Moisture effects on building and structural timber

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Abstract

The effect of moisture content (MC) on some mechanical and physical properties is presented. End-users’ attitudes to timber, drying quality and MC are discussed. Quality requirements for timber products are proposed and compared with some grading rules and standards when it comes to limits for distortion.

The effect of moisture content (MC) on structural components is presented based on tests conducted at Chalmers University of Technology in Sweden. The shape of timber changes due to variations in moisture content (MC). In Scandinavia, the producers of timber normally dry timber to a moisture content of 18% MC. However, after the studs are built into the wall structure, for example, they may become distorted as a result of further drying in the structure. The final MC in a heated building in Scandinavia is about 8%. It is therefore important to produce and deliver timber products dried to the moisture content appropriate to the construction site. Four tests have also been conducted on whole wall structures. The walls were made of studs conditioned to 18% MC, whereupon the structure dried to 8% MC in a normal indoor climate during a period of three months. The two walls with gypsum cladding on both sides reveal that the free twist is significantly restrained by about 75%. The two walls with gypsum cladding on the one side only reduce the twist by about 13%. However, the spring is heavily increased in this type of structure.

Timber buildings and construction methods are discussed. Three scenarios of mounting wall studs on the building side are presented and discussed in conjunction with requirements for MC and distortion limits. The deformation of sawn timber during and after the drying process is the most important reason for downgrading. Better interaction between the producers of timber and building contractors is recommended.
Moisture effects on building and structural timber

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- Introduction and background
- Effect of moisture content (MC) on
  - Mechanical properties
  - Physical properties
- End-users’ attitudes to timber, drying quality and MC
  - Quality requirements and distortion
  - Grading rules and standards
- Effect of moisture content (MC) on
  - Structural components
  - Timber buildings and construction methods
- Conclusions
Introduction

• Timber as a building material

• Wet timber vs. dried timber

• Wood properties influenced by MC

• Production methods influenced by MC

• Structures affected by MC

• Quality of timber – are buyers aware of what is good/right quality? Are they prepared to pay for it?
Background
Opportunity and threats

Effect of moisture content (MC) on mechanical properties

- Differences between clear wood (small pieces) and timber
- Design of timber structures
- The effect of MC is regulated by building codes (DIN, Eurocode etc)
- Some examples
Effect of MC on wood and its compression strength and modulus of elasticity parallel to the grain

Strength vs. percentile of matched spruce timber

According to Hoffmeyer (1995)
Effect of MC change on mechanical properties [\%/\%] between 8\% and 20\% (for softwoods)

<table>
<thead>
<tr>
<th>Property</th>
<th>Clear wood</th>
<th>Round timber</th>
<th>Sawn timber (EN 384)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression (∥ and ⊥)</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Bending strength</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Tension (∥)</td>
<td>2.5</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Tension (⊥)</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear strength</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOE (∥)</td>
<td>1.5</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>


Eurocode 5: Design of timber structures
Service classes relate to the variation in timber performance with moisture content (MC)

<table>
<thead>
<tr>
<th>Service class</th>
<th>MC corresponds to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>temp. 20°C and RH ≤ 65% *</td>
</tr>
<tr>
<td>2</td>
<td>temp. 20°C and RH ≤ 85% *</td>
</tr>
<tr>
<td>3</td>
<td>temp. 20°C and RH &gt; 85%</td>
</tr>
</tbody>
</table>

* RH exceeds only few weeks per year
Effect of moisture content (MC) on physical properties

Large variation in terms of shrinkage/swelling as a result of changes in MC
Large effect on timber shape and distortion
Design of timber structures
Durability → timber with MC < 20%
Some examples

Shrinkage in different directions (spruce & pine)

1% change in MC leads to:
0.01% change in longitudinal direction,
0.1% change in radial direction and
0.2% change in tangential direction

Diagram showing moisture content in different directions:
- Longitudinal
- Radial
- Tangential
- Volume

Moisture content [%]

1C 2C 3C
**Shrinkage/swelling properties**

Strain in the longitudinal direction caused by a change in equilibrium MC from 90% to 30% RH

**Structural timber elements deflected due to uneven moisture distribution**

Multi-storey timber buildings — settlements of each floor ≈ 8mm
End-users’ attitudes to timber, drying quality and MC

- in general
- drying quality

• Quality requirements
• Distortion

Timber quality for builders

• Load bearing
  – straight and stress graded
• Non-load bearing
  – straight, knot-free joinery
• Boards, façade timber
  – straight, durable, can be painted
Timber quality for builders means:
no distortion
Drying quality defined by the producers

Moisture content (MC)
different classes in terms of target MC and permissible deviations

Absence of case hardening

Absence of checking

The moisture content itself is not important for the builder (user)

A change in moisture content could cause distortion

Too high moisture content (>20%) could lead to mould or rot

Too low moisture content (<10%) could cause timber to be more difficult to nail
Modes of distortion

Twist

Spring

Bow

Background to requirements for the maximum distortion in a wall stud

Geometry of a wall

+ Requirements from standards: workmanship of buildings
### Wall studs — height 2.5 m

- Requirements for wall inclination $< 6$ mm and curvature of the wall (vertical) $< 8$ mm
- Spring $< 4$ mm

Joining boards to studs: **bow $< 6$ mm**

- Sideways deflection $< 2$ mm
- Twist $< 5$ mm

### Results of visual grading of studs

Grading criterion:
- usable and not usable

- 9-15 studs with different levels of twist, bow and spring were used
- 37 different building sites were visited
- 1,736 assessments were made

Acceptance levels were:
- 40% in Sweden and 37% in Germany
### Distortion limits for a stud
45 x 95 mm, length 2.5 m

<table>
<thead>
<tr>
<th></th>
<th>Our proposal</th>
<th>prEN 1408</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>≤C18</td>
</tr>
<tr>
<td>Bow</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Spring</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Twist</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

Our prEN 1408 proposal
Comparison of maximum limits for twist [mm]

<table>
<thead>
<tr>
<th>Timber use as:</th>
<th>MC after drying</th>
<th>Board 22 x 100</th>
<th>Stud 50 x 100</th>
<th>Beam 50 x 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed max</td>
<td>14-17% ± 2%</td>
<td>10</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Nordic Timber</td>
<td>20% ± 4%</td>
<td>9</td>
<td>5</td>
<td>8.5</td>
</tr>
<tr>
<td>BSEN 519:1995</td>
<td>20% ± 4%</td>
<td>6</td>
<td>10</td>
<td>16.8</td>
</tr>
<tr>
<td>NZS-3631</td>
<td>At delivery</td>
<td>15</td>
<td>5</td>
<td>20</td>
</tr>
</tbody>
</table>

Standards and grading rules in different countries in terms of permissible distortion values after drying are much too generous.

The requirements for max. distortion must apply to the entire length of the final product.
What happens to timber in a structure?

• Check the moisture variations
• Example: show the behaviour of timber built in partition walls in a building exposed to moisture changes
• Recommendations for the handling of timber
Moisture content variation in southern Sweden
(unheated room, 90x100x600 specimen)

According to Gustafsson (1996)

Relative Humidity (RH)

Indoors

(Hagentoft 2003)
Behaviour of timber built in partition walls in a building exposed to moisture changes - *tests performed*

- Walls – double-sided cladding
  - single-sided cladding
- Studs restrained from twisting
- Screw connections
Prerequisite

• Distortion, in particular twist, is reversible,

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<table>
<thead>
<tr>
<th>Measurement 1</th>
<th>Measurement 2</th>
<th>Measurement 3</th>
<th>Measurement 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median moisture content [%]</td>
<td>Median twist [°]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 5 10 15 20 25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Walls - double-sided cladding

Set-up for wall tests
Change in MC from 18% to 8%
Walls – double-sided cladding
Results – twist

<table>
<thead>
<tr>
<th>Stud no</th>
<th>Δ Twist [°]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>Restrained</td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
Walls – single-sided cladding

Set-up for wall tests

Walls – single-sided cladding

Results – twist
**Walls – single-sided cladding**

**Results – twist**

![Graph showing twist results](image)

**Walls – single-sided cladding**

**Results – spring**

![Graph showing spring results](image)
Walls – single-sided cladding
Results – spring

Results from the wall test

- Double-sided cladding:
  - free twist restraint by 75%

- Single-sided cladding:
  - free twist restraint only by 13%
  - Spring is heavily increased!
Walls – results
Twist vs time

-charts showing twist vs time for different moisture content levels (W44 to MC) for walls marked S1 to S5.
Walls – results
Twist vs time

- W44
- W43
- W42
- W41
- MC

EDG Drying Seminar - 2006
Robert Kliger
Construction methods
Building on site - mounting scenarios

1. Mounting studs and cladding on both sides at the same time directly after the delivery of timber
   MC not as demanding, straight enough to perform the job

2. Mounting studs and cladding on one side first and later on the second side of the cladding
   Not recommended. Rigorous requirements for connections and cladding. Right MC for the final structure.

3. Mounting studs or structure without cladding
   Right MC for the final structure. Rigorous requirements for straightness. Use timber less prone to distortion.

Timber studs on concrete slab
Construction methods
Building on site – under the roof

The same scenarios as before
Right MC as in the final structure,
but not as demanding requirements for
connections and cladding
Important for timber producers

- Take more interest in how the timber will be used!
- What production method is used by the contractor/builder?
- Try to suggest the “right” MC of timber for the “right” application
- Be aware of interaction with other materials
- Justify the higher price by fewer problems for the builder!
Conclusions

The deformation of sawn timber during and after the drying process is the most important reason for downgrading.

Better interaction between the producers of timber and building contractors.
Be prepared for much more rigorous demands from end users.

Thank you for your attention!