arriving at a right diagnosis.

5.4 Arriving at a Conclusion

5.4.1 The conclusion is the synthesis of the findings and analyses of the previous chapters of the report. It should echo the terms of reference and state the results to demonstrate that the objectives were achieved. Moreover, it should highlight all justifications for the investigation and the methodology adopted. All chapters should fit together. The conclusion should be concise and provide a sense of the completeness of the report to the reader. The tone of the conclusion should be definitive and unambiguous. All qualifications and reservations should have been deliberated on in the sections on 'limitations' or 'caveats'.

5.5 Other Points to Note

5.5.1 All reports must be properly copied and bound without loose sheets. Allow adequate margins for binding and/or recording notes and remarks. A clear and consistent numbering system should be used with different formats for sections and sub-sections. Page numbers should be inserted. Ensure the accuracy of the report, including its spelling and arithmetic.

5.5.2 In the case of a joint expert report, clear agreement or disagreement on each of the opinions given by the other expert must be shown with supporting reasons. Adequate time has to be allowed for the experts to read each other's responses before submitting the report to the courts.

Section 6.0 References

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Section 7.0 Appendices

Appendix 7.1 Glossary of Terms

The terms commonly used in the description of defects for report writing shall be interpreted as follows:

Terms		Interpretation
Absorbed water	-	Water or vapour penetrating into the body of a material by absorption.
Air infiltration	-	The movement of air through a wall system from an area of high air pressure to an area of lower air pressure.
Capillary	-	The action by which the surface of a liquid is elevated or depressed, depending upon the relative attraction of the molecules of the liquid for each other and for those of the solid.
Capillary Action	-	Water or vapour that is contained in connected voids or capillaries within the body of the material.
Condensation	-	The change of state from water vapour to liquid water.
Corrosion	-	The oxidization of metal by an electrochemical mechanism.
Damp patch	-	Moisture saturated surface with no significant trace of water. A process whereby moisture contained within air is deposited in a liquid or solid stated on a cool surface.
Dew point	-	The temperature at which a volume of air will become saturated and below which condensation will occur.
Dry water mark	-	Stain on surface caused by past water penetration. The surface is dry.
Efflorescence	-	White crystalline deposits formed on a material, following evaporation, from soluble salts transported to the surface by water.
Electrical capacitance	-	Capacity to hold electricity.
Electrical resistance	-	Property of not conducting electricity.
Flooding	-	Covering of an area that is usually dry with a lot of water.
Hairline crack	-	Crack below 1mm wide, and not being structural or otherwise stated.
Hygroscopic	-	The readiness of some materials to absorb moisture, sometimes directly from the air.
Infrared radiation	-	A form of electromagnetic radiation with wavelengths slightly longer than red light. It is not visible but can be felt as heat e.g. radiation from the sun and can be detected by photographic film and other devices.
Major spalled concrete	-	Spalling greater than $0.3m^2$ and extensive. No reinforcement bar exposed or otherwise stated.

Terms		Interpretation
Minor crack	-	Crack from 1mm to 2mm wide, and not being structural or otherwise stated.
Minor spalled concrete	-	Spalling up to $0.3m^2$ and sporadic. No reinforcement bar exposed or otherwise stated.
Moisture Mapping	-	The use of an electrical moisture meter to outline the limits of an area of dampness and mark out degrees of dampness within these limits with an aim to pinpointing the source of the damp.
Pipe leakage	-	Water wrongly leaked from the defective joints or cracks of pipes.
Pore water	-	Water or vapor that is contained discrete voids within the body of the material.
Rain penetration	-	Rain water wrong seeped in the building via the holes or cracks of the external wall.
Relative humidity	-	The ratio of the amount of water vapour present in the air to that which the air would hold at saturation at the same temperature. It is usually considered on the basis of the weight and vapor pressure.
Rising damp	-	Ground water seeping seeped through capillary action in porous building materials.
Residual construction moisture	-	Build-in water associated with wet trades, poor storage conditions or inadequate protection during construction.
Saturation	-	A condition existing when the air contains as much water vapor as it can hold at a specific temperature and pressure. It also represents 100 per cent relative humidity.
Severe crack	-	Crack wider than 2mm, not being structural or otherwise stated.
Professional building surveyor	-	A professional building surveyor is a corporate member of the Building Surveying Division (BSD) of the Hong Kong Institute of Surveyors (HKIS). A professional building surveyor has extensive education, training, and experience in building surveys and defects diagnosis. A BS is the expert who carries out the studies, planning, actual arrangement and inspection on site, and carrying out of tests and/or recording with regards to water seepage investigations.
Water seepage	-	Water wrongly getting in or out through hole or crack.

Appendix 7.2 Other Tests for Water Seepage

Part A: Non-destructive Testing Methods and Equipment

Part A aims to provide relevant information on the principles and characteristics of different testing methods and the equipment applicable to water seepage investigations. This would help readers of this guide to consider the use of alternative methods to help manage each situation. The following table illustrates some appropriate technologies and equipment that can be considered for detecting water seepage in different situations:

Item	Possible Technology	Principle	Remarks
1	Closed-Circuit Television (CCTV)	Examines the image or video obtained from within the pipework.	• Suitable for the inspection of drainage pipes for cracks and other defects
2	Dye or Chemical Tracer Test	Examines the seepage water for dye or chemical tracers.	• Contact with the suspected source is required • Often effective for simple cases • Dye may be visible to the eyes, but laboratory examination is often required
3	Electrical Capacitance	Measures the change in the electrical impedance of the object. The wetter the material, the greater the response.	• Easy and Fast • Readings can be obtained through most building materials • Won't damage or puncture the materials
4	Electrical Earth Leakage	Traces the measurable currents across the roof surface in the presence of an applied electric field.	• Non-destructive • Can be performed in the rain • Can work on overlays
5	Electrical Resistance	Applies voltage across two points and measures the current/ electrical resistance.	• Non-destructive • Water spray may not be required. • Contact with the suspected area is required • Easy to handle • Economical
6	Humidity Sensors	Measures the relative humidity of the air space/moisture condition of the building materials.	• Non-destructive • Highly sensitive and repeatable • Cheap, handheld • Easy to operate

Item	Possible Technology	Principle	Remarks
7	Microwave Leakage Detection	Measures the dielectric constant of the material to evaluate the free moisture content.	• Gives instant measurements • Light, handheld • No direct electrical contact • High initial cost • Applicable to most porous materials
8	Nuclear Moisture Meter	Uses a radioactive source to count the hydrogen atoms in a material.	• Can measure moisture to a depth of up to 280mm • Extremely accurate • Non-destructive • In-situ, quick • Health and safety measures are required
9	Nuclear Magnetic Resonance	Uses a nuclear magnetic resonance spectrometer to detect the hydrogen nuclei in a material.	• Can quickly determine the distribution and nature of the moisture content of a material • Can track changes and measure diffusion coefficients • Health and safety measures are required.
10	Pressure Test	Builds up pressure within a pipework system and observing any pressure drop on pressure meter.	• Simple and commonly used in the commissioning of pipework • Can destroy internal decorations. • All outlet points should be capped off before test • Result is sensitive to temperate variation during the test.
11	Radar	Compares the radar travel time to locate the moist area that exhibits a longer travel time.	• Non-destructive • Water spray is not required. • Contact with the suspected area is required • Relatively fast • With Radar Impulse Graph as evidence • Requires a specialist to interpret the data • Expensive
12	Rapid Infrared Thermographic Scan	Compares the thermal difference in the seepage area before and after the water spray test.	• Non-destructive • With Infrared photos as evidence • Water spray is required • No need to contact the seepage area. • Indirect source chasing method • More reliable for hot water spray or source • Very fast and efficient

Item	Possible Technology	Principle	Remarks
13	Ultrasonic sound sensor	Generates ultrasonic sound to detect air paths, which may also be water paths, through a building element.	• Quick, quiet, and unintrusive • No water supply required • Causes little disturbance to occupants

Part B: Ancillary Investigation and Tests

Part B aims to provide readers with further information on the ancillary investigations and tests which may be required in conjunction with the more common testing methods to achieve a full investigation. Other relevant tests may include opening up, borescope inspection, flood test*, negative pressure test, flow meter monitoring, hygroscopicity test, leak detection tapes, and litmus /pH papers, etc.

Item	Investigation & Test	Application	Commentary
14	Acoustic Leak and Sound Detector	Detects any crack/ break point at the test location (i.e., concrete/ pipes)	• Determines the break point/crack, not water path
15	Chemical Analysis	Laboratory scientific test of samples of plaster/concrete	• Cannot directly detect the source and its water path • Destructive test
16	Endoscopic Inspection	Insides of pipes	• Inapplicable to internal diameters of less than 6mm
17	Impact Echo Test	Detects any crack/ break point at the test location (i.e., concrete/ pipes)	• Cannot directly detect the source and water path
18	Metering (Flow Measurement)	Checks the flow rate of a water meter	• Not sensitive to slow flow rate • Cannot directly locate the leak point
19	Pressure Test	Check potable water supply pipe	• May damage the pipe under pressure
20	Flood Test*	Bathtubs, shower trap, floor, water tank	• Preparation work is required • Time-consuming
21	Water Spray Test	Tiled wall, window surround	• Special equipment and standards are required • Time-consuming

* For detailed procedures, refer to **Appendix 7.3**

Appendix 7.3 Application Procedures of the Flood Test

This section describes the procedures of a typical flood test for floor slabs, bathtubs, and shower trays. Reference is made to the specifications in the contract for water seepage investigation of the Buildings Department, HKSAR Government, and ASTM D5957-98, 2005 - Standard Guide for Flood Testing Horizontal Waterproofing Installations. Either liquid dye or clean potable water can be used for the test. In order to avoid the likely distortion of the results by other water seepage tests, the flood test should be carried out independently from any other test.

7.3.1 Liquid Dye Test

a. Use dyes of different colours for different test areas, especially where they are close together.
b. Food grade liquid dye (fluorescent, if appropriate) should be diluted according to the ratio recommended by its manufacturer (e.g. not exceeding a maximum ratio of 1:100 [dye:water]).
c. Make sure that the volume of the mixed colour solution is adequate for flooding the test area to a suitable depth (see Item j below).
d. Thoroughly mix the diluted colour solution before use.
e. Undiluted liquid dye should never be used directly on the test area.
f. If necessary, fence off the test area temporarily by building a waterproof protective curb (e.g. cement/sand curb sealed with waterproof tapes).
g. Plug the drainage outlet, if any.
h. Select and clearly mark three to ten checkpoints (CPs) within the seepage area. Check the moisture contents of the CPs with a moisture meter (see Section 3.3 of this guide on the use of the EMM). Record the EMM readings of at least four additional reference points (RPs) outside, but adjacent to, the seepage area. The RPs should be in a dry area with the same construction material as that of the affected ceiling or wall surface.
i. Take three sets of EMM readings every 15 minutes for all CPs and RPs before commencing the test.
j. Flood the colour solution over the test area to a minimum of 15mm deep with a mean depth of 25mm.
k. Keep the colour solution on the test area for 24 hours.
l. Carefully examine the test area, especially the ceiling below and other sides of the adjacent walls, for any sign of seepage. Consider the methods described in Section 4.0 of this guide to assist in the inspection.
m. Unplug the drainage outlet to drain the colour solution.
n. Remove all temporary works and clean the test area thoroughly.
o. Take three sets of EMM readings every 15 minutes for all CPs and RPs before starting the monitoring of the test results, but preferably not on the same day of the test.
p. Monitor the test area regularly until the test ends.
q. The appearance of colour dye in or around the seepage area should be a sign of seepage and allow you to trace its path from the test area (the source).

r. If colour dye is not observed anywhere in or around the seepage area within three weeks of the flood test, the test should be negative.

7.3.2 Test with clean potable water

a. Only use clean water available from a potable water tap for the test;
b. Repeat Procedures (f) to (o) of Paragraph 7.3.1 above;
c. The moisture content of the CPs should be closely monitored. Sufficient sets of moisture data should be taken every 15 minutes during the test period and for two hours after the completion of the test;
d. If the moisture content of the CPs in or around the seepage area has significantly increased during the test period, that should indicate seepage and allow you to trace its path from the test area (the source).

Appendix 7.4 Application Procedures of the Fluorescent Dye Test (FDT)

The following are general precautions and a setup of a typical FDT for drainage outlets and various sanitary fitments. They also apply to the colour water spray test for walls adjacent to bathtubs and shower trays. Refer to Appendix 6.2 for the flood test of drainage outlets and fitments. Reference is also made to the specifications in the contract for water seepage investigation of the Buildings Department, HKSAR Government.

7.4.1 General Precautions

a. Use dyes of different colours for different areas and fitments, especially where they are close together.
b. Food grade liquid dye (fluorescent, if appropriate) should be diluted according to the ratio recommended by its manufacturer (e.g. not exceeding a maximum ratio of 1:100 [dye:water]).
c. Make sure that the volume of the mixed colour solution is adequate for flooding the test area and fitments. In no case should it be less than ten litres (L).
d. Thoroughly mix the diluted colour solution before use.
e. Undiluted liquid dye should never be used directly on a test area or fitment.

7.4.2 Wash basin and kitchen sink

a. The test works best for normal-sized basins/sinks (capacity: 8-10L).
b. Plug and fill the fitment with tap water up to its overflow drain level.
c. Pour 100mL of liquid dye into the fitment.
d. Thoroughly stir and mix the dye and water in the fitment.
e. Add more water into the fitment until the colour solution overflows into the drain for at least 30 seconds.
f. Keep the colour solution in the fitment for at least five minutes before unplugging the basin/sink.

7.4.3 Water closet

a. Open the cistern cover and pour 100mL of liquid dye into the water cistern.
b. Thoroughly stir and mix the dye and water in the cistern.
c. Flush the water closet four times.

7.4.4 Floor drain and vertical grating

a. Fill up a container with approximately 10L of tap water.
b. Pour 100mL liquid dye into the container.
c. Thoroughly stir and mix the dye and water in the container.
d. Install a waterproof protective curb to enclose the floor drain/vertical grating.
e. Pour the colour solution from the container into the drain.

7.4.5 Bathtub

a. The test works best for normal-sized bathtubs (capacity: 80-100L).
b. Plug and fill the fitment with tap water up to half full.
c. Pour 300-400mL of liquid dye into the tub.
d. Thoroughly stir and mix the dye and water in the fitment.
e. Wash the adjacent sealant with the colour solution in the bathtub to a height of at least 1.5 metres from tub's bottom level for not less than five minutes.
f. Drain 3L of the colour solution manually into the overflow drain, if one exists.
g. Keep the colour solution in the fitment for at least 15 minutes before unplugging the tub.

7.4.6 Shower tray

a. Plug and fill the fitment with tap water up to the curb of the shower tray.
b. Pour 150-200mL of liquid dye into the tray.
c. Thoroughly stir and mix the dye and water in the tray.
d. Wash the adjacent walls and sealant thoroughly, including the guide rail of the sliding door (if any) with the colour solution in the tray for at least five minutes to a height of not less than 1.5m, which is equivalent to the height of a normal shower.
e. Keep the colour solution in the fitment for at least 15 minutes before unplugging the tray.

7.4.7 Points to note

a. The test areas should be thoroughly cleaned after you complete the test.
b. Select and clearly mark three to ten checkpoints (CPs) within the seepage area. Check the moisture contents of the CPs with a moisture meter (see Section 3.3 of this guide on the use of the EMM). Record the EMM readings of at least four additional reference points (RPs) outside, but adjacent to, the seepage area. The RPs should be in a dry area with the same construction material as that of the affected ceiling or wall surface.
c. Take three sets of EMM readings every 15 minutes for all CPs and RPs before commencing the test.
d. Carefully examine the seepage area and the fitment, especially the ceiling below and on the other sides of the adjacent walls, for any sign of seepage. Consider the methods described in Section 3.0 of this guide to assist in the inspection.
e. Take three sets of EMM readings every 15 minutes for all CPs and RPs before starting the monitoring of the test results, but preferably not on the same day of the test.
f. Monitor the seepage area regularly until the test ends.
g. The appearance of colour dye in or around the seepage area should be a sign of seepage and allow you to trace its path from the test area (the source).
h. If colour dye is not observed anywhere in or around the seepage area within three weeks of the flood test, the test should be negative.

Disclaimers

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