SUSTAINABLE DEVELOPMENT OF TIMBER STRUCTURES IN THE FACE OF MOISTURE DAMAGES

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ABSTRACT

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ABSTRACT

This thesis provides knowledge regarding moisture and timber relationships. The aim is to examine timber properties in the face of moisture pollution. The vast majority of houses in Finland are liable to this problem. This thesis deals with moisture management and its maintenance. As we take timber as the main material we examine the methods of testing, using and preventing the timber from destroying. This work offers knowledge of timber structures widely used in Finnish constructions. Research on this topic was done to find out problems and suitable solutions. As the result, the best engineering solutions are described and provided in this thesis.

Keywords Moisture, Timber, Engineering, Maintanance, Building design.

Pages 33 pages

CONTENTS

1 INTRODUCTION

In this thesis moisture and timber relationships are analysed and researched. Understanding of timber behaviour under elevated moisture content is essential. Years of previous experience are analysed and the main problems are stated. From the engineering perspective, we provide a solution for these main problems. The practical part is important for both engineers and regular home builders. The main design moments are structurized and evaluated in this thesis. The characteristics of timber should be understood and then articulated in the design solutions. A wide range of literature was used as the background for this work. Eurocodes and specific wood design books were a good base for this work. This topic is highly important because the majority of Finnish family houses have been built out of wood. Around 80 per cent of them experience moisture related problems. Most of them are due to poor engineering design and the lack of crucial knowledge.

The aim of this research based thesis is to state the common problem of moisture damage for timber houses. Following this, the detailed review of given information was made and the best engineering solutions were described. After completing the research, it was necessary to provide best guidelines in terms of design of the structure.

Such a topic is valid because building physics is quite a new subject in the construction. Due to the fact that construction faces new levels and challenges it has always been developing. It has been developing till this day and meets new solution constantly.

1.1 Background

The aim of this thesis is to reveal moisture management and its maintenance. Wooden structures are taken into consideration. This research developed timber as building material covering moisture problems occurring during the construction and following usage. A typical timber building is considered as a house to be made in a certain area according to its climate and moisture. As we take timber as the main material we examine methods of testing, using and preventing it from destroying. It is clear that without a detailed understanding it is hard to use the right materials especially timber like components. That is why the builders need a proper understanding on the topic of timber moisture problems. How to manage moisture in timber structures? How to prevent it? What insulation is the best? How to treat and maintain it all? These questions are usually being asked the most frequently. The thesis reveals the main moisture problems, comprises techniques and certain guidance. Common methods accumulated by years of using timber are included here.

1.2 **Objective**

In order to satisfy the objectives of the thesis a detailed research was carried out. There is a complete description, analysis and practical part of timber usage in relation with moisture. Specific observations acknowledge the main weaknesses and benefits of using timber in the construction industry, most specifically in single family houses. This thesis explains the relation between timber structures and possible moisture damages from both engineering and general perspectives and principles of sustainable development. The effectiveness of this research led to the conclusion of structuring main moisture problems. The thesis represents applied research.

1.3 **Methodology**

On the subject of elucidating timbers as the basic structure material the following forms of research were used:

1. collecting and analyzing data,
2. evaluating and justifying methodological choices,
3. providing working examples.

2 WOOD IN MODERN ARCHITECTURE

Timber is the only renewable building material which gives the warm feelings and emotion of comfort. Timber in building designing combines aesthetics and functionality. This specific material is able to transform any building space.
Choosing a construction material is a challenging and time consuming process which takes lots of time and effort. Building quality depends on material types and characteristics of timber. The following characteristics are loved by many constructions related professionals: Durability and Strength, cost and availability, aesthetic value, logistics and ease of maintenance.

The construction budget defines the building looks and properties. Wood fits in well. Timber is used in many residential buildings. In Finland over 80% of single family houses, 70% of terraced houses and 99% of recreational houses have timber structures.

2.1 Wood grading system

Under the "Nordic Timber Grading Rules", wood is sorted into main grades: From US I to US VII, where grade US-I is the highest quality, used for top-class joinery and exposed cladding. Grade US can be subdivided into grades US-I to US-IV. Grade V is the most common grade in construction, while grade C is used in areas such as packaging.

2.2 Properties

Timber is good construction material. It is important to understand its properties when using it on site. Best quality timber has the good strength. Timber as anisotropic material meaning It has different properties at different points. The timber strength depends on cross section part used. Strength of timber is enough to build low rise constructions. Also thermal resistance of timber is quite good compared to other construction materials. Using only timber in building family houses is quite good solution. Summarizing all of the above properties it becomes clear that wood is a quite good material when dealing with small building due to its good workability and cost. Also timber is natural material and does not affect environment. It is ecological and well balanced. The last thing deserves to be pointed out is that wood has attractive appearance which is loved by many people.

2.3 Advantages

Timber is the most popular building material and has large number of varieties. Timber as construction material can be used as load bearing structures and surface material. Execution of structures has big number of possibilities. Timber is suitable for winter and summer building due to its good usability. Execution of timber structures is possible without high lifting capacity. In addition to this, timber itself does not produce toxic or other environmentally harmful substances. Energy needed for processing timber products considerably smaller compared to other typical construction materials (eg. steel, concrete). Wood is material that is affordable for everyone. Timber enables lightweight structures which allow building to be constructed on different types of soil (load bearing capacity of soil). Comparing wood to other building materials using wood definitely saves time. Especially important is to point out that wood is quite good choice in construction in northern regions with bad weather conditions. Wood is faster to install and easier to treat than other materials. Also, wood building plans are easy to read and understand from construction engineering perspective. It makes it more applicable for everyone. Also, wooden houses are easier to treat or adjust after the construction. Due to elasticity and robustness timber can be built on areas where earthquake risk is high.

2.4 **Challenges**

It is well known fact that timber is natural product and made out of cells thus it has its advantages and disadvantages. Unlike artificial materials made with modern science, timber is exposed to number of challenges. It is important to point out that timber is sensitive to environmental conditions and can be affected by them. Timber is sensitive to moisture that has a direct effect on its strength and stiffness which is presented in this work. Decay and rot are major problem when facing excessive moisture. Moreover, thermal conductivity increases as the moisture content increases. Despite all the disadvantages timber usage has a positive ecological balance and its failure behavior can be predicted.
The following table displays detailed information about wood species.

Types of Wood	
Soft Wood	**Hard Wood**
Pine Wood	Teak Wood
Cedar Wood	Rose Wood
Fir Wood	Oak Wood
Spruce Wood	Maple Wood
Hemlock Wood	Ash Wood
	Mango Wood
	Mahogany Wood
	Beech Wood
	Cherry Wood
	Walnut Wood

Figure 1. Types of woods

3 MOISTURE RELATED PROBLEMS OF TIMBER

3.1 Main causes of moisture

World Health Organization (WHO) in 2009 has defined that there are ten common moisture problems in the buildings; plumbing leaks and spill

1. groundwater or rainwater leaking through building envelopes
2. condensation
3. water licking by capillary suction through porous materials in the foundation
4. poorly vented or unvented swimming pools
5. insufficient dehumidification by ventilation systems
6. usage of wet materials during constructions
7. infiltration of warm or moisturized outside air
8. poorly compensated drainage due to air conditioning, heating and ventilation system deficiency
9. and exfiltration of moist or warm indoor air through holes and cracks in the enclosure during cold weather

3.2 Mold and Fungus as outcome

It is a well-known fact that wood is a natural material, so it is widely exposed to natural threats such as fire and moisture. Wood is hygroscopic material. It means that wood can absorb some amount of water. Normal moisture content of construction timber is around 8-25%. It usually depends on relative air humidity. Relative air humidity varies widely from region to region. Timber properties may be different in different regions. The equilibrium moisture content usually depends on air temperature and air humidity that overall wood remains steady. After the wood is cut it usually reaches its final moisture equilibrium in a couple of weeks.

The fiber saturation point is a term used in wood mechanics. It is a point where all the extra water is removed from wood and only water bound in cells is left. In Finland at 20°C degrees is about 30%. At this point timber has the capacity to absorb extra water if needed. This is a decent structural benefit.

There are thousands wood species used in construction. Every wood has its own properties and acts differently. Mechanics of wood depends on part of wood being used.

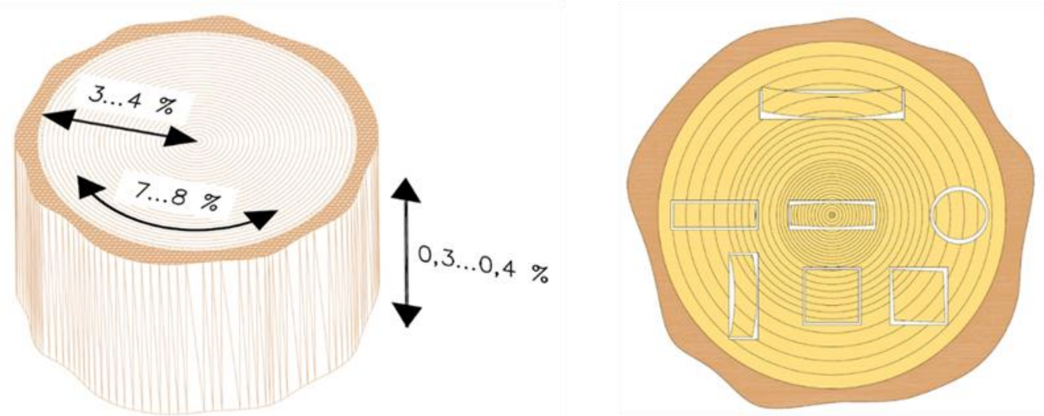

Figure 2. Wood cross-sections (Puuinfo 2020)

Wood Anisotropy arises from its fibrous structure and varies in terms of stiffness and strength. Coming from absolutely wet to dry condition wood shrinks. In terms of radial direction wood shrinks about 4%. Inner layers of wood are usually drier than its outside layers. This makes the drying process a bit complicated. Also during drying different forces occurs in timber specimen what causes warping. So during the construction moisture dynamics should be taken into consideration. It can potentially harm a building by losing overall building stability and structural balance. Wood beams can sink in the middle if the moisture content is too big. The cracks can happen in the different timber regions. Typically, as wood dries it only gains strength. Dried wood doubles bending strength and compression ability compared to fresh one. Dried wood is around 12-15% of moisture. The tensile performance is best at 6-12% moisture. In conclusion it is essential to point out that as wood dries it only gains strength in terms of building properties. Nevertheless, timber is still linked to air humidity and cannot drop below certain point because wood is 100% natural material.

In contrary when wood gains and absorbs moisture to the point of 20% it begins to suffer from it. Typical air humidity is around 80% and wood cannot ignore that. It begins to get molded. This is a quick process and can happen within a few months. When timber is exposed to 90% of air humidity, then wood may rot very quickly. 70% air humidity is the critical point above which wood is not on the safe side. It is important to point out that air temperature should be above 0 degrees (0 to 40 degrees C). If we are talking about below 0 temperatures which is typical for northern countries wood does not suffer any damage from molding and decaying. Due to the fact that these harmful spores need nutrition and temperature to grow.

Fungus cannot reach inner layers of wood so the structural properties cannot be touched by it. However, these types of bacteria can potentially be dangerous for human health because they can cause different body reactions such allergy and poisoning.

Wood is an ancient building material. Years of wood working experience accumulated its common challenges. When we are talking about inside wood materials we can state that excessive moisture can cause problem delamination. This is about wood products formed by layers such as flooring. This is basically the separation of layers because the product is non-homogenous.

Mold is another typical problem caused by moisture. It relates to both humans and structure. For human beings mold can be hazardous and in some cases can potentially lead to health problems. Mold spores can lead to respiratory infections. For wooden structures mold can compromise its integrity. The main thing is that mold should be prevented. It is often done by a moisture meter. It shows places with higher water content that need to be treated.
Moisture rich timber is good nutrition for any type of termites and insects. If this problem is not prevented, insects can spread throughout the building.

3.3 **Principles and strategy of sustainable development in timber structures**

Wood is sustainable material and widely used in Finland. Finland uses wood for different purposes. Annually Finland gains around 110 million m3 with only half being properly used.

The most damaged places in wooden based buildings caused by moisture is of course base floor structures and also nearest joints. Many people lack knowledge when using timber. Here we should break down the most common causes of damage and their circumstances. Today new building regulations help us with that. The result of wood being exposed to moisture for prolonged periods of time is that wood becomes moldy and decay. All types of woods are susceptible to this damage. Everybody who wants to build with wooden materials should understand biological and physical properties. In terms of wooden structures, it is important to ensure sufficient attention to problematic areas. Statistically around 80% of the damages in wooden buildings come from elevated moisture. The typical reasons for that are the following: wooden houses are directly touching the ground, wooden houses directly touching water, eaves are missing, not enough space for moisture related expansion, ground capillary rise water content has not been stopped, and wooden houses lack proper moisture insulation and air ventilation.

Modern wooden houses are widely equipped with wet rooms such as bathrooms, saunas and washing areas which previously were outside. This caused a moisture problem inside a house including water pipes that were susceptible for leaking.

When figuring out the moisture content and its damage to buildings of different ages it is important to realize what method of construction is being used. It is considered that the main problem of houses built in the 1950s is seepage along the cellar walls.

Figure 3. Bad moisture isolation (USS 2020)

Figure 4. Basement Seepage after rain (Pinterest 2020)

Other problems are often deteriorating the roof surface and pipes which causes leaking. In houses built in the 1960s there are many typical problems in certain parts of building. Typically, the roof problems are concentrated near roof ducts and usually happen in the springtime.

Figure 5. Roof duct moisture problem (918constructions 2020)

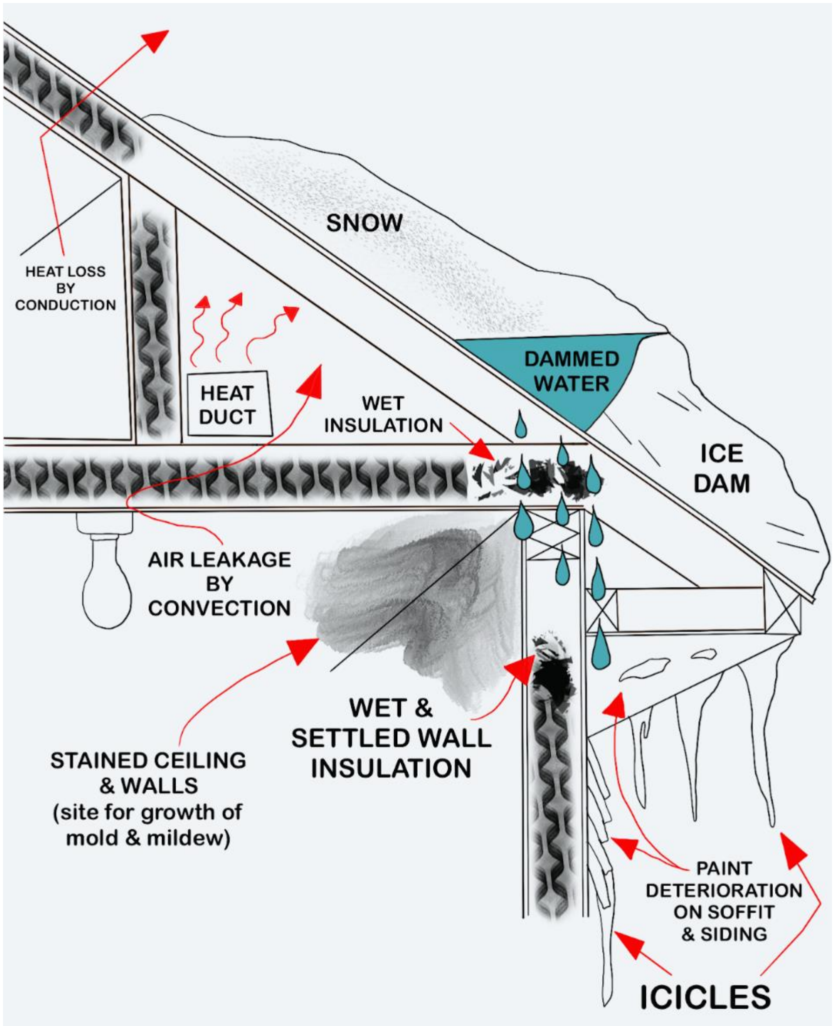

Figure 6. Moisture interaction with building envelope (Exteriorsbypremier 2020)

In these houses water pipes are concentrated in the floor structure and all the leakage can remain unnoticed. Also walls are exposed to moisture if not properly insulated. In the houses built in the 1970s the worst damage is located in the roof region near roof duct. In the 70s builders were still implementing water pipes inside wall structures; this type of damage is notable problem. In the 1980s builders started to use sufficiently inclined roofs and as the result it reduced amount of leakages. However, all the problems are still relevant today.

Figure 7. Pitched roofs versus flat roofs are safer choice in the face of moisture (A9architecuture 2019)

4 TYPICAL ENGINEERING DESIGN PROBLEMS IN TIMBER STRUCTURES

When evaluating the common problems, they are usually about the following reasons: roof inclination is not sufficient, floor damage caused by wet areas, building is not divided by moisture layers from the ground. According to the research done in 1995 by Partanen 70% of flat roof buildings get damaged. Only 35% houses with pitched roofs had problems. 42% of the houses had been damaged by wet areas. Damage caused by wet areas had 42% of houses. 50% of damages caused by outside water directly affect interrupting building integrity. However, pipe leaks are still common and typical for all types of houses.

Analyzing previous mistakes, it has become clear that moisture problems depend on materials and structural design as the most significant reasons with half of the damage achieved during the construction stage. Ageing and material deterioration are also the reason for it. Accumulated experience shows us that wooden houses are quite problematic. However, the building methods used is more important than the materials used. 1995Houses made in the 50s are stone based and their waterproofing characteristics are not related to wood to some extent. In the 60s and 70s most damage was caused by insufficient inclination. This experience shows that wood is not a bad material, the same problem was in stone based structures. It is just a matter of construction regulation and the method of construction.

Damage in facade areas of wooden houses was also studied and documented. This problem is not that significant as the previous one but still deserves to be paid attention to. This problem is about the protective eaves missing that hold water from facades.

Figure 8. Eaves protecting facade from water (Tulsaprotech 2017)

Usually facades are made by subcontractor companies and they typically do not pay enough attention to facade details while pursuing deadlines. Facade horizontal lines can typically hold water inside. Wall extension and corners if not specially treated can disturb the moisture stability. Vertical boards tied or nailed too close to each other makes it hard for wood to enlarge. Building wood structures in wet areas typically require more precise design to avoid these problems.

Public discussions are still going on about construction quality. The reason is that air issues caused by mold. Mold and moisture is the problem that affects not only wooden houses but the whole construction overall. In the broad sense there are two main reasons for that. Deadlines sometimes enable mistakes to happen that will cause problems especially for small subcontractors. This problem touches not only Finland but also other countries, especially southern countries with high temperatures and air humidity. Overall Finnish norms are perceived to be quite good. This problem must be researched in the future with expertise. Also building physicists should create new solutions and approaches. Structural solutions should be relevant and reliable.

5 REQUIREMENTS

In Finland moisture problems still remain, even though all the research and building physics are public now. Even though information is accessible; common mistakes are going on during construction. In fact, the ground floor and its joints are the most critical place of design, as well as wet rooms. But it is very possible to eliminate these problems and ensure long lasting serviceability of these structures. The general requirement is to raise the floor surface far enough from the ground and separate them. Under the ground floor it is necessary to have certain protective layers which help prevent water capillary rise. So we can stop water coming from below. It is important to have subsurface drainage for water. The crawl space under the wooden structure should be well ventilated. Wet areas should be made out of stone type structures and should be tightened up. Many problems come from these little movements of timber. Waterproofing in these areas should be properly complied. These simple steps help to avoid common problems. Cellar could only be made from stones. All the pipes should not be hidden from eyes, because they may leak.

5.1 How to avoid damage?

Even though building physics is still a developing topic not all the problems are eliminated. According to Partanen`s study held in 1995 it had been found out that the same problems were continuously repeated. Basically in new wooden buildings around 80% of problems are related to wet areas and ground floor. In terms of preventing damage, ground floors and their joints are the most difficult parts to design. By working carefully on building planning, construction and maintenance It is very possible to provide long lasting stability and building safety.

The main recommendation is to raise the ground floor sufficiently from the ground level. Below the ground supported floor it is necessary to put the moisture barrier which prevents water capillary rise from the wet ground. Moisture strain can be eliminated by providing ground slope and putting drainage systems around the building. The crawl space is an important element of the structure. The crawl space allows the ventilation process to build up under the building. Air ventilation prevents rotting. While in the winter time pipe insulation prevents freezing problems. The thermal insulation helps with this one. Thermal insulation should be placed under the concrete slab.

When it comes to the wet areas, they should be built from the stone type materials even in the wooden building. It is better to separate wood and wet areas even if there is good insulation. Water and stone create a perfect dialogue between each other not only because of water resistance and damage. It also gives aesthetics which perfectly fits any wooden building. Light timber structural elements are likely to move slightly which creates cavities and imperfection in terms of construction appearance. It is necessary to put reliable insulations to prevent problems. These simple ideas are quite helpful.

5.2 Steps for preventing damage

Throughout the years many recommendations have been set up regarding preventing moisture. Traditionally the recommendations include raising the ground floor and creating crawl space, creating eaves and external surfaces. Looking back to the old building it is clear that many mistakes could have been avoided by better understanding of building engineering and material behavior. Architectural experiments often push the industry to create something new. These types of experiments are inevitable because of the nature of the human mind. These experiments pushed building back to the ground surface avoiding engineering problems. Creating widely loved cubic shaped buildings with flat roofs are always relevant. It is clear that certain engineering solutions are not an eye catching element in terms of architecture, but they certainly are practical. Nowadays better dialogue has been created between engineers and architects. Many solutions have been modernized.

Finland decided to implement strict measures in terms of preventing moisture damages. To eliminate ignorance on this topic, Finland implemented building codes which covers every part of construction. In 1998 the building codes on moisture was renewed. The recommendations are the following. All the floors should be lifted up at least 300mm from the ground level. All the surrounding water should be redirected away from walls with minimum ground level inclination of 1:20 and area around should be implemented with drainage systems. To be on the safe side moisture layer should be 300mm. To stop capillary rise from the ground. Also the thermal insulation is required to be put under the ground concrete floor slab. Functional waterproofing should be implemented in the wet areas and on the roof. The minimum inclination of the roof should be about 1:40 to make it possible for water to leave the roof area. It is highly recommended to put water pipes on the open areas where possible water leaks can be seen early enough to treat them right. These recommendations are enough to make a wooden house waterproof to a certain degree.

Building regulations are quite extensive today in Finland. A service guide requires to be provided for any building. Building regulations pay a lot of attention to the quality of the design.

6 TECHNICAL PRINCIPLES AND REQUIREMENTS FOR TIMBER HOUSES IN RELATION TO MOISTURE

Penetrations Commonly Found in Roofs	How to Maintain Drainage Plane Water-Tightness
Joints between pieces of roofing	Shingling or sealing provides continuity
Roof edges	Overhangs, copings and drip edges provide capillary breaks
Roof intersections with adjoining, taller walls	Through-flashing provides continuity where a lower story roof intersects the wall of the higher level and where any roof meets a dormer wall. Flashing and counter-flashing of veneers and low-slope roof membranes keep water out of joints between materials
Skylights and roof hatches	Flashing, curbs and counter-flashing provide continuity
Chimneys	Flashing, crickets and counter-flashing provide continuity
Air handlers and exhaust fans	Flashing, curbs and counter-flashing provide continuity
Plumbing vents	Flashing and counter-flashing provide continuity
Penetrations Commonly Found in Walls	**How to Maintain Drainage Plane Water-Tightness**
Windows	Head flashing, jamb flashing and panned sill flashing provide continuity
Doors	Head flashing, jamb flashing and panned sill flashing provide continuity
Outdoor air intakes	Head flashing, jamb flashing and panned sill flashing provide continuity
Exhaust outlets and fans	Head flashing, jamb flashing and panned sill flashing provide continuity
Fasteners	Sealants provide continuity
Utility entrances	Sealants provide continuity

Figure 9. Common water penetration ways (epa 2014)

6.1 Exterior wall structures.

The outer wall and its various layers must form a unit, which prevents harmful penetration of water into structures. The water vapor resistance and airtightness of the external wall and its various layers, as well as the structures connected to the external wall and the external wall joints, shall be such that the moisture content accumulation of the wall is not happening due to indoor water vapor diffusion or convection, what is harmful for the moisture performance of the structure. If an air barrier or vapor barrier has been used in the structure, seams, edges and penetrations must be tight.

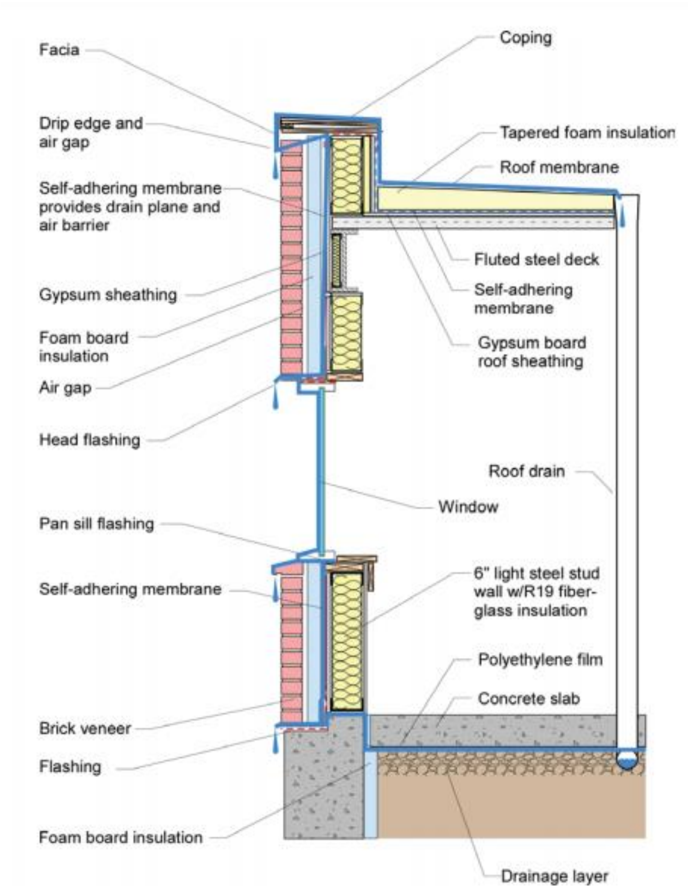

Figure 10. Moisture pathways in building envelope (epa 2014)

6.2 **Exterior cladding**

Water must not get behind the external cladding of the wall structure or if water and moisture are penetrating behind the exterior cladding, the pathways should be designed in such a way for water to freely leave the structure without any damage. The background of the cladding must be ventilated, unless moisture can otherwise escape.

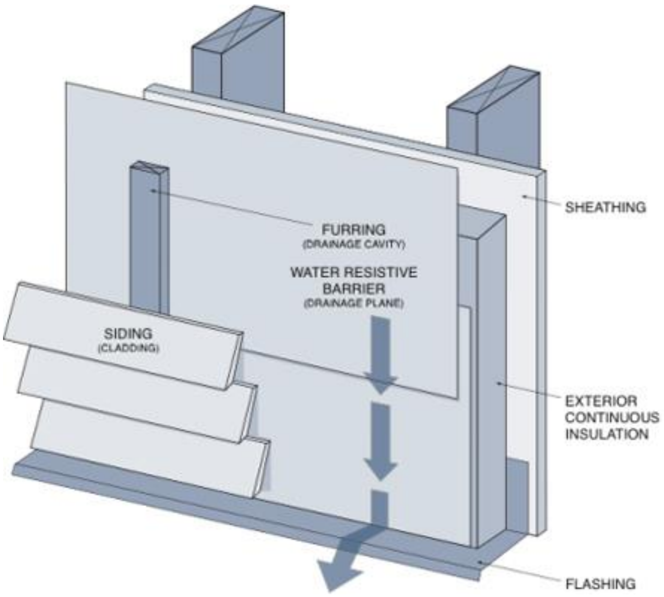

Figure 11. Building moisture protection (WBDG 2016)

6.3 Drainage of water from the roof

Water must leave the water roof without damaging the building.
The roof, with its structures and joints, must have a suitable slope and tightness to drain the water.

Figure 12. Water drainage systems (WiseGEEK 2021)

6.4 **Upper sole structures**

Ventilation of the upper deck layers and the roof must prevent harmful effects caused by water vapor diffusion or air flows.
If an air barrier or vapor barrier has been used, the seams, edges and penetrations must be tight.

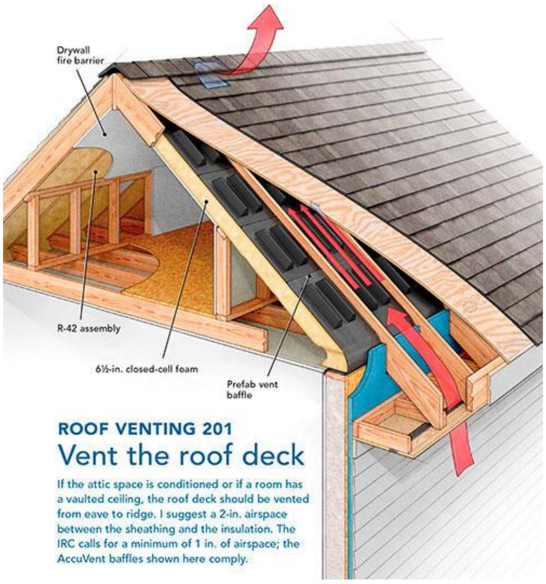

Figure 13. Roof deck ventilation (BuildingScience 2011)

6.5 **Wet rooms waterproofing**

Water must not drain or move as a capillary flow from the wet space to surrounding structures and rooms. For running water, the structure behind surfaces exposed to repeated splash water or surface condensation must be watertight. Wet room flooring and wall covering should act with waterproofing characteristics; and the wall behind the coating must have a separate waterproofing.

Waterproofing is not required in the wall of a separate toilet and steam room behind the coating. The roof covering of a wet room must withstand splash water, intermittently high due to the use of the room without relative humidity and temporary moisture condensation on roof surfaces. The waterproofing of the wet room must form a whole unit, which is tight on all its waterproof surfaces and the seams, penetrations and joints. Under floor covering or floor covering act as waterproofing for wet rooms. The existing waterproofing must be watertight and connected to the waterproofing of the wall. Wet room structures must be so rigid that heat and moisture movements do not damage the wetland waterproofing; or surface structures. Wet room must have a sloped floor. The slope of the wet room floor must allow water to drain into the floor drain. Waterproofing and floor drain connection must be tight.

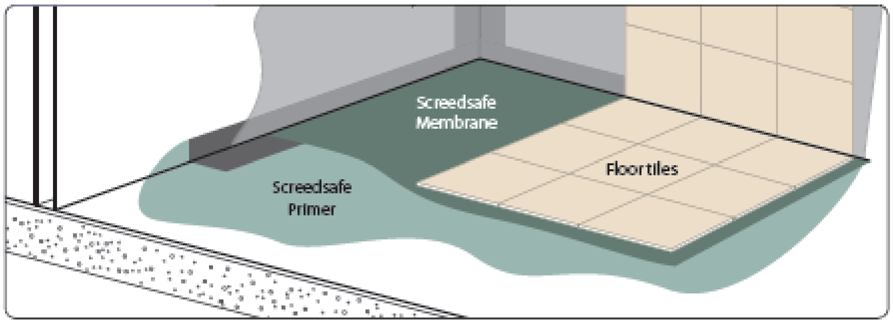

Figure 14. Floor moisture protection system (ccl-wetrooms 2015)

7 BUILDING INSPECTION

7.1 Weather and mechanical degradation of the timber:

The weather cycles not only the season ones but also the sun and rain cycles can shrink and deteriorate wood. How far it can go depends on the timber properties such as density, natural resistance to climate, level of protection. Wooden sheet products can warp or distort in places with most tension.

7.2 Insects and timber:

Building regulations should consider the insects' damage to timber. The insect prevention system should include specially treated timber such as chemical barriers on soil and physical ones. Chemical barriers are unstable if it is exposed to continuous moisture exposure. In this case it should be reinstalled.

7.3 Main sources of moisture in the buildings are:

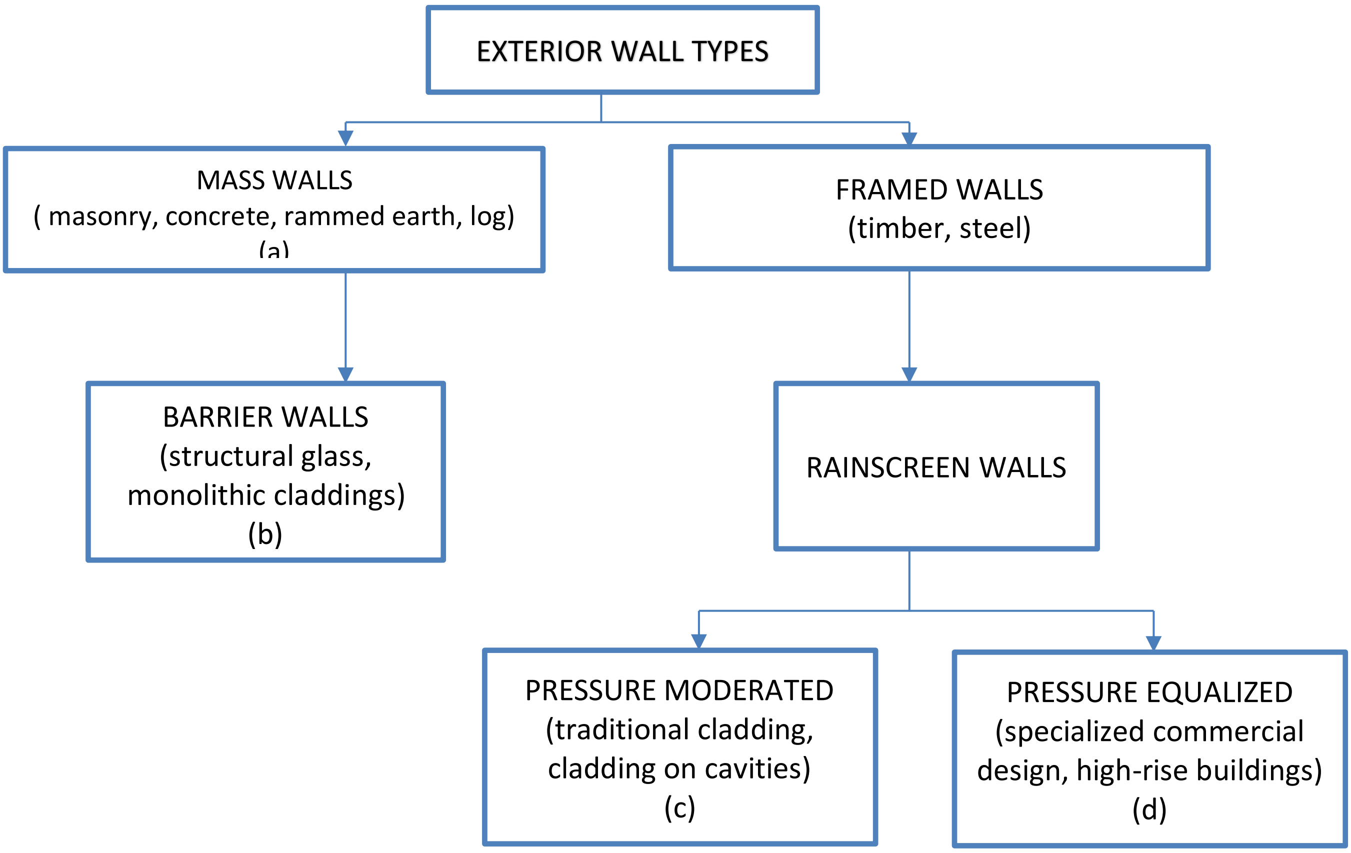

Figure 15. Wall types in moisture interactions.

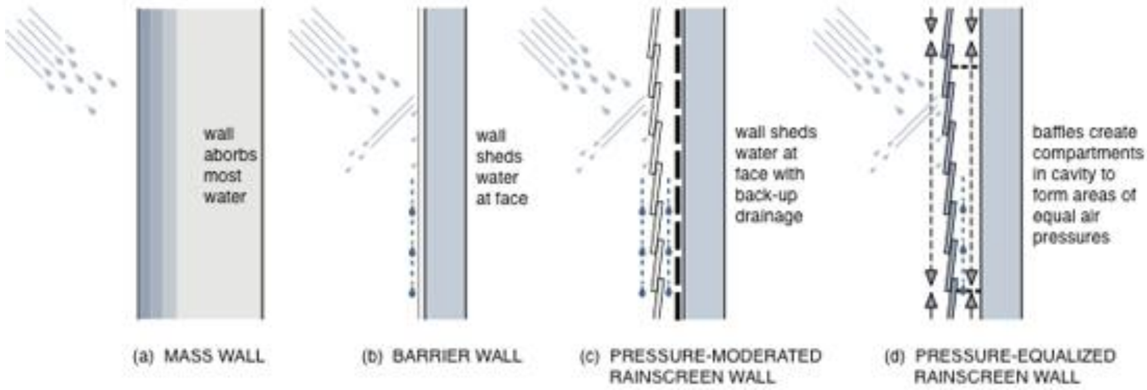

Figure 16. Walls in face of moisture interactions (WBDG 2016)

7.4 **Wall types and structure**

Selection of wall type is an important stage of construction. In terms of moisture safety wall structure should be well structured. There are a few types of walls for instance barrier walls that reflect water away or the walls with the rain screen. Usually the barrier walls do not provide acceptable performance, whereas rain screen walls are the only practical and effective walls. There are several things that should be noted. Wall cladding should be inclined in such a way to provide water sliding away from the inner wall in the most efficient way (1). The water that possibly penetrates cladding should be drained away by special routes (2). Special ways for air ventilation and water evaporation should be designed, not only that but the special materials should be set up (3). These materials should be durable enough to withstand the years of building life (4). These factors including eaves overhanging define how much rain deflected from the wall. In some climatic regions the wind driven rain is hard and can damage the walls and facades, so the external layer is of high importance. There are various ways inner layers can dry out and it depends on wall structure and materials and of course climate. In some climate zones evaporation is a slow process and inner drainage is a must.

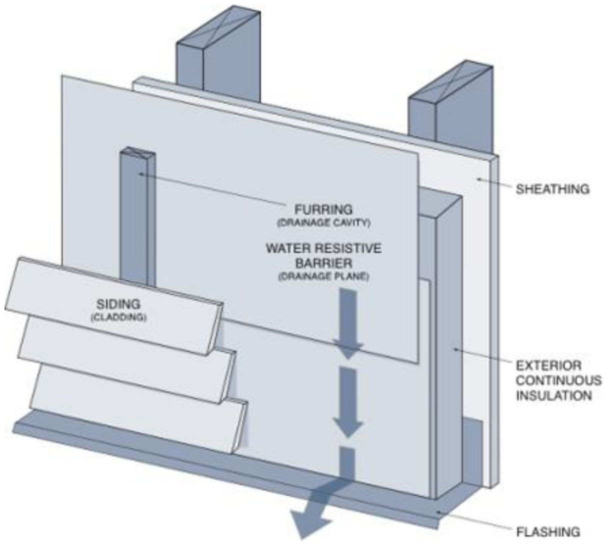

Figure 17. Wall system (WBDG 2016)

Rain screen walls are the most helpful tool in terms of a rainwater control. The last decades of building design research advise using water resistive barriers. It is basically water resistant materials, usually plastics. They are right behind drainage, behind the cladding. They are typically connected with building transitions, doors, windows and ventilation spaces. It is difficult to provide moisture safety without flashing because most of the building components have certain transitions or changes in shape. These cavities and endangered zones can be treated with flashing overlaps. Most of the flashing designs have proved itself over time and are now used widely. The building codes advise certain positions regarding flashings.

7.5 **Joint design**

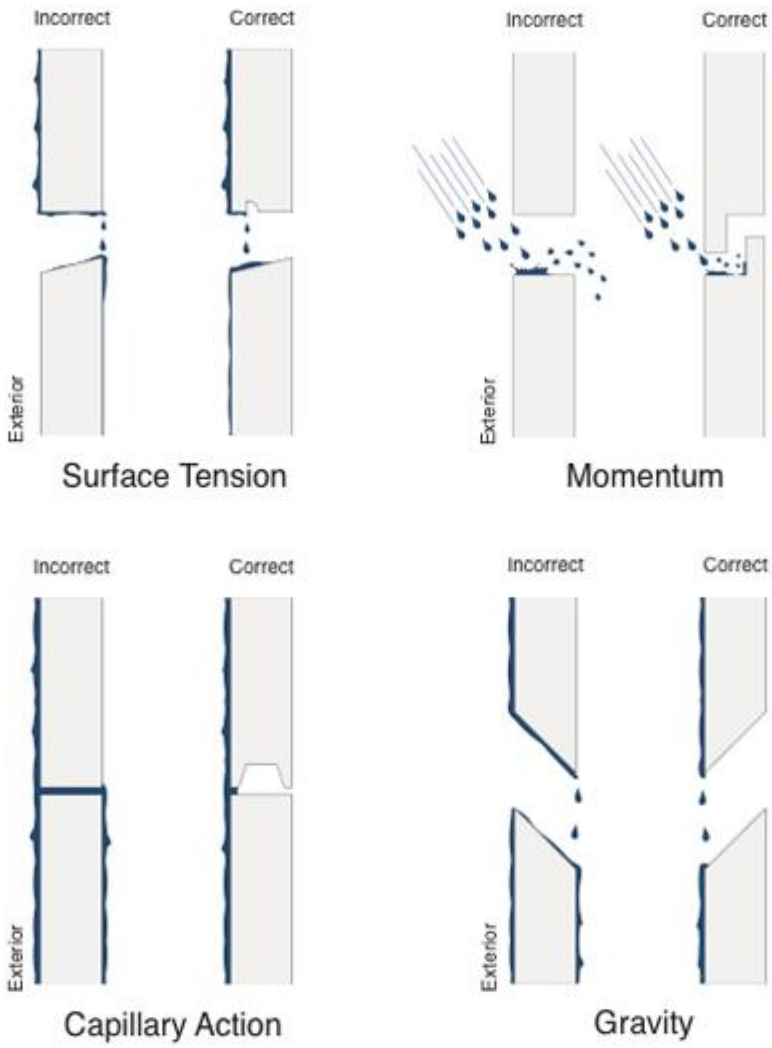

Figure 18. Joint types (WBDG 2016)

Joints in the wall cladding is an element that needs to be designed in the right way. Sometimes joints are sealed with special fillers. Important thing to take into consideration is that the modulus of elasticity of the sealers should be taken into consideration so that it can take the expansion of joints. For open joints it is essential to exclude moisture penetration on practical basis. Important thing is that these cavities should not let the water penetrate exterior layers. Also in climates like in Finland these cavities may accumulate water that later becomes ice which can lead to developing walls and cladding deformation.

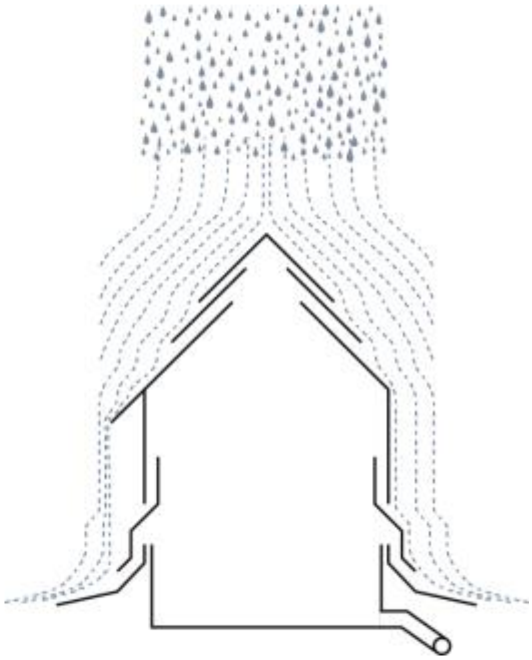

Figure 19. Building envelope (WBDG 2016)

When it comes to the roof the same principles are applied. Flashing overlapping and layering are the key. This is a proven way of shedding water away from the building.

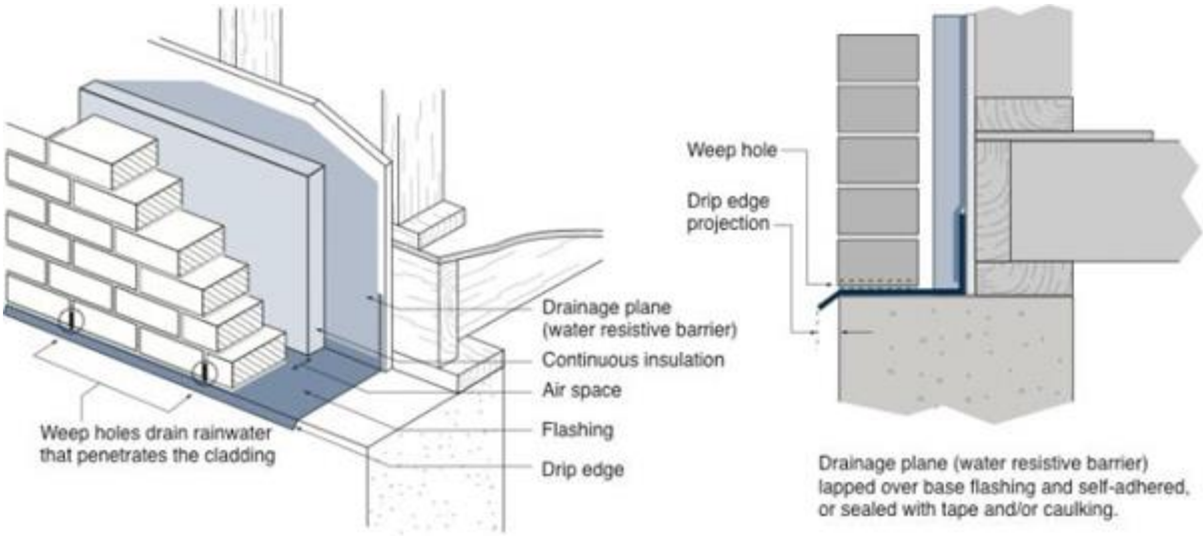

Figure 20. Envelope design (WBDG 2016)

The bottom flashing should be made from good reliable material. Usually it can be plastic based material, but the base one should be made from metal like material.

7.6 **Control of capillary rise.**

When It comes to the bottom part of the building it is important to provide safety against capillary rise of water. Usually water goes well with hydrophilic materials. For instance, widely used building materials such as concrete and wood can absorb water and transport it. Other materials such as plastics and steel and others do not react anyhow to water. So the first way of waterproofing is to put hydrophobic materials under the building so that they do not have any capillaries (1). It makes it impossible for water to penetrate it. Another way is to put a sub layer under the building so the large voids of it makes it impossible for water to go up (2). It is usually done by putting a layer of crushed stone or granular material.

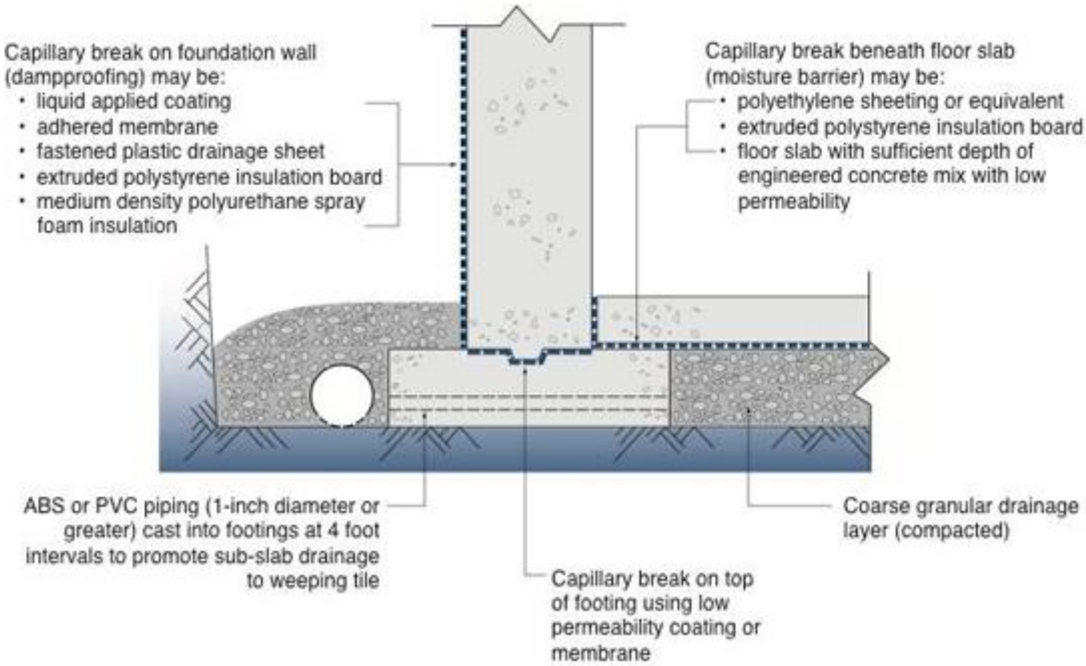

Figure 21. Water inside structure (WBDG 2016)

7.7 **Water Vapor**

It is a well-known fact that water vapor is everywhere in the air. Humidity of the air usually varies from region to region and is present in the inside and outside the building. The physical aspect of the vapor is based on the difference of vapor content within the layers. Due to the fact that vapor pressure differences are quite low compared to air pressure differences, the migration speed of moisture by vapor diffusion is lower than by air leakage. In cold climates vapor pressure gradients sustain throughout the heating season. Even though intensity of this is quite low it is still present over the prolonged time. So as a result, a lot of vapor can accumulate inside the structure and cause damage.

Vapor is transported not only by diffusion but by air leakage as well. When warm and moist air leaks through unintended openings and cavities to the building enclosures, there is a chance of water condensing in the wrong areas when temperature is low. In the extreme cases it can lead to material degeneration and material failure. The air leaks in terms of conditioning can lead to additional expenses

Due to material quality imperfections and poor workmanship that is linked to the construction, designers should keep in mind that air leakage can occur. It is a common problem and condensation often occurs. The most practical way is to provide a building enclosure with an air permeable layer. It is often achieved by applying thermal protection layers. It keeps the structure warm enough, avoids condensation.

Methods to determine wood moisture content and their applicability in monitoring concepts

7.8 **Resistance method**

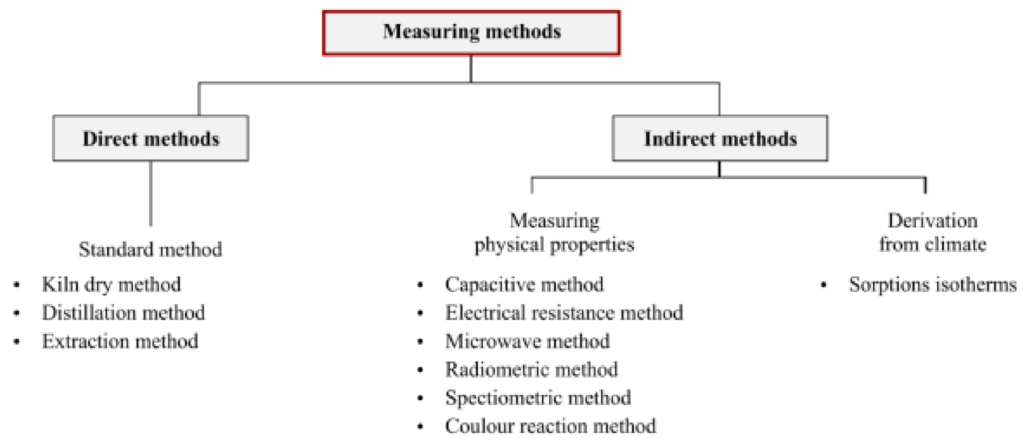

Figure 22. Moisture measuring methods (Journal of Civil Structural Health Monitoring 2014)

The best method of evaluating timber moisture content is the indirect method. It can be easily done without doing too much. This indirect method uses wood properties and electrical conductivity. It is a well-known fact that water has better conductivity than wood. As moisture increases the electrical resistance decreases. By knowing this correlation, the result can be obtained very quickly. The accuracy of the method correlates within 1 percent. This method is pretty much reliable however some factors can violate it. Material temperature can change the measure procedure. Take into account that as temperature increases the resistance decreases. This graph helps to figure out the “indicated moisture content” at 20 degrees C.

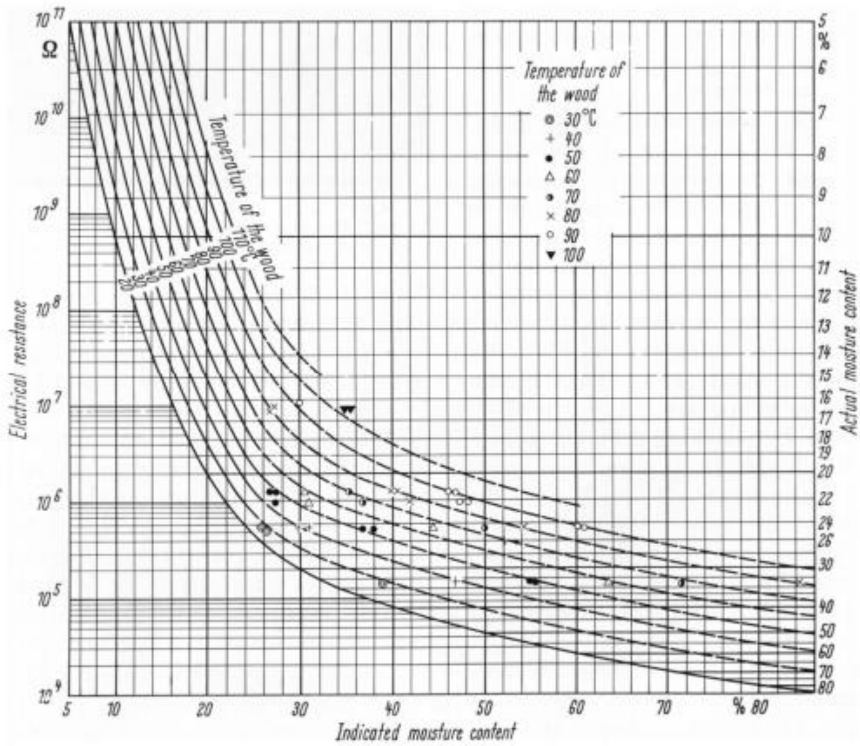

Figure 23. Indicated moisture content (Journal of Civil Structural Health Monitoring 2014)

The process of measuring is this. 2 electrodes are put into the wall at a distance approximately 30mm from each other. They need to be put perpendicular to the grain. If there is glue laminated timber specimen electrodes should be put in the same plate.

7.9 **Dielectric method**

Wood changes its dielectric properties with respect to the moisture content. As moisture increases the dielectric constant increases as well. In order to measure moisture, a condensate should be placed on top of the wood surface. Wood itself acts as dielectric. A special frequency signal is applied to one electrode and is received by the second one. This method is quite accurate to determine the right percentage. The measurement depends on material temperature, density and voltage frequency. This method gives us results on moisture content only near to the surface.

Fig. 11:Commercially available device using the resistance method

Fig. 12: Commercially available device using the capacitative method

Figure 24. Moisture measuring devices (Journal of Civil Structural Health Monitoring 2014)

8 MOISTURE PROTECTION

Moisture protection can be done for short term and long term protection. Water repellent wax covering in Scandinavia countries for wood has a limited usage. This type of treatment protects solely from brief rains and this type of brief water interactions. However long term humid air can overcome this protection.

Some types of timber such as glulam and panel boards have transit protection. This is just a
Temporary protection made only for transportation purposes. This protection is based on base oil. It does not replace full treatment.
Wood surfaces are typically treated with Tung oil which gives temporary anti-water protection. This oil is based on alkyd oil. Usually some chemicals are added in order to repel insects.
When it comes to long term protection, finishing with solid color usually has many treatments with different functions. Priming is done for reducing water absorption. Also the wood stabilizes and provides ways for next treatment.

The long lasting effect of anti-moisture protection can be achieved by adding big amounts of wood oil finally getting superficial coating. Vegetable oil is used; especially linseed oil is popular. Oil absorption is done primarily by heating oil what lowers its viscosity and allows better penetration. Pressure like absorption is a better option. Basically wood gains more self-weight which makes it impossible for water to come in. For some year’s pine oil was used in Finland.

9 CONCLUSION

The aim of the thesis was to provide and establish general knowledge of utilizing wooden structures in the face of moisture damage in Finland. As stated 80 per cent of Finnish family houses experience different level of moisture damages. Most of them were due to poor engineering design and lack of basic building knowledge. These problems are still actual today. Principles of sustainable development were stated and described in this thesis.

This work was written to provide an understanding of using wood with all its advantages and disadvantages. Years of experience in working with timber has accumulated typical problems and their solutions, such as poor engineering design and bad selection of wood types. A detailed explanation of major problems was included and studied with further recommendations.

Moreover, this work can be used as a guidance for anybody willing to build their own house. The moisture content in Finland is reasonably high and varies throughout the year which can cause problems for people. Timber is known as a natural, renewable material with beautiful structures which makes it eco-friendly. That is why it is deserved to be utilized in the right way.

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