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Studies on the wood corrosion on a historic glulam-construction

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ABSTRACT: The exposure to chemically-aggressive media causes a structural modification of wooden members. The related mechanisms are called wood corrosion. The subject of the studies was an approximately 100 year's old warehouse, which was executed as HETZER-construction and has been used as storage for potassium salt. The assessment of the degree of modification and the evaluation of the strength reduction was the aim of the studies. Test on the strength as well as chemical analyses have been carried out. The results showed a clearly visible modification of the examined material due to the exposure to the salts. This was recognizable by the superficial macroscopic modifications as well as by a reduction in the strength of the material in the periphery of the cross-section.

KEYWORDS: wood corrosion, chemically-aggressive media, Otto Hetzer, glulam, Dynstat-method

1 INTRODUCTION

The invention of the glued laminated timber by Otto Hetzer in the early 20th century allowed the building wide-spanning constructions [2]. Amongst others halls in the fertilizer and potassium salt industry were erected by the use of this construction method, which is proven until today by several preserved buildings (see also www.otto-hetzer.de).
However, this field of application subjects the building material wood to particular environmental conditions [6]. For example, the production processes as well as stored substances are releasing chemically-aggressive media, which can cause irreversible structural modifications of the wooden members.
The modification of the wood due to chemically-aggressive media is not taken into consideration in the static calculations according the currently valid version of the Eurocode 5 [7]. Some suggestions concerning this problem are listed in [6].
Though, the knowledge of the degree of the modification is a significant requirement for static calculations concerning the load bearing capacity.

2 WOOD CORROSION

Due to its chemical balance wood has a high resistance against chemically-aggressive media. If the correct environmental conditions are present, the wooden members will be subjected to corrosion [6].

The wood corrosion is a structural damage beginning on the surface, which is caused by chemical and physical reactions. These reactions are caused in particular by strong acidic and strong alkaline media (pH $\leq$ 2 respectively pH $\geq$11).
If there are salts involved, the cell structure is destroyed by crystallization processes. The lignin and the hemicelluloses are degradated due to hydrolytic splitting.
The in the individual case present destructive mechanism is dependent on the type of the impacting media. This fact is a result of numerous investigations on timber constructions additionally stressed due to chemically-aggressive media.
The level of the destruction depends on the several aspects. These aspects could also be called a corrosion system, which is depicted in Figure 1.

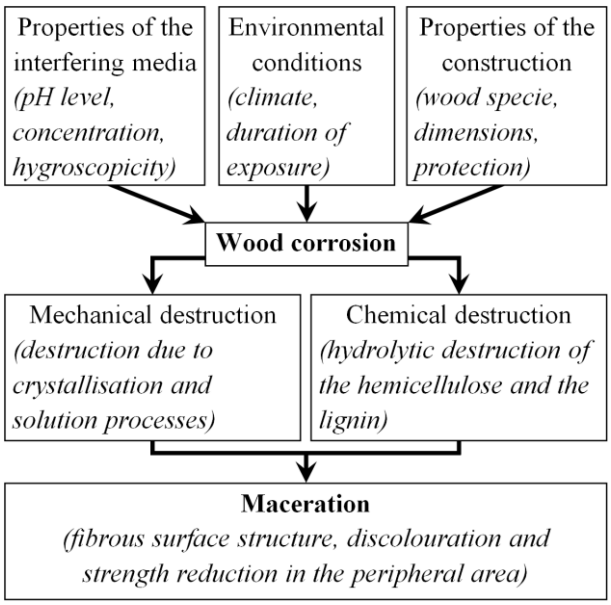

Figure 1: *schematic depiction of the wood corrosion*

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On a large amount of the so far observed constructions it was determined that the destruction of the wood structure is limited to the cross-section near the surface.
This destruction is visible by a greyish-brown discolouration and a fibrous surface structure. In some cases the separation of whole strips of wood along the annual ring limits was observed. Furthermore, the peripherical cross-section shows a reduction of the strength as well as an increased density. In the inner cross-section there is no such strength reduction.
Glued laminated timber has a higher resistance concerning the wood corrosion as long as large, compact members are used and no large shrinkage cracks are appearing. Furthermore, the type of glue significantly influences the resistance against chemically-aggressive media.

3 SUBJECT AND AIM OF THE STUDY

The effect of the salts on the load bearing capacity of the historic glued laminated timber has been examined in the course of material tests [1]. The main focus laid on tests with the Dynstat-method as well as on chemical analyses concerning the salt content.
The results of this technical material study should be used as basis for future investigations concerning the structural stability of existing glued laminated timber constructions which are additionally stressed by chemically-aggressive media.
The subject of the study was a warehouse which was erected in 1912 by the use of the HETZER-construction method. The load-bearing structure of the warehouse consisted of eleven parabolic trusses made from glued laminated timber according to the patent DRP. 197773 [5]. The trusses (wood species: spruce) had a double-T cross-section (see Figures 2 & 3).

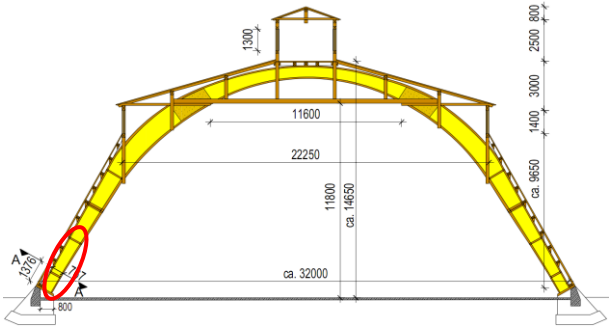

Figure 2: *view on the truss construction; the examined section is marked in red*

After the demolition of the ware house in April 2010 several parts of the construction have been transferred to the University of Applied Sciences, Eberswalde/ Germany (HNE Eberswalde) to carry out technical studies on the wooden members.

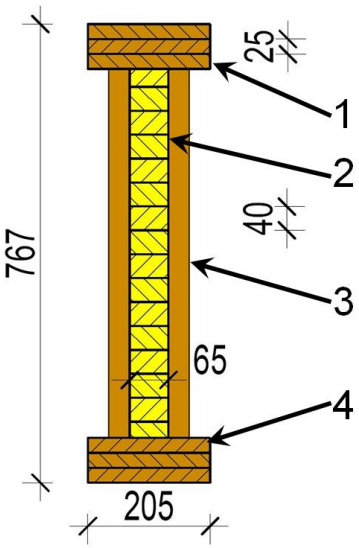

Figure 3: *sectional view A-A of the truss construction – 1: top chord; 2: web; 3: solid wood bracing; 4: bottom chord (all dimensions in mm)*

The sample material had clearly visible marks of corrosion. The surface was greyish-brown discoloured and fibrous. The discolouration reached a depth of 20-25mm from the surface. Furthermore, the already mentioned separation of wooden strips could also be found. The Figures 4 and 5 are showing the macroscopic appearance of the sample material exemplarily.

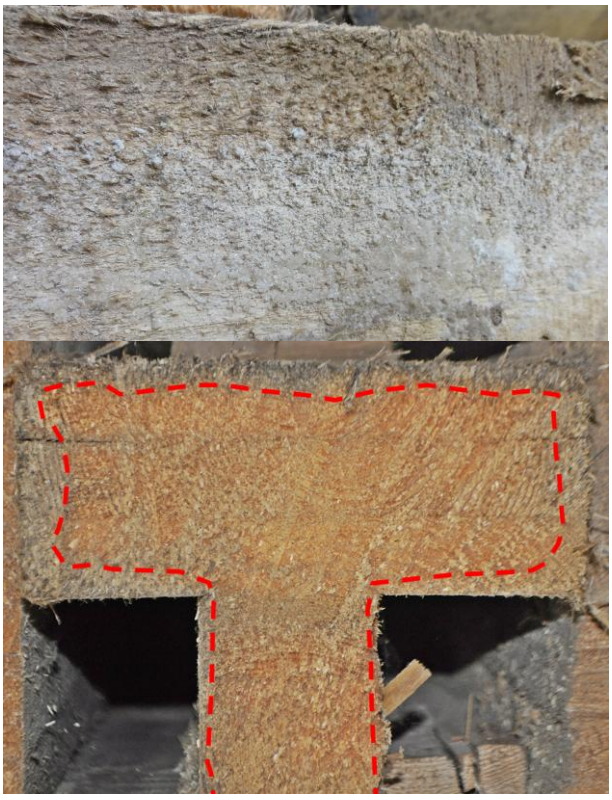

Figure 4: *top: fibrous surface structure and greyish discolouration as well as salt deposits on the bottom chord; bottom: sectional view on a chord and the web (the borders of the discolouration are marked in red)*

Figure 5: *discolouration of the peripherical cross-section, shown on a bar-shaped sample from a chord lamella (the discoloured area is crosshatched in red)*

4 RESEARCH METHODOLOGY

4.1 SAMPLE EXTRACTION

The extraction of the samples was limited to an area of a length of approx. 1,50m near the support of the truss (see Figure 2). The observed part of the truss has shown the clearest corrosion marks of all the available truss fragments. This can be explained by the direct contact between the salt and the wooden members during the service life of the warehouse.

Bar-shaped samples with a cross-section of b/h = 10/15mm and a length of ℓ = 65mm (web) respectively 205mm (chords) have been extracted from each lamella of the chords and the web of the truss. The sample extraction included every lamella of the observed truss fragment. In total 60 bar-shaped samples have been extracted – 30 samples from the cords and 30 samples from the web.

These bar-shaped samples have been cut into approximately 4mm thick disc-shaped Dynstat specimen along the longitudinal direction of the sample (see Figure 6). In this way, it was possible to create depth profiles which cover the whole length of the samples.

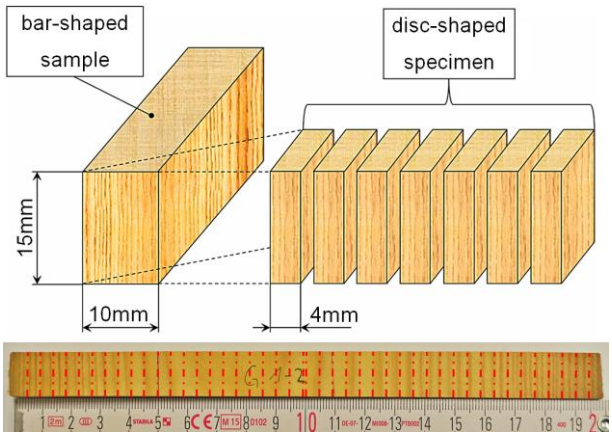

Figure 6: *top: schematic depiction of the specimen cutting; bottom: separation of a bar-shaped sample into disc-shaped specimen at the example of a sample from a chord lamella*

Each sample from the trusses web was cut into fourteen disc-shaped specimens. The samples from the chord lamellas were divided into 44 disc-shaped specimens each. In total 1740 specimen were cut from the overall 60 samples as shown below.

Sample series „chord“:
30 samples with 44 specimen → 1320 specimen

Sample series „web“:
30 samples with 14 specimen → 420 specimen

4.2 STRENGTH TESTS WITH THE DYNSTAT-METHOD

The remaining strength of the material has been determined by flexural tests with the Dynstat-method according to DIN 53435:1983 [9] respectively. TGL 1-204/8:1965 [10]. In the nowadays valid version of the test specifications [9] the application of the Dynstat-method is restricted for the test of plastic materials. Studies [11] have proven the principally applicability of this test method for technical studies on wood. This applies especially for the material-saving determination of the material properties and the development of strength profiles along the width respectively the height of the cross-section.

The specimens have been loaded with a continuous rate of deformation until a failure occurred. The test setup is depicted in Figure 7.

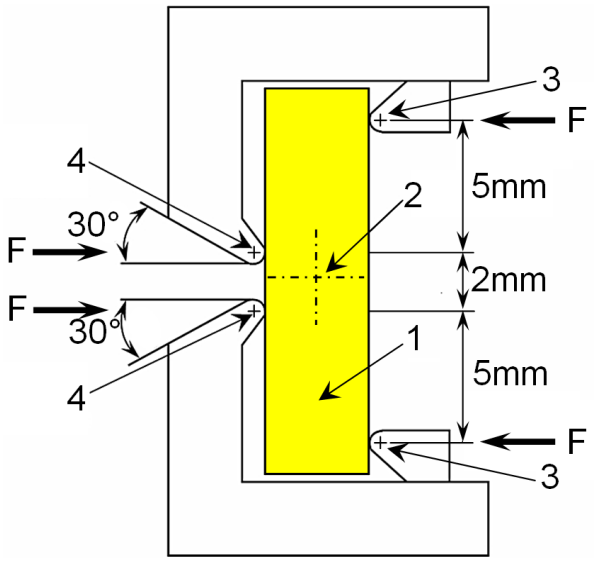

Figure 7: *test setup of the Dynstat-method – 1: specimen; 2: rotation axis; 3: bending support (r = 0,5mm); 4: bending blade (r = 0,5mm)*

The test apparatus used is shown in the Figures 8 and 9.

Figure 8: *Dynstat apparatus (type Dys-e 9303)*

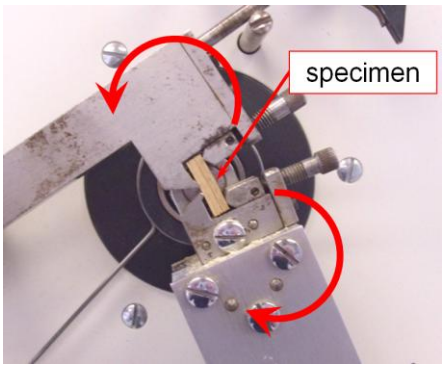

Figure 9: *specimen in the test apparatus during the test*

The flexural tests were accompanied by the determination of the density according DIN 52182:1976 [12] and the wood moisture according DIN EN 13183-1:2002 [13] by the determination of the dimensions and the weight of the conditioned specimen (υ = 20°C and φ = 65%) as well as in dry state.

4.3 CHEMICAL ANALYSIS OF THE SALT CONTENT

The salt content was determined by the use of the optical atom emission spectroscopy with inductive coupled plasma (ICP-OES). This analysis method is based on the interaction between the elements contained in the samples and the electromagnetic radiation emitted by them.
By stimulating a vaporized sample solution, the outer electrons of the contained elements are raised to a higher energy level. The supplied energy is emitted during the relapse of the electrons to their base energy level in the form of light. The emitted light has a specific wavelength and frequency which is characteristic for a specific element (see [14]). By measuring the wavelength and the intensity of the emitted light the contained elements and their concentration can be determined in comparison to given calibration data.
This chemical analysis was carried out exemplarily on one sample from the web and the chords. The samples were chosen according to their distinctive strength profile. In total 58 specimens have been analyzed chemically.

5 RESULTS AND EVALUATION

5.1 RESULTS OF THE PHYSICAL-MECHANICAL TEST

The flexural test have been evaluated according the regulations in DIN 53435:1983 [9] and TGL 1-204/8:1965 [10]. Accordingly the maximum flexural stress equals the bending strength of defect-free wood. However, a conversion of the determined strength values on the strength of small defect-free specimen in accordance with DIN 52186:1978 [12] (bar-shaped specimen, test configuration is shown in Figure 9) with the help of suitable factors is required.
Such factors for the conversion of the bending strength and the density have been determined in the last years at the HNE Eberswalde (see [11]).

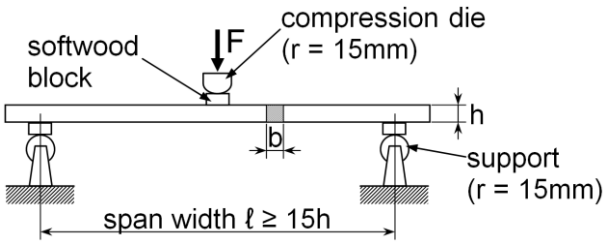

Figure 10: *test configuration for the flexural test on bar-shaped, defect-free specimen according to DIN 52186:1978 [12]*

The relation between the properties of Dynstat-specimen and bar-shaped, defect-free specimen (wood species: spruce) is specified in [11] as shown in the following Equations (1) and (2):

- density:

$$\rho_{DIN52186} = \frac{\rho_{Dynstat}}{0.92} \quad (1)$$

- bending strength:

$$f_{m,DIN52186} = \frac{f_{m,Dynstat}}{0.54} \quad (2)$$

where $\rho_{DIN52186}$ = density of bar-shaped, defect-free specimen in accordance with DIN 52186, $\rho_{Dynstat}$ = density of Dynstat-specimen, $f_{m,DIN52186}$ = bending strength of bar-shaped, defect-free specimen in accordance with DIN 52186, $f_{m,Dynstat}$ = bending strength of Dynstat-specimen

The influence of the wood moisture on the bending strength has also been considered by the application of a conversion factor. It is specified in [15] that the bending strength decreases by 4% if the wood moisture increases by one percentage point. This is valid for the increase of the wood moisture below the fibre saturation point. The equivalent conversion factor can be determined as shown in Equation (3):

$$k_{fm,\omega} = \omega_{Gl} - \omega \cdot 0.04 + 1 \quad (3)$$

Where $k_{fm,\omega}$ = conversion factor for the influence of the wood moisture on the bending strength, ω_{Gl} = equilibrium wood moisture in [%] which attunes under the predominant climate (here: ω_{Gl} =12%), ω = wood moisture during the tests [%]

After the conversion of the test results a statistical analysis concerning possible statistical outliers took place (test according to GRUBBS, see [22]). In the result of this analysis no statistical outliers could be determined.
Furthermore, the distribution of the test results has been analyzed by the help of the KOLMOGOROV-SMIRNOV-Test (see [22]). It was determined that the bending strength as well as the density are approximately normal distributed. The actual distribution is positively skewed (rate of skewness: density: 0.551; bending strength: 0.582). This means that the greater amount of

test results is located below the mean value of the assumed ideal normal distribution.
The Figures 11 and 12 are depicting the absolute frequency as well as the assumed ideal normal distribution of the density and the bending strength of all specimens.

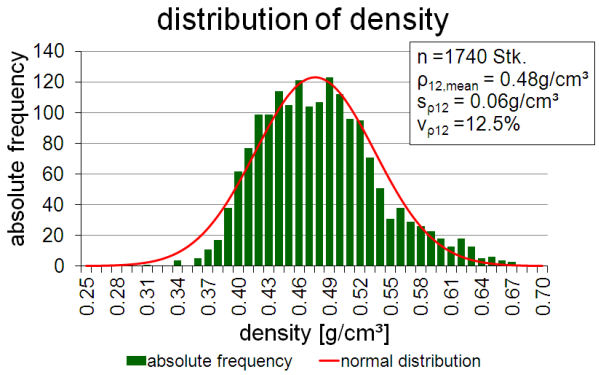

Figure 11: *distribution of the density of all specimens*

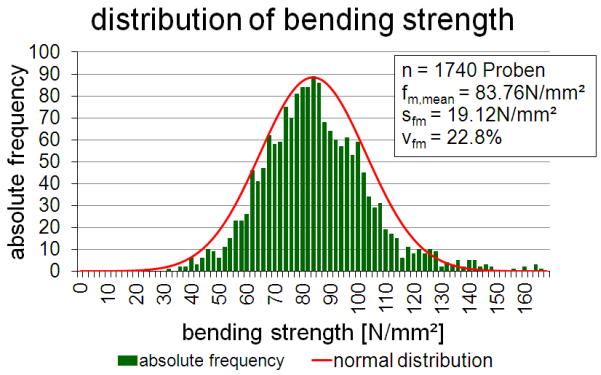

Figure 12: *distribution of the bending strength of all specimens*

The results of the statistical analysis of the converted test results are listed in Table 1 and Table 2.

Table 1: *results of the statistical analysis of the converted test results – sample series „chord“*

	density ρ_{12}	bending strength f_m
amount of specimen n	1320 Stk.	1320 Stk.
minimum x_{min}	0.31 g/cm³	23.2 N/mm²
maximum x_{max}	0.67 g/cm³	141.9 N/mm²
mean value x_{mean}	0.47 g/cm³	82.1 N/mm²
standard deviation s_x	0.06 g/cm³	17.1 N/mm²
variation coefficient v_x	12.1%	20.8%

Table 2: *results of the statistical analysis of the converted test results – sample series „web“*

	density ρ_{12}	bending strength f_m
amount of specimen n	420 Stk.	420 Stk.
minimum x_{min}	0.37 g/cm³	38.3 N/mm²
maximum x_{max}	0.68 g/cm³	164.4 N/mm²
mean value x_{mean}	0.50 g/cm³	88.8 N/mm²
standard deviation s_x	0.06 g/cm³	23.7 N/mm²
variation coefficient v_x	12.0%	26.7%

The evaluation of the test results was carried out as a comparison with the normatively regulated material properties of spruce according to DIN 68364:2003 [16]. In this standard the mean density is given with a value of 0.46g/cm³ and a variation coefficient of 9.7%. The mean bending strength has a value of 80N/mm² and a variation coefficient of 14.2%.
The comparison between the test results and the material properties according to DIN 68364:2003 [16] has shown that the density of the examined material is slightly increased. The mean density is located in the top variation range of the normatively regulated density (sample series “chord”: 0.47 g/cm³; sample series “web”: 0.50 g/cm³). The observed increase can be attributed to the salt deposit in the peripherical wood structure. The comparison of the mean density of the examined material and the density according to DIN 68364:2003 [16] is depicted in Figure 13.

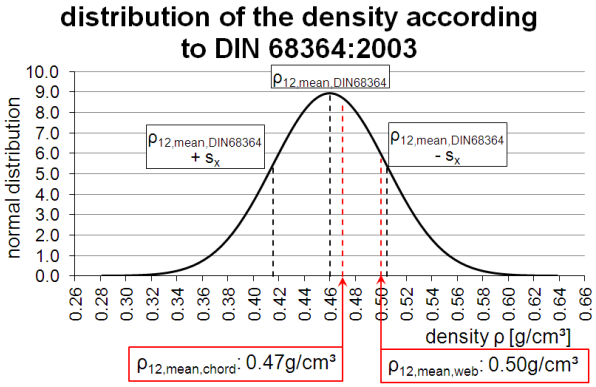

Figure 13: *comparison between the densities of the examined material with the density according DIN 68364:2003[16]*

The bending strength of the examined material is also higher than the bending strength according DIN 68364:2003 [16]. An equivocal explanation for this observation could not be found on basis of the studies that have been carried out. The comparison of the mean bending strength of the examined material and the bending strength according DIN 68364:2003 [16] is depicted in Figure 14.

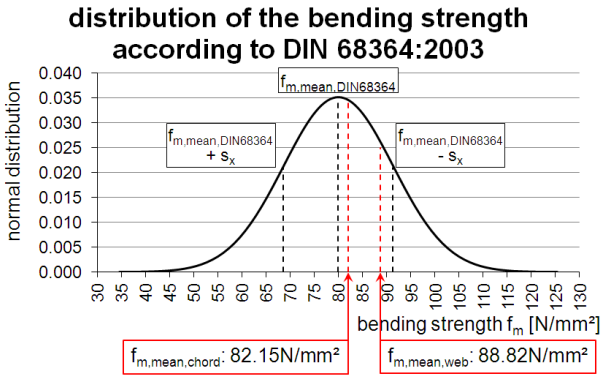

Figure 14: *comparison between the bending strength of the examined material with the bending strength according DIN 68364:2003[16]*

The evaluation of the mean values of the bending strength has shown that the examined material was obviously not affected by the impact of the salts (see Figure 14). However, considering the depth profile of the bending strength it is clear that the strength in the peripherical cross-section is reduced in comparison to the inner cross-section (see Figure 15).

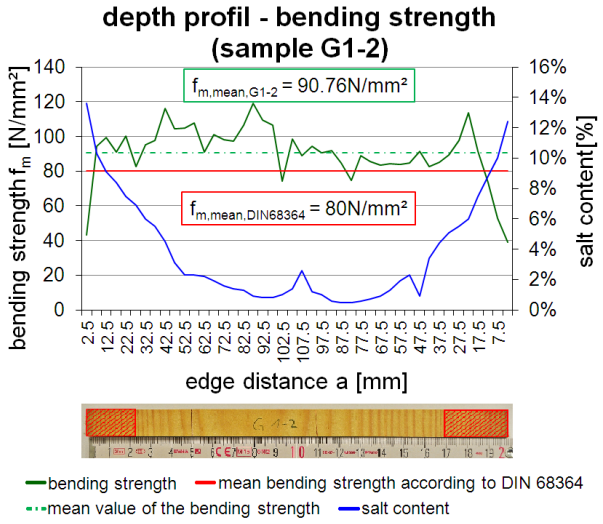

Figure 15: *depth profile of the bending strength – sample G1-2 (sample series „chord“)*

5.2 RESULTS OF THE CHEMICAL TEST

In the result of the chemical analysis mainly potassium chloride, sodium chloride and magnesium chloride could be determined to be deposed in the wood structure. Furthermore, several sulphates in lower concentration were detected. The concentration of these sulphates equals the amount of sulphates which have to be expected in long-term obstructed timber. Therefore, the effect of the sulphates on the examined material's properties is neglected.

The total concentration of the detected chlorides in the peripheral cross-section has a value of approximately 10% (sample series "web") respectively 13% (sample series "chord"). The concentration decreases towards the inner cross-section. The analyzed sample from the web has a salt concentration of approximately 4-5% in the inner cross-section. The concentration of the inner cross-section of the sample from the chord was approximately 1-2%.

To qualitatively determine the influence of the salt deposition on the bending strength a linear correlation and regression analysis has been carried out. This analysis refers to the entire specimens which have been chemically analyzed. The results are depicted in Figure 16.

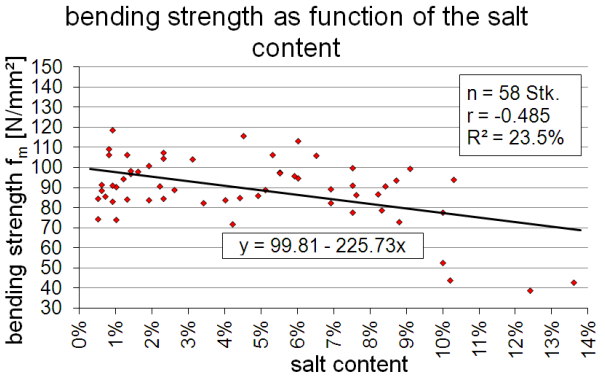

Figure 16: *depiction of the relation between the salt concentration and the bending strength*

Figure 15 shows clearly that the bending strength decreases with the increasing salt concentration. This is also proved by the negative correlation and regression coefficients. It should be noted at this point that the examined relation is only moderately expressed. The correlation coefficient has only a value of -0.485. The relatively small sample size of only 58 specimens can be seen as the reason for this fact.

5.3 DETERMINATION OF THE CORROSION LAYER THICKNESS

The corrosion layer is the peripherical part of the cross-section which shows a clearly visible respectively measureable alteration due to the influence of the chemically-aggressive media. These alterations are manifested – as already described above – as a macroscopic modification (discolouration, fibrous surface structure) as well as a reduction of the material's strength.

The thickness of this corrosion layer can be determined graphically on basis of the results of the technical material studies which have been carried out. General rules are listed in [17] which are derived from studies on timber construction in the potash industry. These rules are listed below.

1) The bending strength in a distance of 14mm from the surface is approximately constant. The mean value is depicted as a straight line in this area.
2) The bending strength beyond this intact inner cross -section (core area) decreases steeply.
3) The thickness of the corrosion layer results from the intersection of the steeply decreasing strength in

the peripherical cross-section and the 75%-line of the mean bending strength in the intact inner cross-section (core area) plus the half of the specimen's thickness.

This method was applied exemplarily on the test results of on sample of each sample series. These are the same samples which were chemically analyzed.
For the sample from the sample series „chord", the thickness of the corrosion layer equals 13.5mm. The sample from the sample series "web" the thickness had a value of 11mm.
The Figure 17 depicts exemplarily the graphically determined thickness of the corrosion layer of sample G1-2 in comparison to the determined salt concentration.

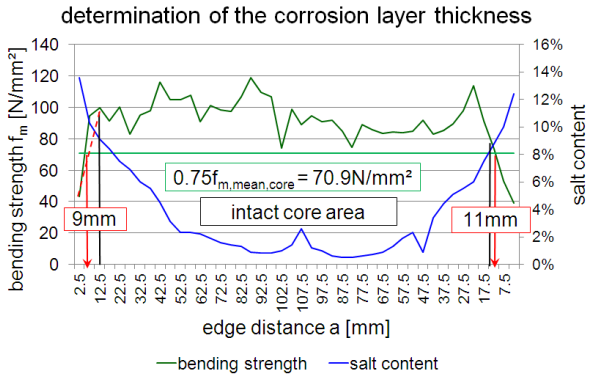

Figure 17: *graphical determination of the corrosion layer's thickness according [17] (sample G1-2)*

The Figure 17 reveals that the bending strength in the assumed intact inner cross-section is partially lower than in the damaged peripherical cross-section. The salt concentration in the assumed intact inner cross-section is relatively high with values up to 8%.
The in [17] described method has been derived from test on small, defect-free specimen (bar-shaped specimen, see Figure 9). Therefore, the unconditional applicability of this method on the bending strength of Dynstat-specimen is questionable.
Thus, a second graphical method for the determination of the corrosion layer's thickness was applied. The second method uses the 5-percentile value of the bending strength of defect-free wood according to DIN 68364:2003 [16] as reference. Then, the corrosion layer is the part of the cross-section in which the test results are lower than the reference value.
With the help of this consideration a corrosion layer's thickness of 5mm (sample series "web") respectively 10mm (sample series "chord") could be determined. The Figure 18 depicts exemplarily the graphically determined thickness of the corrosion layer of sample G1-2 in comparison to the determined salt concentration.
The corrosion layer's thickness which was determined in comparison to the 5-percentile value of the bending strength of defect-free wood according to DIN 68364:2003 [16] is seen as the decisive thickness.

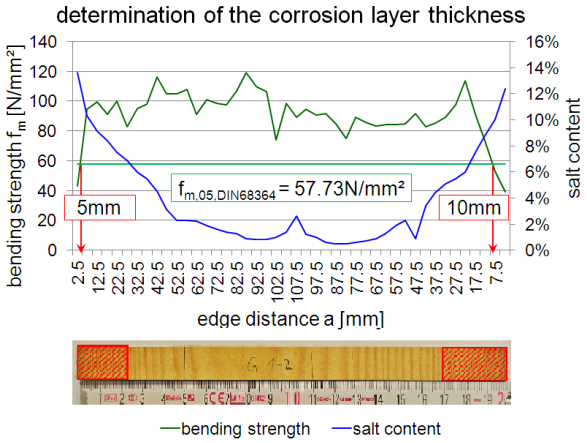

Figure 18: *graphical determination of the corrosion layer's thickness (sample G1-2)*

The main reason for this consideration is the nowadays valid safety concept for the design of timber constructions. This concept uses 5-percentile values as the characteristic values for the design. Another reason is – as described above – that the in [17] described method can only be applied on results of the Dynstat-method with restrictions.
Therefore, the thickness of the circumferential corrosion layer of the examined material is declared with values of 5mm on the web respectively 10mm on the chords (see also Figure 19).

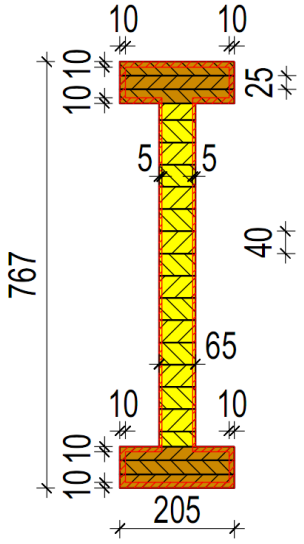

Figure 19: *thickness of the corrosion layer*

5.4 COMPARATIVE CALCULATIONS CONCERNING THE STRUCTURAL STABILITY

The knowledge of the thickness of the corrosion layer creates the basis for the analysis of the structural stability of a timber construction which is affected by the influence of chemically aggressive media. A proposal for the design of such constructions can be found in [6].

According to [6] there are two ways to statically calculate such constructions. Both methods are similar to the hot-state design according to Eurocode 5 [18]. On the one hand, it is possible to calculate with the reduced material strength due to the influence of the chemically-aggressive media (method 1). On the other hand, the cross-section can be reduced by the thickness of the circumferential corrosion layer (method 2).
The comparative calculation concerning the structural stability has been carried out by the use of both methods. The results of the physical-mechanical and chemical tests created the basis of the calculation.

Method 1: calculation with a reduced material strength
The modification factor to take account of the influence of the chemically-aggressive media $k_{mod,aM}$ was selected according to the results of the chemical tests.

Method 2: calculation with a reduced cross-section
The cross-section of the glulam trusses has been reduced by a value of 5mm. This equals the thickness of the corrosion layer which was determined for the web of the trusses.

The results of the comparative calculation revealed that the static utilization rate of the glulam trusses under consideration of a reduced material strength (method 1, $k_{mod,aM}$ = 0.95) equals the utilization rate under consideration of a circumferential corrosion layer (method 2, d = 5mm).
The results of the proposed design methods given in [6] can be proved by the results of the technical studies which were carried out. Therefore, these design methods are adequate for the prognostic calculation of the structural stability of timber structures under consideration of the influence of chemically-aggressive media.

5.5 DETERMINATION OF THE CHARACTERISTIC MATERIAL PROPERTIES

Another initial value for the calculation of the structural stability of a timber construction which is affected by chemically-aggressive media is the assignment of the affected members to the officially approved system of strength classes for glued laminated timber members. This is achieved by the determination of the characteristic material values.
In this case the characteristic values were determined according EN 384:2010 [18]. The test results of all tested specimen (sample series “chord” and “web”) have been divided into two new groups. The first group included the entire specimen from the undamaged cross-section (intact inner cross -section). The second group was formed by the specimen from the corroded peripherical cross-section. The advantage of such a partition is that as the actual load bearing capacity of the undamaged cross-section can be estimated more accurately.
The characteristic values of the strength properties are determined according EN 384:2010 [18], chapter 5.4 as shown below (see Equation 4).

$$f_k = \overline{f_{05}} \cdot k_S \cdot k_V \quad (4)$$

where f_k = characteristic value of the strength in [N/mm²], $\overline{f_{05}}$ = mean value of the 5-percentile values which are weighted in proportion to the amount of specimen in [N/mm²], k_S = correction factor to consider the amount of samples and specimen according to EN 384:2010 [19], Figure 1, k_V = correction factor to consider the low variability of the 5-percintile values of machine-graded timber in comparison to visually graded timber

The 5-percentile value f_{05} is determined as shown in Equation 5:

$$f_{05} = \bar{f} - s_x \cdot t_{95} \quad (5)$$

where f_{05} = 5-percentile value of the strength in [N/mm²], $\bar{f}$ = mean value of the strength in [N/mm²], s_x = standard deviation of the strength in [N/mm²], t_{95} = t-factor of the Student-distribution for 1 - α = 95 %

The characteristic value of the density is determined according EN 384:2010 [18], chapter 8 as shown below (see Equation 6).

$$\rho_k = \frac{\sum \rho_{05,j} \cdot n_j}{\sum n_j} \quad (6)$$

where ρ_k = characteristic value of the density in [kg/m³], $\rho_{05,j}$ = 5-percentile value of the density of a sample in [kg/m³], n_j = amount of specimen in one sample

The 5-percentile value ρ_{05} is determined as shown in Equation 7:

$$\rho_{05} = \bar{\rho} - 1{,}65 \cdot s \quad (7)$$

where $\bar{\rho}$ = mean value of the density in [kg/m³], s = standard deviation of the density in [kg/m³]

A characteristic value of the bending strength of 25.67N/mm² in the corroded peripherical cross-section respectively 45.40N/mm² in the intact cross-section was derived from the test results. The characteristic density equals a value of 413.81kg/m³ in the corroded peripherical cross-section respectively 376.23kg/m³ in the intact inner cross-section.

These results are again proving the reduction of the material’s strength in the peripherical cross-section in comparison to the intact inner cross-section. The density in the peripherical cross-section is increased. This fact is caused by the deposition of salt in the peripherical cross-section as already mentioned above.

The characteristic material properties of timber are nowadays regulated in the EN 338:2010 [20], Table 1. The comparison of the characteristic values of the test results with the characteristic values of the strength classes in EN 338:2010 [20] allows an assignment of the material in the corroded peripherical cross-section to the strength class C24. The material in the intact inner cross-section can be assigned to the strength class C27 although the characteristic bending strength is much higher than listed in EN 338: 2010 [20], Table 1 (see also Table 3).

Table 3: *possible assignment of the examined material to the strength classes of timber according EN 338:2010 [20]*

	C24	peripherical cross-section	C27	inner cross-section
bending strength $f_{m,k}$ [N/mm²]	24	25.67	27	45.40
density ρ_k [kg/m³]	350	413.81	370	376.23

Following the regulations of EN 14080:2013 [21], Table 1 it is possible to assign lamellas of the strength class C24 to the T-class T14. Lamellas of the strength class C27 can be assigned to the T-class T16.
Since the extraction of the samples included every lamella in the cross-section the assignment mentioned above can be assumed for the whole cross-section.
However, this assignment could only be seen as orientation since the flexural modulus of elasticity is also decisive in order to assign timber to a strength class. Furthermore, the characteristic values of the test material are derived from test on defect-free wood. The transmission of the results to full-scale timber members is only possible with the help of an adequate regression function. At the moment there is only inadequate knowledge for wood affected by chemically-aggressive media.
On basis of the orienting assignment of the examined material to the strength and T-classes of timber a valuation on the load bearing capacity of the glulam timber members is now possible.
According to EN 14080:2013 [21], Table 3 glulam timber which is entirely made of lamellas of the T-class T14 can be assigned to the strength class GL24h according to EN 14080:2013 [21], Table 5. If the entire lamellas are assigned to the T-class T16 the glulam timber could be assigned to the strength class GL26h.
These possible assignments are only valid for modern glued laminated timber. Whether this is also valid for historic glulam members is questionable at the moment. The main causes are the lack of knowledge about the historically used glues as well as the fact that historic glulam members were produced without finger joints.

6 CONCLUSIONS

The results of this study are revealing that the examined material was clearly altered due to the salt exposure in spite of its high resistance against the effect of chemically-aggressive media.
The chemical analysis has shown that the salts are not only deposed in the peripherical cross-section but also in its core. The concentration was measured with a value of 10-13% in the peripherical cross-section respectively 1-5% in the core.
The influence of the chemically-aggressive media is amongst others clearly visible by the macroscopic alteration of the wood structure near the surface. The surface structure of the examined material was fibrous and showed a greyish-brown discolouration. This discolouration reached a depth of 20-25mm.
The results of the material test have proven the macroscopic alteration of the examined material. Although, there is no significant reduction of the strength in the inner cross-section there is a significant reduction of the strength in the peripherical cross-section. The density decreases from the surface towards the inner cross-section. This refers to the analyzed salt concentration.
The thickness of the circumferential corrosion layer was determined on basis of the examined material's bending strength. Two methods were used – firstly the method according to [17] and secondly a comparison between the test results and the 5-percentile value of the normatively regulated bending strength according to DIN 68364:2003 [16]. In the result a thickness of 5mm on the web respectively 10mm on the chords was determined.
A comparative calculation according to the method described in [6] showed that the prognostic calculated load factor (method 1 - calculation with a reduced strength) approximates the actual load factor (method 2 - calculation with a reduced cross-section).
The influence of the chemically-aggressive media on the material's properties is not taken into consideration in the currently valid timber construction rules so far [7]. However, this study has shown that this influence has to be taken into consideration on existing timber structures.
The results of this study led to further investigations on the influence of the chemically-aggressive media on the load bearing capacity of historic glued laminated timber constructions. This includes the determination of the strength of glulam and solid wood member in full-scale as well as a study on the glued joints. These studies will be mentioned in future publications.

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