BS 5250:2021 – Management of moisture in buildings – Code of Practice

Commentary

BS 5250:2021 contains the latest guidance and recommendations for the management of moisture in buildings, which has been expanded by the introduction of a more pragmatic and integrated approach to analysing risks associated with excessive humidity and condensation, based on recent failure analysis techniques, including a 'whole building' methodology. The standard represents the 'state of the art' in terms of assessing, controlling and preventing the risks of moisture in buildings, and gives both design and practical recommendations supported by scientific research.

Overview

BS 5250:2021 replaces BS 5250:2011+A1:2016 and is the sixth edition of the standard since it was first published in 1975, when it started life as a Code of practice for the prevention of condensation in buildings. This latest edition of BS 5250 uses an integrated and pragmatic approach to identify the causes and effects of all sources of moisture in buildings, and its impact on both the building fabric and the health of the occupants.

Moisture risk in buildings has changed considerably over the past few years as new methods of construction have been developed, along with the changing functions of building type, the lifestyles of the occupants, and of course climate change. This means that apart from dealing with an analysis of the various separate elements, the interactions between them and the effects on the whole building as a system must be considered.

The latest revision to BS 5250 was stimulated by the publication of a BSI White Paper *'Moisture in buildings: an integrated approach to risk assessment and guidance'* in 2017, which acknowledges that the assessment of moisture risk in buildings requires a different approach than that previously adopted. It is now based on the knowledge that in both new and existing buildings, the gap between the design on paper and that of 'as built' may vary significantly. Consequently, there are few buildings without evidence of 'in service' effects of residual moisture from construction, moisture generated in normal use, and more seriously, moisture caused by building faults.

The Standard now takes account of the above scenarios by identifying moisture risk according to the type of building and the quality of the build. This is split between 'As Designed in Theory' (ADT), which refers to buildings as though built as designed, without construction faults or degradation in use; and 'As Built In Service' (ABIS) which refers to conditions resulting from commonly occurring problems or failures which arise either during construction or as buildings age, are altered or the materials used degrade.

BS 5250:2021 takes a 'whole-building' approach, which addresses moisture in buildings using a framework based on assessment, design, construction, and serviceability. This ensures that physical interfaces (the junctions between floors, walls, ceilings and roof) of the building envelope and the systemic effects of the whole, as well as the physical and historical context, and the 'as built' and 'in-service' conditions, are all addressed and integrated.

Apart from design guidance on how to avoid moisture related problems in both internal and external envelopes of the building (junctions, floors, walls and roofs), the Standard also includes information on the impact of heating and ventilation systems on the internal climate, and the modelling for calculating condensation risk of mould growth, surface condensation and interstitial condensation.

Scope

BS 5250:2021 provides recommendations for the management of moisture in buildings using an integrated and pragmatic approach. Unlike it's predecessors, the latest edition now includes information on all states of water, as gas, liquid or solid and the interactions between these states. It also describes the principal sources of moisture in buildings, the mechanisms for its transportation and deposition and provides guidance on how to manage and mitigate the risks during the assessment, design, construction, and operation of the building.

The Standard does not cover measures specifically dealing with flooding and escape of water in buildings. It is, however, applicable for all types of buildings, whatever their form of construction, both new-build and existing, and for both domestic and non-domestic uses. It is not relevant for buildings used for storage at sub-zero temperatures.

In terms of pitched roofs, BS 5250:2021 contains design recommendations for dealing with moisture risk for various types of cold and warm pitched roofs using tiles and slates with high water vapour resistant (HR) or low water vapour resistant (LR) underlays. Proprietary site-assembled sheet metal roofs, pre-formed (composite) insulated roof panels, fully supported metal and structural insulated roof panels (SIPS) and hybrid pitched with flat roof systems are also considered and suitable recommended design details provided that mitigate the risk of damaging condensation and condensation.

Content

BS 5250:2021 contains five Normative sections which identify the key factors related to the assessment and design requirements for managing moisture risk in buildings: -

1 – General

- Scope
- Normative references
- Terms, definitions and abbreviated terms

2 – Design and Guidance to avoid moisture related problems

- Design to avoid moisture related problems
- Guidance for builders, owners and occupiers
- Remedial Works

3 – Design Principles – building services

- Application of design principles – heating
- Application of design principles – occupied space ventilation

4 – Design Principles – fabric details

- Application of design principles – junctions
- Application of design principles – floors
- Application of design principles – walls
- Application of design principles – roofs

5 – Condensation Risk

- Calculating Condensation Risk

Annexes

There are also seven Informative Annexes which support the Normative key sections:-

A – Guidance for designers and builders – whole building approach

B **–** Properties of materials

C – Diagnosis of dampness problems

D – Moisture in buildings

E – Guidance for builders

F – Guidance for occupiers on how to avoid damaging condensation

G – The temperature and moisture content of air

Bibliography

Review of Contents

BS 5250:2021 is divided into five sections dealing with specific topics related to the assessment and risk management of moisture throughout the building envelope. The first three sections concern guidance and recommendations for assessing and preventing moisture related issues that may face designers, builders and occupiers of buildings including the importance of building services (heating and ventilation) in controlling the internal environment of the building.

- Section 1 – General – Scope, Normative References and Abbreviations
- Section 2 – Design and guidance to avoid moisture related problems
- Section 3 – Design principles – building services
- Section 4 – Design principles – fabric details
- Section 5 – Condensation Risk

Section 1 General

The scope of the standard covers an integrated and pragmatic approach to the management of moisture risk in buildings, ranging from interstitial and surface condensation, too high or too low internal relative humidity, rain penetration or high levels of ground water. It also describes in detail the interactions between water as a gas, liquid and solid state and which may impact on the sources of moisture in buildings, its transportation and deposition. Most importantly, the standard provides guidance on how to manage those risks during the assessment, design, construction and operation of the building.

A full list of Normative references to other British and European Standards along with descriptions of the terms, definitions and abbreviated terms is provided.

Section 2 Design and Guidance to avoid moisture related problems

This section provides essential information for all those involved in the design, construction and maintenance of buildings ranging from design issues to consider to avoid moisture related problems, assessing the likelihood of condensation, methods to use for assessing moisture risk, the internal climate of the building, the external climate and the build- up of the external envelope.

Three methods for assessing condensation risk are defined :- prescriptive guidance based on experience of commonly used applications have been used over many years; by modelling where appropriate standards such as BS EN ISO 13788 or BS EN 15026 and BS EN 10211 are used for determining the risk of thermal bridging; and by understanding and applying the principles of moisture safety in buildings.

The importance of correct detailing of the elements of the external envelope of the building are also examined, acknowledging that its essential function is to provide protection to the occupants and contents, by excluding rain and wind whilst moderating the flow of heat in both directions. The rate at which heat, air and moisture are transferred through the various layers of the external envelope, and the risk of interstitial condensation, are determined by the properties of the materials used for the various layers of the construction and their relative position to one another. The risk of condensation occurring at any point in a construction element is determined by the differences between the internal and external temperature and vapour pressure, the type of materials used including any cavities, and the relative position of those materials.

This Section provides detailed recommendations on the correct arrangement of the materials in the various construction elements, the importance of controlling transfer of moisture across cavities, selection of appropriate thermal insulation and the selection and use of air and vapour control layers.

Alterations and extensions to buildings including remedial works are also covered by reference to extensive information contained in the Informative Annexes C and E.

Section 3 Design Principles – building services

This section covers recommendations for the provision of heating and ventilation systems to control the internal environment of the building and prevent the risk of harmful moisture and condensation. Design principles applied to the various heating methods of the building to prevent surface condensation by achieving a balance of internal temperatures, solar gain, internal heat gain, ventilation rates and local climatic conditions and the thermal response of the building fabric, are also covered. The various options for maintaining adequate ventilation to the internal occupied spaces using natural, passive stack and mechanical ventilation systems are examined and detailed recommendations provided.

Section 4 Design Principles – fabric details

Contains the four key elements of the building envelope – junctions; floors; walls and roofs and provides design guidance and recommendations for the key construction details to ensure the risk of both surface and interstitial moisture related to the structural elements are mitigated, both at the design and in service stages of the life of the building. The importance of the correct detailing of construction elements by the provision of damp proof courses, vapour control layers, insulation, and ventilation products (mechanical and passive) are made using clearly indicated drawings and diagrams.

Clause 9. Application of Design Principles – junctions

The heat loss and surface temperature of the various materials in juxtaposition with one another at the critical junctions between the elements of the building envelope, commonly known as the 'thermal bridge' is discussed in detail. The severity and risk of 'thermal bridging' can be assessed by calculation using a formula that includes values for internal surface temperature, internal air temperature and external air temperature measured across the junction detail. The effects of thermal bridging at junctions on the risk of surface condensation or mould growth is important especially in buildings with high internal humidity.

Clause 10. Application of Design Principles – floors

The various categories of floor constructions – ground bearing, suspended and basement, are discussed, both in new and existing buildings. Moisture risk due to ground moisture caused by the lack of a damp proof course, post construction moisture due to the drying out of the floor screed or structural slab, moisture generated by the building occupants and their activities during the lifespan of the building are discussed in detail. As built in service conditions such as water leaks and defects in the external envelope of in piped services, including the impact of climate change on excessive rainwater build up causing pressure on drains and culverts which may overflow and affect the lower floors of adjacent buildings also add to the list of potential risks of moisture for floors.

This clause also includes connective and systemic effects related to the various floor constructions as far as good design and workmanship is concerned, to achieve a waterproof below ground construction including the wider implications of the adjacent environment. Compatibility of waterproofing systems, the addition of insulation and ventilated voids below suspended timber floors, the sealing of joints and junctions of the waterproof membrane, and for integral structural waterproofing systems - attention to the construction joints to avoid thermal bridging, are all covered in the recommendations and guidance.

Clause 11. Application of Design Principles – walls

This clause identifies five key sources of moisture that designers should take account of when assessing the risk of moisture in walls:-

- ground moisture
- rainwater
- as built (ABIS) conditions – external leaks, escape of water and undue air leakage
- construction moisture – water incorporated in mortar, plaster or render released as the wall dries out
- moisture generated by the occupants and their activities which may change during the life of the building

A check list in the form of a table of categories of context, coherence, capacity and caution relating to the construction details of walls is provided to support the various sub-sections which are listed as solid masonry walls of brickwork, blockwork, stone, concrete or other materials without a cavity; cavity masonry walls consisting of brickwork and blockwork with cavity; framed constructions of timber, concrete or metal with an external finish of either masonry, tile hanging, render or boarding; cladding systems such as glazing, curtain walling or insulated metal panels supported on structural framing members; structural insulated panel systems (SIPS) which are self-supporting; cross-laminated timber (CLT)/mass timber; modular/off-site or basements.

Moisture risk and its management, any connective and systemic effects that apply to new and existing buildings, including 'as designed' and 'as built' conditions are identified, and recommendations provided for construction details in all the above wall categories.

Advice on the application and design of cavity trays, weep holes and openings in walls to avoid the risk of moisture and surface and interstitial condensation occurring.

Clause 12. Application of Design Principles – Roofs

Pitched and Flat roof designs are addressed with regards to identifying and assessing moisture risk and the prevention of interstitial and surface condensation by the use of sealed ceilings, air and vapour control layers, vapour permeable underlays, and the ventilation of roof voids.

BS 5250:2021 acknowledges five key sources of moisture risk:-

a) water incorporated during the construction process (including precipitation);
b) precipitation after construction (e.g wind driven rain);
c) water vapour arising from the occupants of the building and their activities;
d) atmospheric moisture drawn into the roof during humid or damp weather conditions; and
e) As Built In Service (ABIS) conditions : external leaks, escape of water, undue air leakage

The Standard provides guidance on the calculation methods for assessing moisture risk in roofs in the form of a Table relevant for 'as designed in theory' (ADT) and' as built in service' (ABIS) conditions for various pitched, flat and composite roof types. These are listed as cold pitched roofs with an HR underlay; cold pitched roof with LR underlay; warm pitched roof with HR underlay; warm pitched roof with LR underlay; Hybrid pitched roofs; cold flat roofs; warm flat roofs above a concrete slab; warm flat roofs with timber/metal deck; inverted flat roofs; cold pitched roof with flat roof apex; site-assembled sheet metal roofs; pre-formed (composite) insulated roof panels; fully supported metal roofs; structural insulated panel systems (SIPS) for both pitched and flat application.

Designers are alerted to minimise the risk of surface condensation on the ceiling of any occupied spaces by ensuring that thermal insulation is continuous and that thermal bridging at roof/wall junctions and around openings should be minimised. The risk of interstitial condensation in a roof depends on the following conditions:-

a) the amount of water vapour generated within the building;
b) the vapour resistance and air permeability of any air and vapour control layer (AVCL) ceiling or internal finish;
c) the location of the thermal insulation relative to other materials and voids;
d) the presence of voids within the roof, and whether or not they are connected to the outside atmosphere;
e) the vapour resistance and thermal conductivity of the thermal insulation;
f) the vapour resistance and air permeability of any underlay or sarking;
g) the air and vapour permeability of the external roof covering, and;
h) the moisture risk in refurbishment if an existing roof build-up is being retained and overlaid.

The location of materials within the roof build-up is important, with those having the highest vapour resistance being placed on the warm side of the thermal insulation and those with the lowest being placed on the cold side. Provision must also be made for the safe dispersal to atmosphere of any moisture which might occur within the roof voids.

Where insulation is built up in more than a single layer, the thinnest layer should be located on the warm side and where combinations of different insulation materials occur, the material with the greater vapour resistance should be placed on the warm side.

Design considerations take account of internal finishes and ceilings, particularly the importance of maintaining air tightness to prevent the transfer of moist air into colder roof voids.

Recommendations for installing sealed ceilings and openings in ceilings to prevent moist air entering roof voids are highlighted, along with the importance of sealing openings in roofs (such as rooflights) and the risks of condensation occurring within a refurbished roof, where both changes of use and changes to the structure, should be taken into account.

Air leakage through gaps in ceilings plays an important part in allowing substantial amounts of heat and moisture to be transferred into the roof space by convection. Restricting the risk of this happening by sealing the ceiling or lining by using and Air and Vapour Control Layer (AVCL) or air leakage barrier will significantly reduce the transfer of both heat and moisture, improve the energy efficiency of the building and minimise the risk of interstitial condensation. The most commonly overlooked items that cause the greatest risk, are openings in the ceiling such as hatch covers and recessed light fittings, and it is important that these products are installed with suitable seals to prevent air leakage, particularly when located in or near moisture generating rooms such as bathrooms.

<u>Pitched Roofs</u>

When considering the roof build-up, designers and specifiers must assess the air permeability of the complete roof system – in the case of a pitched roof, the substructure (sheet sarking or square-edged board sarking, battens, and counter battens), the underlay type high vapour resistance (HR) or low vapour resistance (LR) and the outer weatherproof covering of tiles, slates, or sheet materials (metal or fibre cement).

The covering of a pitched roof consisting of discontinuously laid roofing elements such as tiles or slates laid on battens with an underlay, and possibly board sarking, can be either air permeable or air impermeable, depending on the air permeability performance of the tiles or slates, the choice of underlay (HR or LR) and board sarking. Careful choice of products selected for the roof build-up is needed, to avoid potential risks of interstitial condensation within the various layers. For example, an LR underlay may reduce the risk of condensation in the roof void but might increase the risk of condensation in the batten space with the possible decay of timber battens and corrosion of metal fixings, unless there is sufficient movement of air between the battens and through the gaps in the external roof covering.

BS 5250:2021 reinforces the above principles established in previous editions of the Standard, providing detailed recommendations for assessing the air permeability of the roof build up along with design details that incorporate ventilation openings where HR and LR underlays are used with both cold and warm pitched roof constructions.

In Cold pitched roofs, where the insulation is laid on the horizontal ceiling, the loft space is colder than the occupied internal spaces below and so when assessing interstitial condensation risk there are a number of inter-related factors which must be taken into account: - the internal vapour pressure; the rate at which air and water vapour is transferred by air leakage and diffusion from the occupied spaces into the loft via the ceiling or gaps around penetrations; the rate at which water vapour is transported from the loft to the outside air (via ventilation gaps); through the underlay into the batten space (determined by the vapour resistance and air permeability of the underlay); and how effectively any water vapour is removed from the batten space (determined by the air permeability of the roof covering).

For new and existing buildings, insulation levels can be high, with the risk of poor workmanship leading to air leakage through the ceilings and higher risk of condensation in colder loft spaces. The recommendations are therefore to minimise thermal bridging, particularly at the eaves, improve airtightness and maintain ventilation routes at the eaves.

As-built and in-service conditions place importance on the level of workmanship within the loft space (insulation, storage platforms), ceiling airtightness and their integrity throughout the lifespan of the building. This connective and systemic approach to the continuity of the internal thermal insulation and uncontrolled air leakage into cold roof voids is paramount in minimising the risk of interstitial condensation.

Recommended minimum free area of openings for loft space ventilation is provided in an easy to use table which specifies eaves and high level ventilation requirements based on free area of the opening in square millimetres per linear metre of eaves or high level vent. The ventilation requirements for complex roof shapes, such as hipped or pyramidical roofs, can be calculated using a formula based on empirical research.

Warm pitched roofs and hybrid roofs are also considered, where the use of an air and vapour control layer and the ventilation of small cold roof voids is described in the various combinations of roof build up using HR and LR underlays and air permeable and air impermeable roof coverings.

Flat roofs

In new build flat roofs can be insulated to a high level but as a result of poor design or construction may be subject to higher risks of moisture related issues due to the differences in temperature between the external and conditioned space is likely to be high. Existing cold flat roofs may have a wide variation of conditions since many do not have any insulation and do not conform to current standards.

The design of flat roofs should aim to achieve the following:-

- minimise thermal bridging at perimeters and penetrations
- achieve high level of air tightness between the conditioned space and roof build up
- maintain ventilation paths at the eaves (cold roof), and
- minimise rainwater cooling in the case of an inverted flat roof

Cold Flat Roofs can exhibit interstitial condensation due to the difficulty of achieving a fully sealed AVCL but surface condensation is less likely on the internal ceiling because the thermal insulation keeps the temperature above dew point.

The risk of condensation in warm flat roofs depends on the nature of the supporting structure, and framed structural elements rarely exhibit issues as an effective AVCL, insulation and covering are supported by a roof deck. On the other hand, a warm flat roof with a concrete deck that is only heated intermittently may be subject to surface condensation.

Inverted flat roofs with a framed structure are less likely to exhibit surface condensation but inverted flat roofs using a concrete slab with the building intermittently heated can. If insulation is installed within the roof build up then the impermeable waterproof covering is kept above dew point.

In the situation where a cold pitched roof has a flat roof apex, there is a high risk of surface condensation on the underside of the deck if there is no provision for ventilation. Where an LR underlay is used on the pitched roof ventilation should be provided to the flat roof apex where it meets the pitched roof on all sides, to a minimum of 5,000mm^2/m. Additional ventilation of 5,000mm^2/m is required as close to the midpoint of the flat roof apex if the span is greater than 5m. If an HR underlay is used, then the minimum ventilation free area should be increased to 10,000mm^2/m at low level to the pitched roof in addition to ventilation at high level. The performance of self-supporting sheet metal roofs and site-assembled sheet metal roofs against condensation risk, are generally affected by the degree of weather protection during assembly and the quality of workmanship with respect to ensuring continuity of insulation and airtightness of seals and gaskets. SIPS (structural insulated panel systems) perform similarly, provided the vapour resistance of the inner surface layer is equal or greater than that of the outer layer and all joints between panels are well sealed.

Refurbishment of roofs presents challenges in terms of assessing the risk of increased condensation due to possible change of use of the building and the structural elements e.g. ceilings, roof coverings, wall junctions etc.

Section 5 – Condensation Risk

Clause 13. Calculating condensation risk

This section and clause provides recommended methods for calculating condensation risk based on modelling using relevant standards and supporting software. BS EN ISO 13788 contains recommended procedures for the assessment of the risk of mould growth, surface condensation and interstitial condensation. It contains a method for calculating the monthly mean surface temperature of a building element or component given internal and external temperatures and when combined with data on moisture production and ventilation rate, will determine the surface relative humidity. It also describes a method for predicting the risk of interstitial condensation under certain environmental conditions, and can determine how much condensate may be deposited, how much may evaporate and any balance that may accumulate over a year.

A further standard, BS EN 15026, specifies a system of equations for calculating heat and moisture flows through a structure comprising different materials each of complex transportation properties. It does not take account of air flow through components and without any background guidance for users, is restricted to those with a high level of knowledge in this area of building science. A third methodology using non-standardised software and based on complex two and three-dimensional models using heat, air and moisture movement in building structures is available but are restricted in use by the input required form specialist consultants and research bodies.

Informative Annexes

Annex A – Guidance for designers and builders: a whole building approach

Annex B – Properties of materials

Annex C – Diagnosis of dampness problems

Annex D – Moisture in buildings

Annex E – Guidance for builders

Annex F – Guidance for occupiers on how to avoid damaging condensation

Annex G – The temperature and moisture of air