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INTERNATIONAL COUNCIL FOR BUILDING RESEARCH STUDIES AND DOCUMENTATION

WORKING COMMISSION W18A - TIMBER STRUCTURES

MODIFICATION FACTOR FOR "AGGRESSIVE MEDIA"

A proposal for a supplement to the CIB model code

by

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1. Introduction

Timber has a high resistivity to chemically aggressive agents. This is one of the reasons why timber structures are frequently being used in the construction of storage halls for chemical materials or of industrial buildings with an aggressive environment.
Also with agricultural systems and plants, at certain buildings (storage halls and production buildings) a high chemical stress and strain (loading) is occurring as well.
Failures and damages done to timber structures in these fields of application are showing, however, that the corrosive action of said materials and substances on the timber and the connections (fasteners) is often being underestimated. In the GDR, frequently nailed roof frames and trusses with thin boards are being used for agricultural buildings which have been optimized exclusively in terms of the material consumption. The chemical agents are easily and promptly penetrating the thin boards which will result in a corrosion of the nails.

The CIB Code /1/ is hitherto not yet including any recommendations with a view to considering the attack of chemically aggressive substances on timber structures.
This report shall present a proposal for a supplement to the CIB Code.

The degree of aggressiveness (corrosivity) of the chemical action (e.g. of salts, acids or bases) in a solid, liquid or gaseous state of aggregation, the period of time of the action concerned, the location of the structure concerned as related to the environmental conditions, the kind of timber used and the structural design are altogether resulting in the formation of a corrosion system. These individual factors are deciding the rate of destruction of the timber.

The proposal concerning the provision of a factor for considering the chemical action is based on both investigations and studies using removed timber components and laboratory tests.

2. Proposal for a Supplement to the CIB Code

Timber is resistant to weak acids with a normal indoor temperature and to alkaline solutions with a low concentration. A corrosive action is occurring only due to strongly acid and strongly alkaline solutions. In general, the timber corrosion is insignificant within the pH-value range of 2 > pH < 11.
With the majority of chemicals in a solid, liquid or gaseous state of aggregation, the corrosive action is decreasing in the course of time and a destruction is occurring only in zones located near the surface (see also Erler /2/).

The factor for considering the chemical action is being determined subject to the degree of stressing (exposure), i.e. the degree of aggressiveness.

The cross-sectional dimensions are influencing the effect of the corrosive action on the loadbearing capacity. Therefore, the factor has been fixed subject to the timber cross section. The corrosive action is also being influenced by applied protective systems which will be taken into consideration as well.

The aggressive action of gases is resulting from the concentration of the gas concerned. Based on the concentration of the gases, the degree of stressing of the chemical action is being determined subject to the moisture grade.
A dependence of the degree of stressing on the moisture grade is being verified for solids as well.

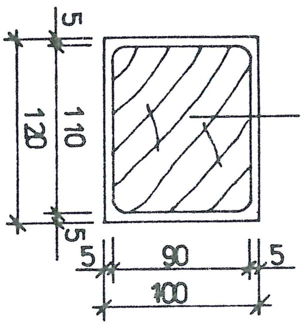
3. Examples

(a) Timber components of storage halls

At a hall for the storage of potash, square timber components sized 100 by 120 mm are being used. The storage hall is not being heated.
Classification: moisture grade 2;
the degree of stressing according to Table 4
is BG II.

The modification factor subject to the cross-sectional dimension and to the degree of stressing is 0.85 according to Table 5 (see /2/).
The statically loadbearing cross section is to be reduced by this value as follows:

$$\text{avail. } A = 0.85 \cdot 12{,}000 \text{ mm}^2 = 10{,}200 \text{ mm}^2.$$



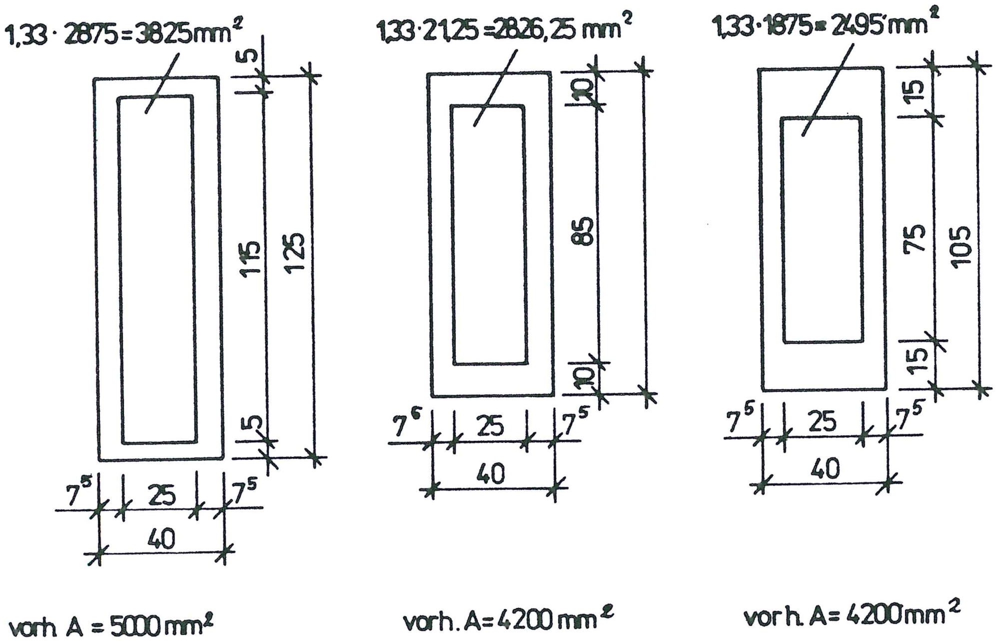
Thus, a protective layer of timber amounting to 5 mm is remaining as a structural corrosion protection.

By means of square timber components removed from existing potash storage halls with a service life of 50 to 70 years, the strength over the cross section has been determined (see Figure 1). One can see that just in the boundary zone of < 5 mm a considerable reduction in strength may be verified.

(b) Nailed roof frames of storage halls

For roofing over an unheated hall for the storage of fertilizers, a nailed roof frame is being used. The members are made up of timber boards sized 25/115, 25/85 and 25/75 mm.
Classification: moisture grade 2;
the degree of stressing according to Table 4 is BG II.
Modification factor = 0.75, $A \leq 9{,}000 \text{ mm}^2$ (acc. to Table 5).

The cross sections being statically fully utilized must be increased by the factor of $1/0.75 = 1.33$.



Small-size cross sections are being penetrated almost completely whereas with large-size cross sections the aggressive substances are incorporating only in the boundary zones (see the Figures 1 and 2).

Therefore, minimum cross sections and minimum thicknesses have been fixed for the degrees of stressing BG II and BG III.

From structural failures and damages done to nailed roof frames with the above-mentioned cross sections of the timber boards (i.e. 25 x 115, 25 x 85 and 25 x 75 mm), a maximum service life of 25 years only can be verified as compared with 60 years in the case of a normal environment.

There are only the following two approaches to increase the service life:

(1) increase of the cross sections, taking into consideration the required minimum values, and

(2) application of a suitable and efficient corrosion protection system.

References

/1/ CIB
Structural Timber Design Code
1983

/2/ Erler, K.:
Korrosion und Anpassungsfaktoren für chemisch aggressive Medien bei Holzkonstruktionen
(Corrosion and Modification Factors for Chemically Aggressive Media with Timber Structures)

Modification factor $\gamma_{d,4}$ as to "Aggressive Media" at the limit state of the loadbearing capacity (GZT) and limit state of the usability (GZN) of structural timber (BH) and glued laminated timber (BSH)

The kinds of medium are being divided into gases, solutions and solids. By means of the criteria as to concentration of the medium and moisture grade, the degrees of stressing (BG) I, II and III are being determined.

Table 1:

Degree of stressing (BG)	Explanation
BG I	not or slightly aggressive
BG II	moderately aggressive
BG III	highly aggressive

Thus, after the classification of the media into ranges of aggressiveness the degree of stressing (BG) is to be determined by means of the tables following hereinafter. With the BG, the modification factor $\gamma_{d,4}$ for aggressive media can be drawn from Table 5 subject to the cross-sectional size of the timber components.

Table 2: Ranges of aggressiveness (A) and degrees of stressing (BG) for gases

Table 2a: Ranges of aggressiveness (A) for gases

Gas, increasing aggressiveness			Group of gas, with a concentration of ... (mg/m^3) A 1	A 2	A 3
1.	CH_2O	(formaldehyde)	1...200	-	-
2.	NH_3	(ammonia)	0.5...20	-	-
3.	SO_2	(sulphur dioxide)	0.2...10	10...200	-
4.	NO_2	(nitrogen dioxide)	0.1...5	5...25	above 25
5.	HCl	(hydrogen chloride)	0.05...1	1...10	above 10
6.	Cl_2	(chlorine)	0.02...1	1...5	above 5

Table 2b: Degrees of stressing (BG) for gases

Degree of aggressiveness (A)	Moisture grade (FK) FK 1	FK 2	FK 3
A 1	I	I	I
A 2	I	II	II
A 3	II	II	II

Table 3: Degree of stressing for solutions

Group	Solution	pH-value	Concentration of the solution	Degree of dissociation (with 1-normal solution)	Degree of stressing
acids	nitric acid HNO_3	below 2	up to 5 above 5	high	III III
	hydrochloric acid HCl		up to 5 above 5	high	III III
	sulphuric acid H_2SO_4		up to 5 above 5/ above 15	medium	I II/III
	acetic acid CH_3COOH	4	above 15	low	I
bases	soda lye NaOH		up to 2 above 2	high	II III
	potash lye KOH	above 13	up to 2 above 2	high	II III
	ammonium hydroxide NH_4OH		up to 5 above 5	low	I II
salt solutions	chloride solutions: KCl, NaCl	7	up to 10/ above 10	medium	I/II
	sulphate solutions: Na_2SO_4 (Glauber's salt)		up to 10/ above 10	medium	I
	$(NH_4)_2SO_4$ (ammonium sulphate)	5	up to 40		I
(organic compound)	urea $CO(NH_2)_2$	2	up to 40		II

Table 4: Degrees of stressing for solid media

Solid medium	pH-value	Solubility in water	Hygroscopicity	Degree of stressing (BG) with moisture grade FK 1	FK 2	FK 3
potash fertilizer	8	good (up to 20 %)	good	I	II	II
urea	9	good (up to 40 %)	high	I	II	II
superphosphate	3	(up to 5 %)	good	I	I	II
sodium chloride	7	good	good	I	I	II
ammonium sulphate	5	good (up to 40 %)	low	I	I	I

Table 5:

Modification factors $\gamma_{d,4}$ for aggressive media subject to the timber cross-sectional size

Degree of stressing (BG)	Cross-sectional size (10^3 mm^2)	Factor $\gamma_{d,4}$
BG I		1.0
BG II	< 9	0.75
	< 30	0.85
	$\geqq 30$	0.95
BG III	< 9	0.65
	< 30	0.75
	$\geqq 30$	0.85

Note: Minimum dimension of the timber component concerned with BG II and BG III: 40 mm; minimum cross-sectional area: 4,000 mm^2.
$\gamma_{d,4}$ is related to the area of the unimpaired cross section.
Permitted timber preservatives (protective agents) are not having any aggressive action on the timber. When using efficient linings (surfacings) or coatings, the value of $\gamma_{d,4}$ will be equal to 1.

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