



**International
Standard**

ISO 22185-2

**Diagnosing moisture damage
in buildings and implementing
countermeasures —**

**Part 2:
Assessment of conditions**

*Diagnostic des dommages causés par l'humidité dans les
bâtiments et mise en œuvre de solutions de remédiation —*

Partie 2: Évaluation des conditions

**First edition
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 205, *Building environment design*.

A list of all parts in the ISO 22185 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The term “moisture damage” is interpreted in many ways. Cognisance of moisture damage is not always consistent between specialists (e.g. engineers, researchers), residents and building users, leading to confusion. For example, residents and building users would consider the occurrence of condensation on window glass or on the surface of a metal sash to be a prime example of moisture damage, but considering the durability of glass and metal materials, it is not always appropriate to call that “moisture damage.” However, supposing the condensation that occurs on the glass becomes the cause of an outbreak of mould on the curtains, it would be called moisture damage. It is imperative to resolve the confusion by defining “moisture damage” and by demonstrating the criteria for diagnosing whether an occurring phenomenon in a building is moisture damage or not.^[1]

This document defines moisture damage in buildings and demonstrates criteria for diagnosing whether a phenomenon that occurs in a building is moisture damage or not, for a common understanding between residents, building users and specialists. It also demonstrates methods for the classification of moisture damage.

This document is the second part of the ISO 22185 series of standards on moisture damage. ISO 22185-3¹⁾ will show a framework for investigating and taking countermeasures against moisture damage.

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1) Under preparation. Stage at the time of publication: ISO/PWI 22185-3.

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Diagnosing moisture damage in buildings and implementing countermeasures —

Part 2: Assessment of conditions

1 Scope

This document describes methods for diagnosing and assessing conditions that can result in moisture damage impacting the building's energy and durability performance. For the purpose of classifying moisture damage, methods in this document range from basic observation techniques to more complex methods using equipment to more accurately or precisely render a condition assessment and provide data. This document does not ensure that the methods identified will result in the full disclosure of all moisture damage conditions.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Qualitative evaluation of moisture damage

4.1 Visual

4.1.1 Process of diagnosing moisture damage by site inspection

The procedures of diagnosing moisture damage by site inspection of existing buildings are explained in this clause. Although visual inspection plays a central role in the inspection, the final judgement is given by integrating all the information from physiological sensing including touching, smelling and hearing. Inquiry survey on clients, users, designers and builders is also essential in this respect. The content and procedures of the inspection depends on the kind of building (e.g. residential, office, factory, store).

In many cases, the procedures of an inspection are as follows:

- a) Request for diagnosis of moisture damages, e.g. from owner, users, designer.

The client asks to diagnose a moisture problem and explains the details of the problems (e.g. kind of moisture damage, kind of building, when and where). The drawing and specification of the building may be referenced.

- b) Site inspection: moisture damage or not?

Site inspection is the most important part and whether moisture damage really exists or not is judged with the help of the inquiry to the client (e.g. owner, user, designer). In this stage, the moisture damages described in ISO 22185-1:2021, Figures 2 and 3 are checked with respect to each building element, material, and room. The moisture damage (e.g. deformation, cracks, exfoliation, discoloration, wetting, mould growth, salting out and efflorescence) are identified by mainly visual inspection with the help of information obtained by the smell when entering the room (olfactory sensation), wetness of the wall (sense of touch), temperature of room and wall (thermal sensation), hammering test (sense of hearing). In this identification process, potential moisture source (e.g. rainwater, indoor and/or outdoor vapor, groundwater) and the resulting moisture damage are taken into consideration. Reference to the site plan, drawing and specification of the building, and the information from hearing about the usage of the rooms and environmental conditions are useful.

c) Estimate of causes for moisture damage.

The cause(s) of the moisture damage is estimated taking into consideration these results comprehensively. In particular, the identification of the moisture source (e.g. indoor or outdoor vapor, leakage of rainwater, ground water, water leakage from piping) is important and not necessarily easy. In this process, ISO 22185-1:2021, Figures 2 and 3 can be utilized.

d) Second inspection and hearing if necessary.

Second inspection and hearing can be required if any questions arise in c), or the cause of moisture damage was difficult to be identified, or inspection at another season is required.

e) Proposal of implementing countermeasures.

The cause of the moisture damage is estimated and the countermeasures are proposed. The countermeasure is different depending on the difficulty of identifying the cause of the moisture damage, i.e. confirmation of whether the estimated cause seems valid, additional survey to identify the cause, analysis or laboratory experiment to identify complex and combined effects. In this stage, ISO 22185-1:2021, Clause 8 should also be taken into consideration.

4.1.2 Points of visual inspection

a) Objects of visual inspection.

The objects of the visual inspection are classified by the inspection position (outside or inside), kind of room, building element (e.g. roof, wall, openings), and situation of moisture damage (ISO 22185-1:2021, Figures 2 and 3).

b) Inspection position: whole building, outside view, inside view.

c) Room: living room, kitchen, bedroom, bathroom, washroom, entrance, closet, corridor, staircase, crawl space, attic space, underground room.

d) Building element: roof, ceiling, external wall, partition wall, floor, foundation, ground sill, opening, building system (installation).

e) Situation of moisture damage: refer to ISO 22185-1:2021, Figures 2 and 3.

f) Change regarding colour characteristics: Hue, brightness, and chroma of the surface can change because of microorganisms (see ISO 16000-18), salt and/or efflorescence, rotting, discoloration by ultraviolet ray, water droplet or wetness.

4.2 Tactile

By touching the surface of the building components such as a wall or a floor, it is sometimes possible to detect the occurrence of a moisture damage. If wetness or cold is felt more strongly than the other parts around when touching the surface of the building components, then the occurrence of condensation or some

kind of water immersion are suspected. If the surface texture conditions are different from the other parts around, the reason should be pursued; in some cases, moisture can be related to those phenomena.

NOTE Texture conditions can include roughness and softness.

4.3 Odour

If an unusual odour is detected in a building, the location of the odour should be identified and the cause of the odour should be clarified. Sometimes, this can be due to moisture. It is necessary to find out what causes dampness. At the same time, the possibility of odour generation due to chemical changes caused by moisture damage should also be kept in mind.

4.4 Sound

By hearing change in sounds when tapping surfaces, the existence of a cavity can be detected. When anomalous sounds are detected, the cause should be clarified. Deformation of building components will make noise. When the sound of moisture dripping in a cavity is detected, the source should be determined.

4.5 Occupant survey

Obtaining information from the occupants of buildings can identify areas of the building that are affected by moisture damage. The occupants can be aware of unusual conditions in the buildings, whether these conditions change during the year, and advise of issues that affect them. This information can identify moisture issues that are not readily apparent during site inspection.

For details, see ISO 21105-1.

NOTE Additional information can be found in ASTM E3026,^[5] ASTM E2270,^[6] ASTM-E2841.^[7]

4.6 Risk assessment

Potential sources of moisture that can contribute to either the damage of the building or the building environment, or both, shall be assessed. Sources that are identified by the surveyor as latent sources of moisture damage shall be reported and included in the evaluation of the building.

5 Quantitative evaluation of moisture damage by measurement

5.1 Measuring relative humidity (RH) and temperature

An RH sensor measures the RH (and often the temperature as well) of air. When the RH exceeds the acceptable range for a long time, moisture damage is likely to occur. Some RH sensors can work independently with an integrated mini data logger, while others should be connected to an external data logger. In most cases, such sensors work reliably in the RH range of 20 % to 95 %. When the RH is extremely high or low, most RH sensors fail to provide accurate measurements.

5.2 Measuring capillary pressure by psychrometer and tensiometer

When the ambient humidity is extremely high, RH sensors are no longer reliable. Instead, psychrometers or tensiometers should be used. There are different types of psychrometers, such as transistor psychrometers and dew-point psychrometers. Transistor psychrometers work as dry-bulb/wet-bulb thermometers to detect the moisture potential, while dew-point psychrometers measure the dew-point of moist air through chilled mirror or other techniques. Tensiometers can be inserted into a moist material (e.g. soil) and measure its capillary pressure. All these sensors are very sensitive to temperature fluctuations and should be calibrated carefully. If the effect of temperature is neglected, as is often the case, capillary pressure is uniquely related to moisture content. As a physical property of the material, this relationship is expressed as a suction curve. For more details on capillary pressure measurements, see [Annex A](#) and ISO 11276.

5.3 Measuring moisture content by electrical resistance

In building materials (e.g. stone, concrete, and wood), the electrical conduction is essentially an electrolytical phenomenon linked to the fluid phase in porosity. For example, the resistivity of concrete can evolve between less than 100 Ωm (in the semiconductor range) when it is saturated, to 10^9 when it is dry (in the insulator range). The water volume influences the ability for ions to move through a porous network.

The electrical resistance of a material R (Ohm) is assessed by inducing a known electrical current I (A) between two electrodes and measuring the resulting difference of potential U (V) between two electrodes, following Ohm's law in [Formula \(1\)](#):

$$U = RI \quad (1)$$

There are several devices (methods) measuring electrical resistance. The two-plate-electrode method, the two-point electrode (or pin meter) method, and the four-probe electrode method are the typical devices. All these methods are done in the range of continuous current, or with low frequency alternative current (<300 Hz).

In the two-electrode method, the potential drop mainly corresponds to the electrical coupling at the contact between electrodes and material, i.e. 40 % of the total difference of potential at a distance is equal to two diameters from the electrode axis. Thus, the measurement is significantly influenced by the material properties in the vicinity of electrodes more than by properties in depth. The four-probe electrode method flows a current between two probes and measures the potential difference between two other electrodes, which allows a large surface to be covered and to increase the sensed depth. [\[9\]](#)[\[10\]](#)

5.4 Measuring moisture content by electrical capacitance

Unlike many humidity sensors that measure the moisture potential in the air or in the material, an electrical capacitance meter measures the moisture content of a material directly. The electrical permittivity of water is often much higher than that of building materials, so the apparent electrical capacitance/permittivity of a moist building material is a function of its moisture content. With a calibrated curve for moisture content (e.g. electrical capacitance/permittivity), it is possible to obtain the moisture content of a specific building material by measuring its electrical capacitance/ permittivity.

5.5 Measuring surface temperature by infrared camera

An infrared camera measures the surface temperature based on the radiative heat transfer. The distribution of surface temperature can be visually inspected. A thermal bridge usually displays a different colour from the well-insulated part. This can originate from poor thermal design, bad choice of insulation material, the wet part with a higher thermal conductivity, or air leakage.

5.6 Measuring mechanical properties by ultrasonic device to check the mechanical damage

An ultrasonic device can be used to check potential mechanical damage caused by moisture. The device emits and receives ultrasonic pulses, which travel within a solid target. By checking the time interval of the traveling pulse, mechanical characteristics (e.g. Young's modulus) can be obtained. When a material is very wet, the pulse travels faster than in a dry state. When there is a fissure in the pathway, the pulse travels more slowly than usual.

5.7 Measuring deformation

Deformation of building components can be measured by strain gauge and other instruments to check dimension change (ISO 29764 and ISO 16534 specify the determination of deformation of thermal insulating products under specified compressive load and temperature conditions).

The surface flatness can be checked by using a laser instrument based on optical reflection. Observation of surface by thermography will detect deformation.

Phenomena of deformation of building components closely relate to expansion, shrinkage, crack and peeling^[1].

See ISO 22185-1 for detailed categories of these phenomena. See also ISO 29764, ISO 16534, and ISO 15822 for more information on deformation.

5.8 Measuring moisture movement by air transport

All buildings allow air to leak through the building envelope, both infiltration and exfiltration. As air contains water vapour, this moisture can be deposited within the building envelope if the temperature within the building envelope drops to the dew point. The air leakage of the whole building envelope can be measured using ISO 9972 and the amount of moisture is not detected at the surface, but will show up as condensation in the building envelope. In certain cases, the result of air leakage in a building can result in thousands of litres of water being deposited within the building envelope.

5.9 Measuring ventilation rate indirectly by CO₂ concentration

If the generation rate of CO₂ in the indoor space is given (in some other way), the ventilation rate can be determined indirectly by measuring CO₂ concentration. This will help to know the moisture flow through ventilation between the indoor and outdoor space.

NOTE Additional information can be found in ASTM E741^[15].

5.10 Measuring mould concentration in air

Detection and enumeration methods of indoor airborne moulds are categorized into sampling by filtration, culture-based method and sampling by impaction. The method of sampling by filtration requires a long-term sampling (0,5 h to several hours). The method of sampling by impaction, a method for active short-term sampling (1 min to 10 min), impacts the indoor air including particles on solid agar media with high velocity through an air sampler. The particles in the air stream impact on the agar surface due to their inertia. Sampling is usually conducted 0,75 m to 1,5 m above ground level.

The typical agar mediums are Soybean Casein Digest, malt-extract agar (SCD), Potato Dextrose Agar (PDA), and Dichloran 18 % Glycerol Agar (DG18). After sampling, the mould spores are cultivated in an incubator at temperature of 27 °C for 2 days to 7 days, and resulting colonies counted with colony forming unit, cfu.

In the examination of the moulds, direct visual inspection is the most important aspect. The kind of material on which the mould grows, and discoloration (e.g. degree, colour tone, and smell) are checked, and filament growth and adhesion of spores are inspected by a loupe. Furthermore, a detailed observation is conducted by a stereoscopic microscope, an optical microscope, a fluorescence microscope, and a differential interference microscope, if necessary. Whether the sample is mould or not is judged by precipitation behaviour of the filamentous sample in the water, cultivation in the agar, and in the end, by the existence of Adenosine Triphosphate (ATP).

NOTE Additional information can be found in AIJES-A0008-2013^[16] and ISO 16000-18^[3].

6 Quantitative evaluation of moisture damage by models

6.1 Situations for the use of models

6.1.1 Complementing measurements / identification of the reason for moisture damage

For inside the wall, the distributions of moisture content, temperature, and heat and moisture flux, which are difficult to measure, can be obtained as a calculated result by using an analytical model. Combined with the measured quantities of the surface, the quantities (e.g. temperature, moisture content, humidity) in the material are estimated. The flows of the analysis are as follows:

- a) calculation of distribution of temperature, moisture content, and heat and moisture flux;

- b) comparison with measured results of the surface;
- c) confirmation of hypotheses by observation or measurement;
- d) obtaining further information.

6.1.2 Evaluation of past phenomena

The phenomena, such as mould growth, salt crystallization, efflorescence and rust, can be observed. However, only the present situation is known by the observation, and it is difficult to evaluate quantitatively. By using models, it becomes possible to estimate past phenomena quantitatively and predict the future status.

6.2 Models used for evaluation

6.2.1 Steady state calculation

The temperature and humidity distribution in a wall system can be obtained by a simple steady-state calculation, if the temperature and vapour pressure on both sides of the wall are stable. Given the conditions of the temperature and the vapour pressure of the air on both sides of the wall system (outdoor and indoor air), the distributions of temperature and vapour pressure can be calculated by giving the thermal and vapour resistance values of every wall component and the surface air layer. This method is suitable as the starting point to check the possible occurrence of condensation in the wall or at the surface of the wall. However, in this method, the influence of fluctuation of the hygrothermal state of air on both indoor and outdoor sides is not considered. For details, see ISO 13788. If the fluctuation is focused on non-steady-state-calculation of hygrothermal performance of the walls, it should be solved by a method shown in [6.2.2](#).

6.2.2 Non-steady state calculation based on hygrothermal models of porous materials

Distributions of moisture content/ ice content/ temperature/ heat flow in materials (walls) can be obtained from the models for non-steady state. It is necessary to use appropriate models and to solve them with an appropriate numerical method. At the same time, appropriate boundary conditions, material properties and the wall structure should be given. For outdoor side boundary conditions, outdoor conditions (e.g. rain, solar radiation, air temperature, humidity, and airflow) should be given properly. See Reference [\[18\]](#) for detailed information of hygrothermal models of porous materials.

6.2.3 Computational fluid dynamics (CFD) for considering air flow influence

By conducting numerical calculation of indoor air distribution by CFD, the air velocity distribution as well as the distribution of the temperature, humidity and the particles in the air (e.g. mould, dust, and droplets) are calculated.

6.2.4 Mould growth (biological model)

In order to grow, mould usually needs acceptable temperature, adequate moisture (e.g. water activity, humidity) and nutrients. In most building environments, mainly temperature and humidity are significant for mould growth since nutrients exist sufficiently.

A few dozen species of fungi are thought to be both important and common in buildings. Each fungus has an optimal range of temperatures that allows growth. Of all essential elements, moisture is the most universal requirement for fungal growth.

Mould growth can be evaluated by using the germination times or growth rates as functions of temperature, humidity and the other environmental conditions (e.g. nutrients, surface structure, and material). For details, see [Annex B](#).

6.2.5 Salt crystallization

For predicting salt crystallization in building materials, salt transfer and water evaporation in the material and its surface must be understood. Field surveys, laboratory experiments and theoretical analyses have been extensively developed to predict and evaluate salt transfer and water evaporation in building materials. However, the understanding of these phenomena is still immature, and a fully satisfactory theoretical model is not completed yet, thus it is too early to propose a standard regarding salt crystallization. However, since several models have been proposed, which can reproduce the phenomena with an allowable precision when limiting purpose and situation, [Annex C](#) introduces a model to understand the present situation.

Crystallization on the surface of porous materials is called “efflorescence”. In the field of concrete, efflorescence (flowering) especially means white crystallized salts appearing after water evaporation on the hardened concrete surface. They are mainly carbonates (or sulfates) originally included in cement.

The damage caused by salt crystallization is strongly related to moisture. Separation or cracks due to pressure increase caused by salt crystallization is a fracture event, and experimental and theoretical research have been extensively carried out from both macroscopic and microscopic points of view^{[19][20]}.

6.2.6 Rust

The degree of rusting, R_i , a rating characterizing the degree of rust formation (rust broken through and visible under rust) on a coating, is defined in ISO 4628-3. It is based on the area ratio of rust spot observed on the surface of a coating. The area of the rust can be determined by computer image processing^[2].

It is generated when metals are in contact with water or moisture and become oxidized. In the case of iron, red rust (Fe_2O_3) is generally formed.

Terms related to rust are: carbonation, expansion, salt adhesion, oxidation.

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Annex A (informative)

Moisture meters

A.1 Tensiometer method

The pore water pressure represents the sum of the following pressures:

- matric pressure (due to interfacial forces acting between the water, air and solid phases);
- overburden pressure (the part of the mass of overlying material carried by the soil water);
- pneumatic pressure (the local air pressure).

Under most circumstances, the overburden and pneumatic pressures are zero.

At normal atmospheric pressures about 100 kPa, the application of the tensiometers is limited to a range of pressures down to about -85 kPa. Tensiometer response time ranges from a few seconds to several days.

A tensiometer comprises a porous cup that is permeable to water connected to a pressure-measuring device. The pores of the wall of the cup are small enough to prevent air passing through. The porous cup is filled with water. When the cup is placed in the soil, water within the tensiometer flows through the porous wall to the soil, or soil water flows into the tensiometer, until the pressure of the water on both sides of the porous wall is equal. When equilibrium has been reached, the measured pressure of the water inside the tensiometer, after correction for the difference in height between the pressure sensor and the porous cup, equals the pore water pressure of the soil water at the position of the porous cup.

A tensiometer usually consists of a porous cup, a connecting tube and a body tube, a pressure sensor and a mechanism for expelling any air which accumulates within the tensiometer. A porous cup is made of a porous material of air-entry value (the pressure required to force air through the water-saturated cup) larger in magnitude than the lowest pore water pressure to be measured. The material shall be rigid and usually unglazed ceramic is used. As a pressure sensor, several forms are used in tensiometers, the most common being mercury manometers, Bourdon gauges and electrical pressure transducers.^[8]

A.2 Centrifuging method

In this method, matric potential is balanced by centrifugal force instead of gravity force in the case of a tensiometer. The soil water with much higher matric potential can be extracted from the soil. A centrifugal machine rotor, which is equipped with a water-collecting pipe and a filtration cylinder containing a sample, is rotated with a suitable cycle so that a centrifugal force corresponding to a target matric potential can be obtained^[22].

The time to attain an equilibrium between the pressure of soil water and a given matric suction (pF 3,0 or 4,2) is much faster by the centrifuging method than by the pressure membrane method.

A.3 Pressure membrane method

Similar to the centrifugal method, in the pressure membrane method, air pressure is balanced to the matric potential alternative to the gravity force. A sample is placed in a sample chamber with a several centimetre thick metal wall. The chamber is pressurized by dry air up to pressure P_1 , and the sample water is connected through a semi-permeable membrane to the outside free water under atmospheric pressure P_0 . The soil water flows to the outside of the sample chamber due to the pressure difference between inner pressure

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P_1 and outer atmospheric pressure P_0 , arriving at an equilibrium state at which the matric potential equals P_1 [\[23\]](#).

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Annex B (informative)

Examples of models used to evaluate mould growth

Examples of fungus growth rate are given in Reference [24] [25]. The contour lines of germination times and growth rates, respectively, of *Aspergillus restrictus* and *versicolor* are shown in the figures with temperature on the horizontal axis and relative humidity on the vertical axis in Reference [25]. According to these figures, the two fungi grow most actively between 0,97 and 0,98 (RH) and 27 °C and 30 °C.

These data show the range in which the mould can grow under constant temperature and humidity with sufficient food, but they do not give information on the mould that grows under fluctuating conditions. A mathematical model giving the mould fungi growth rate on wooden material under fluctuating environmental conditions, [Formula \(B.1\)](#), is proposed in Reference [26]. [Formula \(B.1\)](#) considers the effects of exposure time, temperature, RH and dry periods.

$$\frac{dM}{dt} = \frac{1}{7 \exp(-0,68 \ln T - 13,9 \ln H + 0,14W - 0,33S + 66,02)} k_1 k_2 \quad (\text{B.1})$$

where

- M is mould index;
- T is temperature;
- H is relative humidity;
- W is wood species;
- S is surface quality;
- t is time.

The corresponding empirical model for algal growth is proposed in Reference [27], which can be used to predict algal growth on the external walls.