Know Your Building — *Typical damages*

RIBuild

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637268

Content

In this booklet you find six different topics for visual assessment of buildings. Each topic holds answers on what to look for, types of risks, why it occurs, where to look and possible solutions.

High levels of moisture often result in several types of deterioration and thus reduce the service life of building components. Moisture induced damages include mould growth, wood decay, salt efflorescence, algae proliferation, and frost damage.

The texts are based on the written report about internal insulation in historic buildings. The report can be found on www.ribuild.eu along with project information and checklists for a total visual inspection of historic buildings.

Mould

Mould are microscopic fungi belonging to different biological groups and consisting of many species. They live on surfaces of materials, use easily assimilated nutrients for growth and produce airborne spores. Mould fungi are widely spread across different environments on the Earth, and no natural place with air are free from spores.

What to look for

Extended mould growth on building materials may be visible to the naked eye. Often it appears as black, green or white discoloration at surfaces. Some fungi produce pigments in their hyphae and spores that can cause this discolouration, while others lack these pigments. Therefore, mould growth is not always visible to the naked eye. Therefore, extensive mould growth may be present in buildings even though there are no clear signs. Typical warning signs can be damp surfaces, dried out water stains and rusty nails in the construction.

Risks

Mould in buildings may have negative effect on the perceived indoor environment. Human health may be adversely affected due to the spread of particles, toxins and volatile organic compounds from the mould fungi to the indoor air. Inhalation of airborne microorganisms and the metabolites may lead to immunological reactions leading to different health issues. Furthermore, mould may produce odorous substances, which affect the perceived indoor environment. Due to renovation the costs associated with this growth are substantial.

Why it occurs

The main environmental factors affecting mould growth in building structures are humidity and temperature; moisture being the crucial factor. Suitable conditions for the growth and reproduction of different mould fungi vary. Some thrive at relatively low values of relative humidity (RH = 75%), while most fungi require values of RH (90-95 %) for optimal growth in room temperature. Different building materials vary in their susceptibility to mould growth; some can withstand high moisture content better than others. Mould growth is the result of a complex interaction between all these factors; environmental factors and duration, material properties and the characteristics of mould fungi present.

Where to look for risks

For mould to grow on material there must be nutrients in the form of simple carbohydrates present on the material. All material organic compounds or surfaces with dirt are therefore at risk for mould growth if there is sufficient moisture available. This will typically be the case at cold surfaces especially in corners and behind furniture where the ventilation is low.

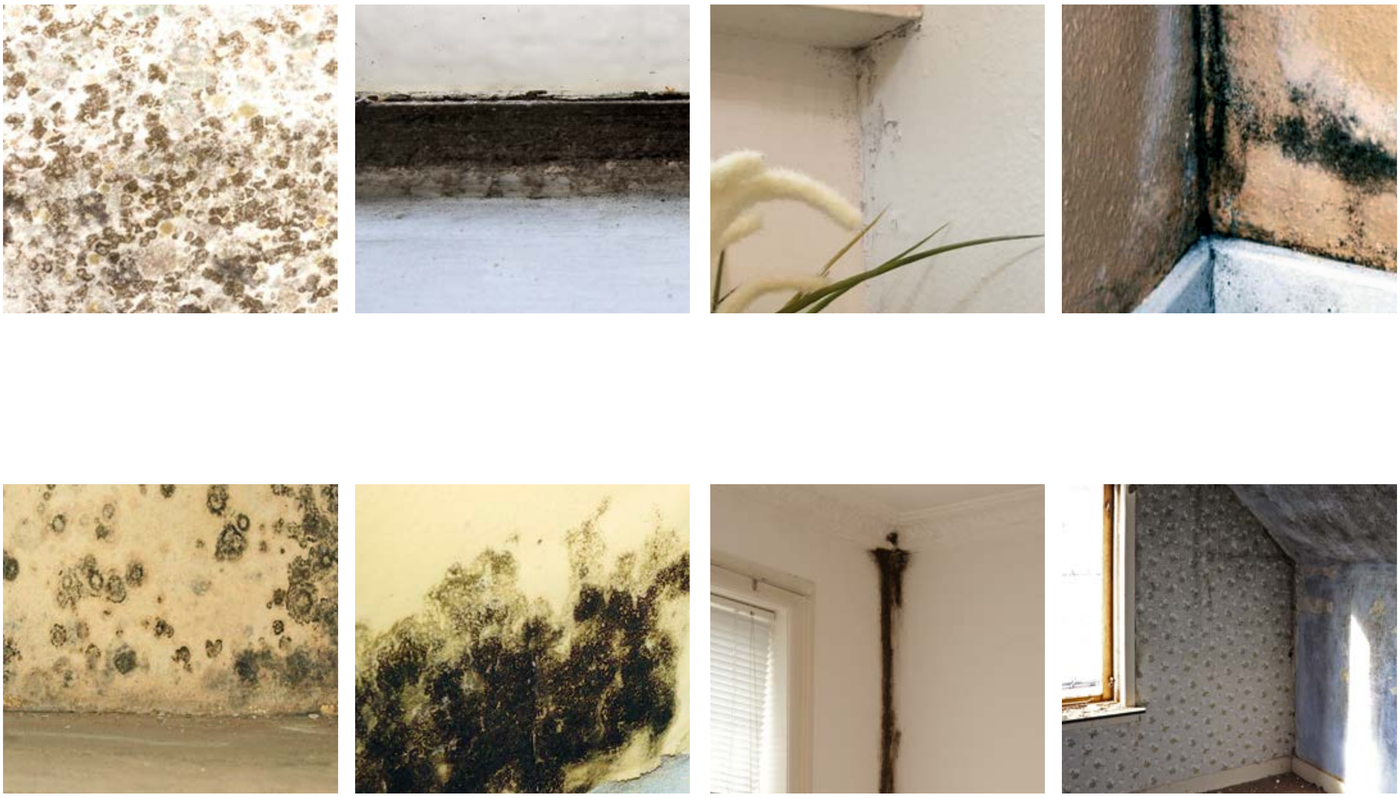
The original external wall in historic buildings often consists of inorganic building material and may therefore be considered as robust from a mould perspective. However, there are also adjoining frames, beams, windows, doors, added insulation and surfaces containing organic compounds, that needs to be inspected. Furthermore, simple dust contains organic material, therefore mould can appear at cold surfaces due to high relative humidity in these areas.

What to do

The cause of the moisture damage should be found and remedied, and damaged material should be replaced or mechanically treated, e.g. by grinding, planning or blasting. Note that residues from the process must be collected and removed to avoid mould residues from remaining.

Drying the material without further action, as mechanical removing of dead mould growth, is not sufficient. Treating surfaces with mould inhibitors such as asphalt or fungicides is not recommended as these products can fortify the development of an odour and/or health hazard to the indoor air. Treatment with chemical agents do not stop or eliminate mould growth and drying may even release particles and toxins from mould-damaged materials.

Examples of mould



Wood rot

Rot or wooden decay is caused by fungal attack on wood. Different fungal species that need high moisture (typical higher than 20 weight % in wood) favour wood as nutrient. The most common species are dry rot and brown rot.

What to look for

Wood rot occurs where wood is in contact with moisture, usually in presence of condensation or water leakages from pipes or leaks in the building envelope, typically from roofs. The wooden construction will be weakened and therefore softer than sound wood, which can be tested with a thin knife or awl. The appearance of wood rot depends on the fungal species that have caused the attack.

Risks

A rot attack causes wood decay, resulting in reduced strength and ultimately collapse of the wooden construction. How fast a rot attack develops depends on the available moisture. If moisture supply is stopped, the attack stops but will return if moisture again becomes available. Some fungal species need long time exposure to high moisture content before the wooden construction weakens substantially, while other species weakens the wooden constructions fast if the conditions especially favours these species. Fungal growth can – depending on the species – result in unpleasant odour and emissions, which must be considered as an indoor problem. Depending on exposure and immunological reactivity of the inhabitants the inhalation of airborne micro-organisms and their metabolites of some species may cause respiratory symptoms.

Why it occurs

Rot or wood decay caused by fungal growth is a failure mechanism for wooden constructions that is closely linked to moisture, as high water activity is a prerequisite for fungal growth. Consequently, fungal growth starts when the moisture content in wood exceeds a threshold value. The threshold value depends on different factors:

- Time of wetness, i.e. time above the certain threshold value
- Previous attacked wood has a lower threshold value than sound wood
- Temperature

Some fungal species (dry rot) are able to transport moisture over several meters, and through other materials than wood, enabling rot attack far away from the moisture source.

Where to look for risks

In historic masonry facades, wood is mostly used for half-timbering in external walls. Although structural floors are not a part of the wall, wooden beam ends and supporting laths may be placed in the external walls and therefore in direct contact with bricks or stones in the external wall. Consequently, the moisture content of the embedded timber will be dependent of the moisture conditions in the wall. Condensation or liquid water sources e.g. penetrating rain are usually a prerequisite for fungal growth. If the building is internally insulated with systems that contain wooden materials e.g. wooden framing, there is a risk of rot if condensation can occur due to insufficient vapour barrier or if water from driving rain is trapped in the internal insulation.

What to do

The most important measures to minimize or prevent rot attacks are:

- Controlling the moisture, ensuring the moisture level will not exceed the threshold value, coupled with a temperature threshold
- Prevent water ingress into the wall; e.g. make sure joints in brick walls are filled, and with no leaks from rainwater drainage systems or through roofs
- Limit the use of wood in critical parts of the envelope

If parts of the original structure are renewed it is possible to choose other materials, e.g. replacing wooden beam ends with concrete beams. When parts of the construction are replaced, not only the damaged wood is removed; sound wood must also be removed to create a safety zone. How much sound wood that should be removed depends on the fungi species.

Examples of wood rot

Frost damage

Frost damage in porous building materials can originate from a variety of physical frost impacts, of which the volume increase of the water-to-ice phase change is the most widely known. Such frost damage is mainly manifested through scaling of the outer surfaces e.g in ceramic bricks and natural stones.

What to look for

Scaling of outer surfaces in bricks means that typically the outer 5-15 mm of the surface is peeled off in single stones or larger areas. This can be in moist areas but also apparently random on facades. Single stones with frost damage indicate that at least these stones are more sensitive than the rest of the stones. A visual inspection of the existing facade may reveal evidence of frost damage from the past, which logically is an indicator of potential future frost damage. In these cases, the application of internal insulation should not be discommended.

Risks

Frost damage is commonly solely related to aesthetical problems, particularly scaling of the exterior surface of the masonry wall, which normally do not lead to structural problems except for very extreme cases. Given more frequent and intense freezing conditions though, which penetrate deeper into the wall, the risk for structural damage may rise when adding internal insulation, if the material is very sensitive to frost damage.

Why it occurs

Porous building materials experiencing high moisture contents and low frost temperatures are at risk for frost damage. If pores in the material are filled with water that freezes and therefore expands, scaling of the outer surface may appear. However, some materials are more frost resistant than others, which depends strongly on the porosity and strength of the material.

Three conditions must be fulfilled for frost damage to occur:

- The material must be sufficiently wet
- The temperature must be sufficiently low, so that water in the material can freeze
- The material must be sensitive to frost damage.

Where to look for risks

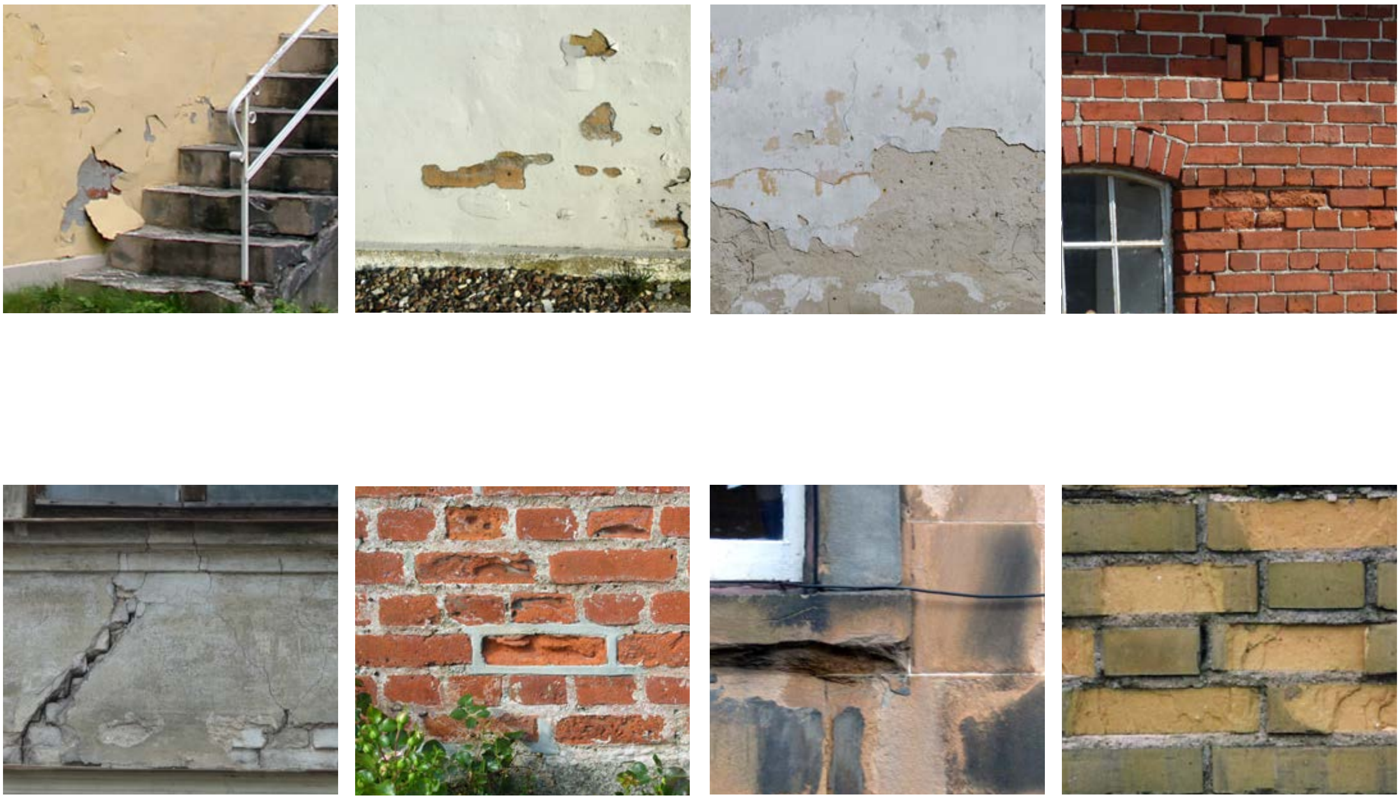
The outer surface layers of historic masonry walls, including plinths, corners, are normally exposed to the highest risk for frost damage.

In porous building materials, both moisture and temperature levels depend on the wall orientation. The prevailing direction for wind-driven rain in Europe is South-West while the lowest facade temperatures occur in North-faced facades. It is subsequently difficult to predict which is the most exposed orientation with respect to frost damage. Areas close to the ground may also be at high risk, as rising damp may cause high moisture contents in this area.

What to do

If the material is wet because of leakage in pipes or rising damp, these moisture sources must be remedied. If there is no extraordinary moisture source, the material may be too sensitive for its use, and internal insulation will increase the risk of further frost damage. Evaluating the frost sensitivity of the existing material is a job for experts; it requires an extensive experimental effort, wherein a large number of material samples has to be available.

Examples of frost damage



Salt efflorescence

Salt efflorescence is an expression for the deposits of salts on the surface of masonry. The deposition occurs when moisture in the wall contains soluble salts, and this moisture is brought to the surface, where it evaporates, and leave the salt crystals behind. The crystals may cause loss of material from the surface.

What to look for

Salt can appear as both white, powdery crystals, or as a white coating, and may appear both internally and externally of the building wall. The salt crystals are able to cause rendering and paint to peel off. But also bare bricks and mortar may turn into powder starting from the surface.

Risks

Often, it is to be seen as an aesthetical surface problem with efflorescence of salts, crust formation and damage due to salt crystallization (spalling, flaking of paint etc.). In other cases, damage may appear due to volume increase and high crystallization pressure, if the façade material isn't sufficiently resistant. The loss of material, e.g. joints, may cause water penetration in the wall. Furthermore, salt will bind moisture from the environment to the material, causing causing a constant high moisture content even after the moisture transport from e.g. ground water has stopped. Red bricks usually have a higher porosity when compared to yellow bricks, and thereby attract more moisture and salt.

Why it occurs

Salt efflorescence is an indication of the presence of moisture. Salts are water-soluble and can therefore be transported with moisture. When the moisture content decreases, salt crystals are accumulated, typically beneath the surface of the masonry. Due to expansion of salt, and crystallization pressure, salt can cause serious damage to masonry. The salts can originate from both the building materials themselves, from the soil, from pollutants in the surrounding air, or from road salt. Salt attracts moisture from the environment including the air. Thus, the moisture level is kept rather constant with the presence of salt, which will crystallize where the moisture level is not constant, i.e. at the surface.

Where to look for risks

Often salts will migrate with rising damp, so basement walls, or the façade near the plinth are often good indicators for presence of salt.

Coastal buildings, and buildings by large roads salted eagerly in winter, are more exposed than other buildings in less saline environments. Damage in pedestal areas are typical. Also special parts of buildings e.g. corners may be prone to higher salt concentrations due to urination. For a complete diagnosis of salt content in masonry, the salinity can be measured in drill dust samples, and should not exceed 0.5 % by weight.

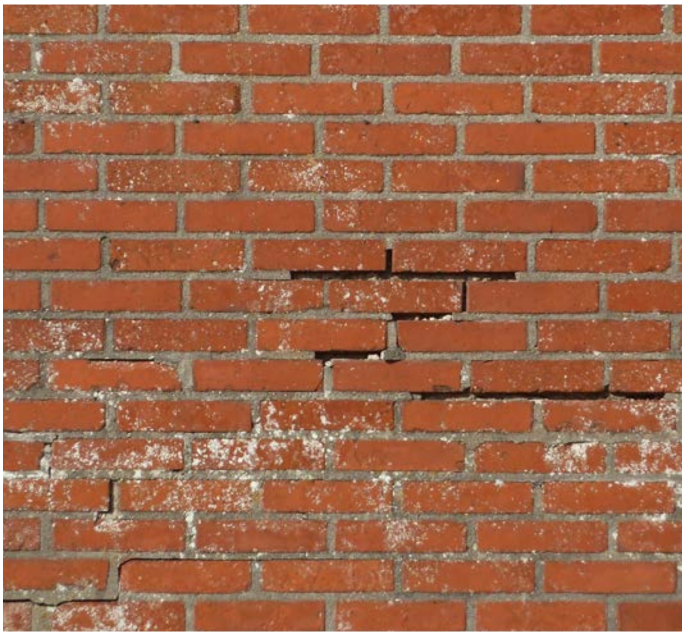
What to do

There are different methods for salt remediation.

- With a planned drying, salts will reach the facade. These must always be removed dry on the surface.
- In the case of brick facades, the joints must be completely renovated up to at least 50 cm beyond the affected areas.
- In the case of partially high salt contents, the salt-loaded areas are removed, i.e. contaminated plaster or stones are removed and new plaster or stone replacement is applied, resulting in a natural reduction of the salt content.
- Special coatings and it systems can be applied to the surface. After the plaster has been saturated with salts, the restoration plaster has fulfilled its function and must be removed.

In special cases, different chemical and physical processes can also be used.

Examples of salt efflorescence



Algae growth

Algae and cyanobacteria are micro-organisms able to create a biofouling film covering building surfaces. These micro-organisms can tolerate climatic variations, maintaining the metabolic activity only when appropriate combinations of dampness, warmth and light are present.

What to look for

Biofouling on building façades form patinas varying in extent, thickness, consistency, and colour from green to grey and black. This may cause readily recognizable stains, readily recognizable stains on the material surfaces. The bright green colour usually takes place on areas that are sufficiently moistened and not directly exposed to sunlight. Algae colonization appears on a large variety of façades (i.e. on stone, brick, plaster and mortar) and it is fostered by the presence of water on the material's surface. On the contrary, during dry and cold weather they tend to die, leaving a dirt deposit which later permits a rapid new growth as soon as suitable weather comes again.

Risks

Algae and cyanobacteria are the main colonizers of building façades, and later they may favour the growth of mould, lichens, fungi and other microorganisms. The biological colonization of external façades by microorganisms can change the aspect of the surfaces and can even compromise the durability of materials. In addition to the aesthetic deterioration, algae and cyanobacteria may also cause a biochemical and a biophysical deterioration of the building façade, like mechanical stress, and loosens mineral grains especially on stone surface.

Why it occurs

Algae growth is influenced by several factors such as climate, building design and façade materials. Among the most important ones are environmental conditions, temperature and free water availability. Façades exposed to dominant winds are more easily colonized compared to other sides of the building. Since the wind may transport both rain and biological contaminants, a façade which is often wet by rainfall promotes the growth of algae.

The main causes for wetting of façades are mainly given by wind driven rain, leaks from rainwater drainage systems and dew water. However, algae and cyanobacteria can survive dry periods and restart their growth when enough water is available. Therefore, the drying of façades during the day is not enough to prevent algae colonization.

Where to look for risks

- Surfaces with water streams often moistened for long periods
- Porous or rough building materials such as bricks, stones and mortar
- North-facing walls not directly irradiated by the sun
- Balconies, roof overhangs and roof drains
- Damaged waste-water pipes

What to do

Case-by-case evaluation and tests are needed for a proper recommendation to solve the problem.

Overall three methods are available:

1. Mechanical methods remove biofilm, stains and patinas from contaminated elements either by hands or tools
2. Physical intervention using ultraviolet (UV) radiation for surface treatments
3. Chemical methods include the use of biocide agents of synthetic origin like pesticides and disinfectant. Notice that legislation on chemicals approved for this purpose differ from each country.

Examples of algae proliferation

Rising damp

Rising damp is the transport of moisture from the ground, into the construction and up above ground level by means of capillary forces in porous building materials as brick and mortar. Rising damp can appear on external walls, or even on internal walls, and moisture accumulation can cause damage to the surface treatments and load-bearing elements, e.g. wooden floor slabs.

What to look for

Moisture in the façade can appear as darkened areas/wet spots and when it appears to be provided from below, the cause is likely rising damp. Rising damp can also be seen internally e.g. in basements or walls near ground level.

Risks

Moist areas in façades appear when the porous masonry is in contact with moisture, and absorbs water by capillary forces and due to water pressure. There are several sources from which the water in a moist façade can originate, including;

- Ground water, infiltrating water (seepage of surface water through the ground) or damp soil surrounding the foundation or basement walls
- Defective piping (either underground plumbing or external drainage systems)
- Surface water (precipitation in the case of the terrain being sloped towards the building)

Why it occurs

Porous building materials experiencing high moisture contents and low frost temperatures are at risk for frost damage. If pores in the material are filled with water that freezes and therefore expands, scaling of the outer surface may appear. However, some materials are more frost resistant than others, which depends strongly on the porosity and strength of the material.

Three conditions must be fulfilled for frost damage to occur:

- The material must be sufficiently wet
- A phase change must occur in the material
- The material must be sensitive to frost damage.

Where to look for risks

All areas close to the ground i.e. outside at the plinth, in basements both inside and outside, and in walls at ground level. Mainly in buildings where bricks or natural stones have been used close to or in the ground.

What to do

Rising damp can sometimes be mitigated according to the moisture source; e.g. repair of defective piping and wrongly sloped terrain may alleviate the moisture source, while moisture from damp soil can be reduced by installation of a drainage system on the external side of the walls below ground. In order to prevent moisture from migrating upwards via the pore channels in the construction, physical damp-proof courses (moisture barriers) can be installed in the perimeter of the wall.

Physical moisture barriers can be of steel plates that are vibrated into mortar joints in the depth of the masonry construction if the joints are continuous. It is also possible to saw through the wall thickness, a section at a time, and place either steel sheets or reinforced roofing felt as moisture barrier.

RIBuild

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637268