Durability by design of wooden cladding and decking – an overview of guidelines and information sources

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Preface

This report is a part of the results in the European WoodWisdom-Net project WoodExter (see more in section 6, Acknowledgements).

The report aims at presenting existing information about durability by design, as it is reflected in handbooks, guidelines, scientific reports, manufacturers’ recommendations as well as other experience-based design information. The discussion is limited to cladding and decking. A further purpose is to elucidate to what extent the recommendations and guidelines are consistent and if they express different views on important detailing aspects. It should be emphasized that the purpose is not to make a synthesis of all available information and produce yet another, but more comprehensive and undisputable guide.

It is obvious that a large number of publications have been devoted to this theme over the years in many countries. Many of them are directed towards a national group of readers, which means that they are only available in the language of that country and not translated into e.g. English for a wider audience. It also means that they may reflect national conceptions and traditions to some extent, and it is therefore not to be expected that they all tell the same stories. Furthermore, the target groups of these publications vary from laymen to students and to engineers, and the scope, contents, and structures of the information are quite diverse.

Some information material only available on web sites has also been included in this overview, and for obvious reasons this has often a lower degree of reliability, partly because it may be promotion material focusing on only a particular line of products, and partly because its quality is not guaranteed by a publisher. It is nevertheless relevant, since web-based information may be the only information that reaches consumers seeking advice. It should be acknowledged that the web pages listed in this report are only examples, and the list makes no claims to present a comprehensive collection.

Also for the printed material that is listed in this report, completeness is by no means claimed. An initiated reader will certainly be able to spot many more scientific reports, handbooks etc which are not included in this material.
Summary

The concept of “durability by design” should be understood as “design for optimal durability”. For building products of wood or wood-based materials it encompasses all variations of dimensions, shapes, joints, fasteners, and treatments including coatings, that may influence the service life, or the durability of the product. The discussion in this report is limited to cladding and decking.

In a European perspective decay fungi is the overriding hazard, and the most important aim for durability by design is to keep the moisture content of the wood below critical levels. Some of the most critical design features are summarized in this report, with reference to a variety of information sources which ranges from handbooks and guideline documents to commercial product information in brochures or on the Internet.

Commonly shared views are found for many design features, while others are subject to differing opinions due to differences in building traditions across Europe. It is suggested that a short-list of the most important and commonly accepted design features will be presented in a brief information leaflet.

Sammanfattning (summary in Swedish)

Begreppet ”durability by design” kräver en uttolkning, som på svenska kan uttryckas som ”utformning för optimal beständighet”. För byggprodukter av trä och träbaserade material omfattar det alla variationer av dimensioner, former, konstruktionstekniska lösningar, fogar, fästdon och behandlingar inklusive ytbehandlingar, som kan påverka livslängden eller beständigheten hos produkten. Diskussionerna i denna rapport är avgränsade till fasader och däck/altaner.

I ett europeiskt perspektiv är tränedbrytande rötsvampar den klart dominerande riskfaktorn, och det viktigaste målet för beständighetsutformning är att tillförsäkra att materialets fuktkvot hålls under kritiska tröskelvärden för rötsvampars aktivitet. Denna rapport summerar en del av de mest avgörande detaljerna i den konstruktionstekniska utformningen, med hänvisning till en skiftande flora av informationskällor som sträcker sig från handböcker och riktlinjer till kommersiell produktinformation i tryckta broschyrer eller på Internet.

För många utformningsaspekter råder bred enighet, medan det råder delade meningar om andra aspekter, till stor del beroende på skillnader i byggtadition i olika delar av Europa. Ett förslag läggs fram om att de viktigaste och mest allmänt accepterade utformningsaspekterna ska presenteras i ett kortfattat informationsblad.
1. Introduction

1.1 What is durability by design?

“Durability by design” is a somewhat simplified term, intended to be understood as “design for optimal durability”. For building products of wood or wood-based materials it encompasses all variations of dimensions, shapes, joints, fasteners, and treatments including coatings, that may influence the service life, or the durability of the product.

Depending on the in-service conditions, the different design aspects will have different relative importance. In combination with and in contact with other materials, the durability of the wood material can be influenced by the adjoining materials through physical or chemical processes. A few such examples are differences in thermal behaviour, wetting of the wood through adjoining water-holding insulation materials, or the influence of released corrosion products from metals.

Durability by design also implies different actions or design features depending on the dominant hazard as well as the expected performance and the accompanying limit states. In cases where severe abrasion by sand, driven by hard winds, is a significant hazard, the design must be governed by concerns about meeting that particular hazard. When insect attacks are a dominant threat, protection is often given by treatments with biocides, but a design also has to be chosen that minimizes the risks.

Generally, however, in a European perspective decay fungi is the overriding hazard, and to counteract premature decay and ensure the desired design life of wooden building products or elements, the most important aim for durability by design is to keep the moisture content of the wood below critical levels. Durability by design is thus to a large extent a question of shaping the construction and the detailing so that an efficient water shedding is attained. Alternatively, or as an additional beneficial design feature, a design is sought that allows for an efficient drying of wood components that have been wetted above critical levels of moisture. With an inverse perspective, it is of utmost importance to avoid creating the negative influence of “water traps”, in other words such design solutions that can be foreseen to cause extended periods of increased wood moisture contents and thereby decay. Given favourable conditions, even a very local colonisation of decay fungi will eventually spread and jeopardize the function of a wood construction on a larger scale.

To summarize the most critical elements in the detail design, the influence of moisture on wood and wood-based materials must be minimized in constructions, and this can be done mainly by:

a) minimizing moisture ingress into the material
   i. providing an efficient water shedding
   ii. providing shelter by eaves or covering parts
   iii. protecting end grain (by detailing)
   iv. avoiding exposed butted end joints
   v. choosing dimensions and profiles that do not cause extensive swelling and shrinkage and that are tolerant to any dimensional changes that may still occur
   vi. using fasteners (e.g. nails, screws) that give minimal stresses, leading to cracks
   vii. applying the fasteners in a correct way, i.e. not too close to edges and ends
   viii. avoiding short distances from e.g. low parts of cladding to ground or hard surfaces, which will add to the wetting by rain splash and lingering snow
   ix. choosing appropriate surface coatings or other treatments, giving special attention to end grain, priming with oils and sealing with sealants and/or paint
b) ensuring rapid drying if the material takes up excessive moisture
   i. giving opportunities for ventilation of surfaces or back sides of panels that may
      become wetted
   ii. using water vapour permeable surface coatings or other diffusion open
      treatments
   iii. keeping contact areas between single wood elements small
   iv. avoiding narrow gaps at joints

There are also other actions to take in order to extend the durability of a particular
building component, like

- remediating cracks that appear in the wood surfaces during use
- avoiding moisture-holding vegetation close to the exposed component
- regularly inspect and remediate ageing or damaged surface coatings

Such actions are, however, part of a conscientious maintenance programme and cannot be
seen as part of the design. Item ix under a) in the list above can be disputed as being part
of the design, but it is a factor that can be planned at an early stage and the choice needs
to be done in harmony with the rest of the detailing.

1.2 Durability by design as a necessity for modern building
    planning and engineering

In a sense, durability by design has always been employed in the planning and execution
of construction works, even though it has often been used in a basic form which has been
mostly intuitive and based on experience and tradition. Such an approach, being less
refined and less well founded on scientific evidence, is not sufficient for contemporary
building planning and engineering needs. There is a growing demand for methods of
calculating life cycle costs of construction works, and a prerequisite for such calculations
or predictions is reliable and manageable methods for predictions of service lives.

One of the major driving forces is the CPD (Construction Products Directive,
89/106/EEC), for which an ongoing process is running with the aim of strengthening it
and giving it more weight by its transformation into a European Regulation. The CPD
highlights the following six Essential Requirements, which must be fulfilled during the
working life of construction works:

- Mechanical resistance and stability
- Safety in case of fire
- Hygiene, health and the environment
- Safety in use
- Protection against noise
- Energy economy and heat retention

Durability by design influences above all the ability to fulfil the first and the fourth of
these requirements and may have some implications for the third listed item. Other
parameters that are integrated into the planning stages as points for consideration include
the aesthetic qualities and, as already mentioned, the long-term costs of a building. Both
of these aspects are clearly dependent on the overall durability of the materials, and all
these requirements taken together strongly argues for durability by design that can afford
optimum durability, fit for the individual purpose.
The general planning stage of a construction can utilize a standard in ten parts, ISO 15686 “Buildings and constructed assets — Service life planning”, which is being developed since more than a decade by the Technical Committee ISO/TC 59, Building construction, Sub-committee SC 14, Design life. Service life predictions (SLP) are at the core of many of the aspects addressed by this standard, including life cycle costing and environmental impacts. Among all the tools and methods brought forward in ISO 15686, SLP is generally assumed to be performed through the Factor Method, in one form or another. The name of the method may be misleading and it has been met with scepticism by critics who claim that it is an oversimplification. This resistance hinges on the notion that the process involves a deterministic approach with only a simple multiplication of factors. In a more generalised form, however, an undefined function is used to express how an estimated service life (ESL) is derived from a reference service life (RSL):

$$\text{ESL} = \text{RSL} * f(A,B,C,D,E,F,G)$$

where

A = Quality of components (also referred to as inherent performance), e.g. natural durability, preservative treatment, coatings
B = Design level e.g. protection by design, detailing, sheltering
C = Work execution level e.g. site management, workmanship
D = Indoor environment e.g. temp., RH, condensation
E = Outdoor Environment e.g. climate, driving rain, shadow
F = In use conditions e.g. wear, mechanical impacts, user influences
G = Maintenance level e.g. quality and frequency of revisions, accessibility

Various ways of refinement of the Factor Method by using probabilistic methods have been outlined in other reports within the WoodExter project. At the least sophisticated level, the Factor Method may be used as a checklist for the influencing factors that must be included in an estimate of service life.

In this context it may suffice to conclude that durability by design includes considerations of factors A, B, and C, which in turn are dependent on and must be deliberated with respect to factors D-G. Furthermore, it is obvious that factors A-C are profoundly important for the resulting performance of a construction or its individual components. In fact, it is very often found that design and work execution (factors B and C) are ultimately determining and that flaws regarding these aspects overrule the influence of factor A.

2. Cladding

The guidelines given in more comprehensive handbooks show variations in their ambitions and scope. Some of them (e.g. [5]) have included descriptions of various quality grades of sawn timber and the surface roughness after sawing or planing, which is omitted altogether in other sources. The following division in sub-sections 3.1 Unifying guidelines and 3.2 Differing views, respectively, attempts to describe in broad terms on which points guidelines are more or less unanimous and on which points practitioners and scientists have not reached consensus and where different “schools” compete. It should be

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said that the discussed aspects of materials and constructions do not claim to give a fully comprehensive account of every conceivable influencing factor and construction case.

Construction parts that must be considered in design:
- distance to the ground
- horizontal joints of elements
- vertical joints of elements
- corner joints
- connections to windows and doors
- connections to roof
- ventilation
- type and placement of fasteners
- building physics (heat and moisture flow, in particular when no ventilation is present [30])

2.1 Unifying guidelines

2.1.1 Choice of wood material

The sawing pattern influences the performance of boards exposed to weathering and intermittent wetting. Radially sawn boards are generally preferred to tangentially sawn (Fig. 1), since they exhibit smaller moisture movements along the flat sides and hence are less prone to cracking and cupping. Even though the awareness of the advantages with radially sawn flat sides is relatively well spread, direct recommendations in favour of such boards are sparse in the flora of guideline documents. The reason for this can be that such boards are difficult to find in practice, since current saw mill processes are not, in general, adapted to this production.

![Figure 1. Radially, diagonally, and tangentially sawn boards [21].](image)

Sawn timber is commercially available in several quality grades, and there are several different systems for grading. The rules for CE labelling of panels are given in the harmonised European standard EN 14915:2006 (Solid wood panelling and cladding. Characteristics, evaluation of conformity and marking), but it contains no compulsory quality requirements. The two standards EN 14519: 2005 and EN 15146:2006 on quality are referred to, but only in an informative annex. In general terms, however, there is no doubt that certain defects should be minimized or avoided altogether. Defects like juvenile wood, wane, loose knots, moulds, blue stain, and cracks will negatively affect the dimensional stability and the integrity of a coating, and may lead to increased tendencies to water uptake and lower the resistance to biodeterioration. The accepted frequency of such defects are stated in different independent quality assurance schemes.
There is general agreement about the reduced tendency for cupping of boards with grooves on the back side, as in Figure 2. There is still considerable uncertainty, however, on precisely how much can be won by this precautionary measure or which of the many possible grooving patterns is the most efficient.

![Figure 2. Reduced cupping of grooved boards on drying [20].](image)

It is also generally recognized that boards with sharp edges are more vulnerable to mechanical damage than boards with rounded edges. Perhaps more importantly, rounded edges are also necessary for the forming of uniform film thicknesses of coatings. Most guidelines do not specify a specific radius for the edge, as in the guidelines from Austria (see Figure 3).

![Figure 3. Recommendations for the rounding of edges [21].](image)

2.1.2 Fasteners

The purpose of fasteners is dual; they shall fix the wood elements in their proper positions but also serve to suppress some of the twisting, bowing and cupping that boards tend to undergo when internal stress is released. At the same time, an exaggerated and incorrect use of fasteners hinders the necessary freedom of movement due to changes in moisture content and will thereby contribute to the formation of cracks.

From the point of view of crack formation it is thus an advantage to use nails or screws only in the middle of cladding boards and battens, and not near both edges. Cupping may become a pronounced problem for wider boards, and the use of only central fasteners is for that reason generally discouraged for boards wider than 120 mm (e.g. in [21]), but it also depends on the board thickness. See also 3.2.3 below). An alternative that counter-acts cupping while slightly decreasing the risks for cracks is to apply fasteners near both edges, but in a zigzag pattern and never in parallel.

While nails is the predominant choice of fasteners, screws have some advantages. They often have a larger withdrawal capacity, and they allow individual boards to be dismounted for maintenance or replacement without damaging adjacent boards. Small cracks that form around fasteners, directly or with time, are common entrance points for water. Pre-drilling (not frequently done with nails) is therefore advantageous. Self-drilling screws exist as an alternative. For both nails and screws it is important to drive them to such a depth that the heads become flush with the surface.
With horizontal shiplap or with tongue-and-groove boards the fasteners may also be covered by the following board. This results in a cladding with no visible nail heads and small risks for water ingress through nail-induced cracks or damage to a coating film. The same is true for more advanced systems of mounting with hooks and clamps that are applied to the backside of boards with short screws.

Figure 4. Incorrect and correct depths of screw heads [21].

Figure 5. Examples of visible and concealed fasteners [21].

Figure 6. Recommended positioning of nails in vertical panels [20].
2.1.3 Building base

To avoid excessive wetting from water splashing back from the ground and to protect the cladding from a snow cover, a minimum distance of 300 mm between the cladding and the ground is commonly prescribed or recommended. This distance is to some extent dependent on the nature and the hardness of the ground. When a cladding reaching down close to the ground is desired for architectural reasons, horizontal boards allow the creation of a “sacrificial zone”. The lowest boards must be easily replaceable when the need arises. This solution can be used regardless of the orientation of the cladding boards higher up.

For vertical panels, particular attention must be given to lower board ends. End grain should be protected with a good paint or other sealant, and preferably also with a preceding oil treatment, in order to achieve minimum water uptake. See the continued discussion in 3.2.4.

2.1.4 End joints

Due to the ease of water transport through endgrain, ends are generally the most sensitive parts of boards. Provided that the upper ends of vertical cladding boards are adequately protected by eaves or metal edge flashings, the lower ends are the most vulnerable parts of the boards.

For horizontal joints in vertical panels, several variations of ventilated construction solutions are possible, such as the examples in Figure 7. The lower board can be protected by a slanted board or by a metal strip. There are variations among published recommendations about the more precise detailing, including distances, but the principles remain the same. Butted end joints (with a small or no gap for ventilation) are extremely vulnerable and should be avoided. They can be acceptable, but only with rigorous sealing of the end grain.

![Figure 7. Examples of solutions for horizontal joints, left [22] and right [21].](image)

Vertical end joints for horizontal panels can similarly be performed in several ways. Figure 8 shows some design examples for open joints. In the upper examples, each end is
supported by a separate joist, and the open space behind facilitates drying. The leftmost picture shows behind the end gap a slit metal profile that forms a channel for runoff of driving rain. The lower part of the figure shows end joints protected by a batten or a metal profile.

Figure 8. Examples of solutions for vertical joints [21], above: open joints and below: joints covered by battens or metal profiles.

### 2.2 Differing views

#### 2.2.1 Choice of wood material

For massive, untreated wood, there are differences throughout Europe as to which wood species are most commonly used in cladding. In the Nordic countries the domestic wood species Norway spruce (*Picea abies*) is most common, while Scots pine (*Pinus sylvestris*) is sometimes locally preferred. Larch is common in the Alpine regions but has also found a growing market in many other parts of Europe. On the whole, the choice of wood species is, expectedly, depending on tradition and local availability, but also some imported species have a place on the market. Other species used include Douglas fir and Western Red Cedar, and less frequently aspen, oak, teak, and Robinia. The heartwood of pine has a higher classification of inherent natural durability to decay than spruce, according to the standard EN 350-2, but this is not true for pine sapwood. One reason for the more widespread use of spruce may be the difficulties and costs involved in procuring pure heartwood cladding boards of pine, and with an unpredictable proportion of sapwood follows a more uneven and more unpredictable performance. The dominant reason is presumably the slower uptake of moisture in spruce and the higher risk of blue stain in pine sapwood.

In addition, several different treatments of wood are available that produce materials that most conveniently can be regarded as different species altogether, since their technical and characteristics and respective susceptibility to biodeterioration differ considerably from those of the original timber. Examples of this are thermally modified timber and timber treated with wood preservatives.
There is no simple way to find reliable statistical information about the occurrence of different wood species across Europe, but it can certainly be claimed that national and regional differences exist and that they are based on experience, availability and tradition.

2.2.2 Board orientation

The orientation of boards is important for their performance in response to variations in climate. For tangentially sawn boards, the bark side undergoes larger swelling and shrinking movements with varying moisture contents. The overriding goal is to ensure that any occurring cupping does not open the cladding to further water ingress. Provided that the boards are planar when mounted, they may cup due to drying out after some time of use. The orientation in Figure 9 depicts what will happen with boards that all have the heartwood exposed and a situation where half of the boards have the opposite orientation in a board-on-board cladding. The two remaining alternatives for orientation will produce open gaps on shrinking and give higher risks for crack formation. This reasoning presupposes that the panels have a higher moisture content to begin with than they will ever have henceforth. It is doubtful whether this condition can be guaranteed.

There is one circumstance that hinders a universal use of the left-hand method in the picture, namely that the surface roughness may be different on the two sides of the boards if it has been sawn from timber of larger dimensions. Generally, the surface roughness should be the same everywhere to give the cladding a uniform appearance.

![Figure 9. Concordant (left) and opposing cupping (right) of boards after shrinking [20]. The left-hand situation is rated as a good method and the right-hand as an acceptable, but it entails a greater risk for cracking of the bottom boards.](image)

As a curiosity, strong views can sometimes be found regarding right and wrong regarding the vertical orientation of vertical boards, i.e. whether the original top end (of the tree) should point upwards or downwards. Convincing scientific evidence in favour of either of these two alternatives has never been brought forward, and this aspect is seldom discussed in any published guidelines.

2.2.3 Fasteners

As already mentioned in 3.1.2, there is an inherent conflict between the wish to suppress unwanted movements in cladding boards by fixing them with many fasteners and the need to use as few fasteners as possible in order to minimize the effects of inevitable movements and ensuing cracks that the fixed points then result in. The mentioned limit of 120 mm board width for single or double fasteners across the width seems to be an
average limit, but different recommendations are found in different sources and for various board profiles and cladding assemblies [22].

### 2.2.4 Lower ends of vertical boards

To cut lower board ends at an oblique angle is recommended unconditionally in several guidelines, the idea being that the sharper edge facilitates the dripping off of water running down the face. It has been shown, however, that this practice has no effect on the water uptake if the end grain has not been given a proper sealing treatment. Instead, the slanted ends may constitute a disadvantage if they make inspections and maintenance more difficult [20].

The other strong recommendation regarding lower ends is to never let them further down than a certain minimum distance from the ground (see 3.1.3). Rain water splashing back from the ground will otherwise add to the load of running rain water that affects board ends. A further disadvantage is that the splashing water brings a lot of dirt onto the boards. At least the first part of this argumentation can be challenged, however, at least for climates with a moderate precipitation. The distance to the ground clearly has some importance for the wood moisture content, but some research results indicate that an efficient moisture protection of ends with oils, primers and sealants has a much more profound effect [31]. Naturally, whenever possible you should use both these principles for protection but bearing in mind that the end treatment is of greater importance if it is regularly inspected and properly maintained.

### 2.2.5 Ventilation gaps

Recommendations for the width of ventilation gaps vary from 10 to 25 mm. Ventilation gaps are, however, not always necessarily effective. Gaps that give no opportunities for air movement have a very limited influence on drying times for wetted wood. As an example, a cladding which is mounted with an air gap to an exterior wall must be fastened on double layers of crossed studs or on staggered studs in order to make any air movement possible. The board-on-board design naturally creates ample space for air movement. Another requirement is that there is a sufficient opening both at the foot and at the top of the cladding; otherwise the gap represents nothing more than a closed air pocket. A potential advantage of mounting the cladding without an air gap is also that a somewhat larger fraction of the heat transported through the wall can reach the panel, thereby driving out excess moisture to a somewhat higher degree.

Different opinions about the merits of air gaps (ventilating or non-ventilating) show up in various texts of guidelines etc. In many cases the advice fails to make any distinction between such air gaps that do have a ventilating effect and such that do not. There is also very little theoretical discussions to be found regarding the effects of ventilating gaps that through convection lead moist air, even saturated, into contact with otherwise unexposed wood surfaces.

### 2.2.6 Coatings

The standard EN 927 “Paints and varnishes – Coating materials and coating systems for exterior wood” describes three classes according to different end-use categories: coatings for stable, semi-stable and non stable wood elements; the latter two are relevant for cladding.
With regards to their moisture dynamics characteristics, two broad groups of coatings for cladding can be discerned: Diffusion open and diffusion tight. The first group contains low-build stains and distemper paints (as the traditional Swedish Falun red paint) and the second group contains all film-forming paints and paint systems that have the exclusion of water ingress as a main feature.

The first group allows wetting of the wood underneath, but they also let the excess moisture out easily during dry periods. The inevitable large fluctuations in wood moisture content leads to dimensional changes that will with time produce checking of the wood surface. These may also bring about a greater stress on fasteners, but the intermittent wetting does not necessarily lead to a greater risk for decay, as long experience has shown. The crucial process here is the rapid rate of re-drying.

The latter group contains pigmented paints (opaque and semi-transparent), which is the most common case, and clear coatings that leave much of the natural appearance of the wood visible. Many attempts have been made to develop clear coatings with a better inherent resistance and screening effect against UV radiation, which gradually breaks down both the binders in the coatings and the underlying wood. New research efforts may soon result in new generations of clear coatings with much improved UV resistance, but due to their poorer long-time durability this is so far a much smaller product group.

As long as the paint film remains intact, without cracks, it can effectively keep the wood moisture content at a low and satisfactory level, below critical values where decay fungi are active. With poor detailing, poor workmanship and with cracks formed in an aged paint film, a greater risk for water ingress follows and that is when the paint can become a liability. The rate of evaporation of water (vapour) through small cracks can generally not match the rate of (liquid) water ingress through the same cracks, and the net result may be an accumulation of moisture in the wood.

Such an unfortunate situation can to a large extent be prevented, though, by proper detailing, workmanship and regular maintenance. In most cases, the paint has an overall protective function. The French guideline booklet [16] from 2007 gives an interpretation of various design features and how they can influence the apparent Use Class, and it adds one unit for “impermeable coatings”. This means that such coatings are automatically classified as having a negative influence, i.e. implying a higher risk. This view is not underwritten by many other guidelines.

3. Decking

Decking is, as an application, more difficult to describe than cladding. They range from fully ventilated structures, high above ground, to structures that are almost permanently subjected to a moist environment due to their proximity to the ground or even direct contact with soil. While some examples of decking are completely protected from rain and snow by an overhanging roof, others are unshielded and will experience very demanding exposures to all kinds of weathering and mechanical wear, more so than most cladding.

Parts that must be considered in design:
- supporting construction
- ventilation of supporting construction and decking
- decking profile
- longitudinal and transverse joints of boards
- water shedding
- type and placement of fasteners
- connections to hand rail posts, stairs etc.

## 3.1 Unifying guidelines

### 3.1.1 Choice of wood material

A large number of wood species are used for decking. The preferences vary strongly, due to availability and tradition. It is not possible to find agreement across Europe regarding which wood species to use (see more in 4.2.1).

It is safe to say that a unifying view on boards for decking is that the quality must be high, since we are frequently touching it directly with our bare feet and bodies. The presence of knots, cracks and other defects should be minimal, and the wood should be straight-grained. More than minimal dimensional changes like warping, cupping, twisting are not acceptable since they increase the tendency for nails to be drawn out and generally present a hazard to the users. (At the same time, such deformations may be of less consequence than in cladding from a point of view of structural integrity, since they do not make a difference for the moisture contents). Just as for cladding, the advantage of radially sawn boards is noted. Such boards (with vertical annual rings) have smaller swelling and shrinking movements laterally and show less cupping and cracking. The same restrictions in availability as for the cladding case are of course applicable also here.

Boards for decking are also, with few exceptions, planed on four sides and have rounded edges. Many producers use special profiles on the top sides of boards with e.g. fine grooves to prevent slipping.

### 3.1.2 Board orientation

For boards that are not radially sawn, there is always a choice of whether to turn the inner or the outer side of the board upwards. With the inner side upwards, the boards may on drying cup somewhat in a convex manner, which still is comfortable to walk on. The opposite orientation, on the other hand, results in concave boards on drying. They will then prevent rain water from running off and instead collect it. The concave shape is also associated with a greater risk for tripping.

The rather theoretical reasoning above presupposes that the boards on the whole has a lower average moisture content after some time than they had when the deck was built. If dry boards are used the situation is different and the whole cupping problem may in principle be reversed. The difficulty in tackling this information problem may be the reason for the issue to be left out completely from several guides. The FCBA/ATB guide [57] recommends that the moisture content should be adapted to the site by mounting boards that have an average of the expected moisture contents in winter and summer.

The choice of orientation is not free, of course, for boards that have been grooved to reduce the cupping tendency (cf. 3.1.1) and for those with surface profiles.
3.1.3 Fasteners

Corrosion resistant screws are recommended as the first choice of fasteners by both the Austrian [62] and the French [58] guides. Also one Swedish guide [61] points out the advantages of screws compared to nails, i.e. the higher withdrawal capacity and that they allow easy replacement of boards, but acknowledges that nails are just as common among do-it-yourself builders.

3.1.4 Board connections to joists and moisture protection

Construction rules with recommended dimensions, joist distances etc. are outside the scope of this report. One feature is, however, closely related to the moisture protection and hence the durability of the decking. End joints should preferably be given an open shape (Figure 10). The left-hand part of Fig. 10 represents a water trap that will compromise both the boards and the joist.

Figure 10. End joints meeting on one common or on two separate joists [58].

Several advantageous design features are collected in Figure 11. A decking is pre-built in sections and mounted on joists arranged in parallel. The fastening screws are applied from the underside, which produces a smooth top surface. And the boards are separated from the joints by washers. The double joists have rounded top edges and profiled lower edges that facilitate raindrop shedding. The whole construction is well ventilated.

Figure 11. Decking with concealed fasteners, mounted as sections on ventilated supports [58].
A very large amount of pictures would be necessary to give account for all possible and recommended variations on this theme. For the purpose of this report it is sufficient to reproduce only a few of them, and they are selected to illustrate the main message: Keep excessive moisture out, especially from the load-bearing structure and sensitive end grain.

Figure 12. Different forms of protection of supporting joists: a) bituminous felt; b) ventilated metal profile; c) thin support above the load-bearing joist; d) a joist with water shedding and a minimized top surface [62].

Similar design solutions may be applied both between the decking boards and the supporting joist and between posts and joists. For standing members, the end-grain projecting upwards is important to protect. The lower ends are often even more important to design for the least possible water uptake, and this usually achieved by metal stud feet that keep the ends at a distance from the ground (Figure 13). Just as with cladding boards, additional protection can be given by endgrain sealants.

Figure 13. Three examples of metal stud feet for the ground support of posts [61].
3.1.5 Surface treatments and coatings

It is generally acknowledged that it is an advantage to suppress the moisture uptake and the moisture movements by the application of oils or water repellents. Some processes for industrial water repellent treatments exist, but the do-it-yourself treatment and maintenance is normally restricted to oils. Film-forming surface treatments (coatings) are used on balconies in some parts of Europe, but it is rare for decking.

3.2 Differing views

3.2.1 Choice of wood material

In the Nordic countries, the most common material is pine, protected by preservative treatment. The treated sapwood attains a higher degree of decay resistance than the untreated heartwood, but this may to some extent be balanced by the lower average moisture content in the heartwood. Larch is another wood species which is used to some extent.

In other parts of Europe, the emphasis lies more on other wood species. Oak and robinia are found, and a long row of tropical hardwoods like azobé, bangkirai, cumaru, and ipé. The FCBA/ATB guide [58] lists some 40 wood species with recommendations for their use, but it contains no data on how frequently they are used in practice.

3.2.2 Moisture protection

Some differences exist in the recommendations for the protection of the supporting structure. While some rather sophisticated distance elements made of various polymeric materials are brought forward in some cases, the simple use of bituminous felt is recommended by e.g. sources 61 and 62.

4. Reference sources

The compilation of information material is by no means complete, as mentioned already in the preface of this report. Due to the very varying character and publishing routes for these sources it would be very difficult to seek out all available published information, even if the search would have been strictly limited to public sources written in English. In addition, the language barriers are very limiting when searching for literature (as well as web pages and other sources) in other languages, and quite a lot of information is apparently written for domestic use.

The references below should therefore be seen as examples, but it is assumed that most of the important and well-known sources are included. The list has been divided in sections for cladding and decking, respectively, although some sources may in fact cover both applications. An attempt has also been made to separate more reliable sources like handbooks and guidelines issued by authoritative organisations from sources with a more limited content or those whose quality is not easily assessed. It should be borne in mind that it has not been possible to purchase a broad range of these commercial publications for the purpose of producing this report, and their true value has therefore not been possible to judge.
Although the European situation is in focus, a few examples of non-European sources have been included.

There is a striking difference in the number of available information sources for cladding and decking, respectively. This presumably reflects the fact that wood cladding has a long history, while decking has strongly increased in volume during the last decades.

The reference sources are not consistently formatted as they would be in a scientific journal, partly because many of them fall between the normal categories of books, journal articles, and conference papers. Another reason is that e.g. author names or publisher is not included in the second-hand information given. It should also be noted that only part of the sources listed below are referenced in the text of this report.

### 4.1 Handbooks, guidelines and scientific articles concerning cladding

1) **External Timber Cladding** by Patrick Hislop (2007). TRADA Technologies Ltd. Announced as: “A highly illustrated professional guide for cladding designers and specifiers including environmental and certification aspects, pre-finished cladding, modified timber, manufactured panels, and now updated with advice on preservative treatments and surface protection.” £40.00

2) **Exterior cladding of redwood and whitewood** (1982). Nordic Timber Council. Announced as: “Published as a guide to potential specifiers and users on selection of a timber cladding and how to detail in order to ensure long life and compliance with Building Regulations”.

3) **Cladding of Buildings**: Alan J. Brookes, Maarten Meijs (2008). Taylor & Francis. Announced as: “This key text addresses the topic of lightweight claddings in buildings and is a useful guide and key reference resource. Written by well-known specialists in the field, this new edition of an established text has been revised throughout to incorporate the latest environmental issues and use of new materials, particularly the new moulded materials. Two new chapters cover wood and terracotta in cladding. The main types of cladding systems are described in detail and methods of production, performance characteristics, applications and methods of assembly are explained clearly. Illustrated throughout with photographs and numerous line drawings, this is an essential overview of the subject for both the student and the practising architect. 210 pp.”


12) External timber cladding. (2007). TRADA. 80 pp. Announced as: “External Timber Cladding is now established as the definitive guide to timber cladding and design, and this second edition reflects significant growth and innovation in the market for cladding materials. Refined details and technical information in keeping with the regulatory framework are included on: environmental and certification aspects of cladding; pre-finished cladding; modified timber; manufactured panels; updated advice on preservative treatments and surface protection.”


14) Kolb, J. (2008). Systems in Timber Engineering: Loadbearing Structures and Component Layers. Announced as: “Timber construction has become completely modernized. It has gained considerably in market share with respect to competing building materials and is dominated by systems such as panel, frame, and solid timber construction. Every timber construction is determined by its structure. Hence it is essential to know the connections and relationships from the design stage right through to the construct ion phase. Systems in Timber Engineering takes a whole new approach to this subject. It is a comprehensive, analytical, and visually organized treatment, from the simple single family house to the large-scale multistore structure. It includes the building envelope, which is so important for saving energy, and systems for ceilings and interior dividing walls, which are so essential from the vantage point of construction. This work uses plans, schematic drawings, and pictures to show the current and forward-looking state of the technology, taking Switzerland as its example, a leading country in the field of innovative timber construction. - 319 pp”


16) CTBA/FIBC (2007). Durabilité des ouvrages bois. (Guidelines for assessing different constructive solutions and how they affect the “Use Classes”. Gives more emphasis to load-bearing constructions than to claddings.) *In French.*


25) Good practice guide - timber cladding, Announced as: “This guide gives a comprehensive overview of the issues to be addressed by designers and installers of timber claddings. This edition has been updated to mirror the changes to E2/AS1.” (http://www.branz.co.nz/cms_display.php?sn=69&st=1&amp;pg=1359)


4.2 Other information concerning cladding


44) Hoppings (UK). Website with installation instructions for consumers and others. http://www.hoppings.co.uk/literature_technical.html
45) http://www.practicaldiy.com/general-building/external-cladding/horizontal-cladding.php. “This article gives very general guidelines for applying horizontal external cladding. … This article is intended for the UK”
52) http://www.vastern.co.uk/cladding.html
53) http://www.wickes.co.uk/content/ebiz/wickes/resources/images/gil/9.pdf : How to choose and use Wickes cladding
54) http://www.russwood.co.uk/cladding/ Manufacturer’s recommendations
4.3 Handbooks and guidelines concerning decking

56) Timber Decking the professionals' manual. This is produced by TRADA in conjunction with the TDA (Timber Decking Association). The manual includes information on all aspects of planning and building a deck.


4.4 Other information concerning decking

64) http://www.russwood.co.uk/decking/index.html

65) Hoppings (UK). Website with installation instructions for consumers and others. http://www.hoppings.co.uk/literature_technical.html


5. Chief points of agreement

Obviously, there is not one single handbook that gives advice that is acceptable by all throughout Europe. There are multiple reasons for this: Differences in building tradition and aesthetic preferences, wood species used, climate, and service life expectations.

It would be useful to distil out the most essential detailing features that are most important from a durability standpoint. It is envisioned that a brief illustrated document will be produced, presenting a shortlist of considerations that must not be overlooked.
Such a document would be widely distributed and made freely available to industry, trade associations and the public. This could be helpful in increasing the awareness of sound construction principles, and thereby increasing the quality of construction works and promoting a wider use of exterior wood in areas where it is less common today.

The general principles presented in this document would be analysed to find the common denominators, and the shortlisted aspects would form a list of, for example, “the big five”, aspects where we really agree about the importance. In turn, this could be the first stage of a more commonly accepted and harmonised extensive European handbook for exterior wood.

The shortlist may include:
1. End grain protection – design solutions, sealants, covers.
2. Water shedding
3. Ventilation
4. Keep the distance to ground
5. Coatings – choice of systems, maintenance

6. Acknowledgements

This report is a part of the results in the European WoodWisdom-Net project WoodExter, with the full title “Service life and performance of exterior wood above ground” and the following objectives: “to take the first steps towards introducing performance based engineering design in practice for wood and wood-based building components in outdoor above ground situations”. The authors gratefully acknowledge the financial support of WoodWisdom-Net (www.woodwisdom.net) and the wood industry partnership Building with Wood for funding the research work. The “WoodExter” research partners are thanked for their cooperation and collaboration in this project.
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