Short description of the laboratory

EMPA, Swiss Federal Laboratories for Materials Testing and Research

Wood Department

Ueberlandstrasse 129

CH-8600 Duebendorf, Switzerland

Head : Prof. Dr. Juergen Sell

http://www.empa.ch/abt115

Tel : +41 1 823 55 11	Fax : +41 1 823 40 07	mail : rene.steiger@empa.ch

Main topics	Example of activities	Number of scientists
• **Wood Science**	- Ultrastructure of wood cell wall and its significance for wood characteristics - Fracture structures of wood – key to the understanding of mechanical failure - Technical characteristics and promotion of underused wood species - Stresses in beech	**3**
• **Wood Technology**	- Optimising wood glueing and surface treatments - Quality preserving storage of roundwood - Improving drying schedules and –procedures	**3**
• **Wood Construction**	- Editing new Swiss Code SC 5 for the design of timber structures (Parts: Basis and application rules of design, material properties, grading) - Evaluation of the mechanical properties of timber and composite materials - Standardising time-proven construction details - Development and promotion of composite wood/concrete decks - Advanced wood assembly systems and reinforcing of timber elements using high-tech fibres (glassfibre, carbon, kevlar, etc.) - Improving durability of weather exposed structures by providing better "protection by design"	**4**
• **Ecological Analysis**	- Comparative ecological evaluation of building products and materials - ZEN Centre for energy and sustainability in buildings	**4**

Main equipment : testing machines (bending, tension, compression, combined loading, fatigue) for tests on small specimens and such in structural size, climate rooms, weathering stands, high-resolution field emission scanning electron microscope (FE-SEM), ultrasonic grading equipment, resistograph, workstations

Activities related to the field of COST Action E24

Mechanical Properties of Swiss Spruce (R. Steiger)

In adapting the Swiss Standard SIA 164 for Timber Structures to Eurocode 1995-1-1 the problem arose of how to modify the strength classes used in Switzerland for spruce squared timber and timber boards in respect to the new European classes given in EN 338. This could not be accomplished simply on the basis of theoretical considerations, so that extensive experimental investigations under bending, tension, compression and combined loading had to be carried out.

Giving information on strength classes is closely linked to the sorting method employed. Only by means of an objective method with clear-cut criteria is it possible to comply with the characteristic values laid down in EN 338. Visual sorting is still widely used. Because of the large number of timber properties which have to be determined, this method of sorting is often only carried out superficially and practically all timber is assigned to the class "normal structural timber". For this reason, and since some important properties like density are not amenable to visual sorting, there has been an increased evaluation of machine grading methods for classifying timber. In Switzerland, the ultrasonic method of sorting is favoured and is being tried out in research and engineering practice due to its simplicity and universal applicability. Beginning with a general consideration of the correlative relationships between the sorting parameters density, Young’s modulus, body wave velocity and the mechanical properties of timber it is shown that it is possible to reliably classify timber using the ultrasonic method. Ultrasonic sorting criteria are given for classifying conditioned squared timber and timber boards and for the pre-sorting of round and squared timber in the fibre-saturated state. In a subsequent section the ultrasonic and visual sorting methods are compared and the classification of the timber used in Switzerland according to the new classes of EN 338 is described.

A further main topic was the verification of the rules given in EN 338 and 384 for calculating the tensile and compressive strengths from the characteristic value for bending strength. In addition, the rules for determining the influence of volume and the given relationships between 5 %-fractile and mean values of density and modulus of elasticity in bending were investigated. Finally, considerations regarding structural behaviour of spruce squared timber under the combined action of bending moments and normal forces were made to control EC 5's assumption of a linear interaction in the bending-tension and in the compression zone when instability problems occur (slender members). The modelling of the failure of short members by a nonlinear superposition of bending moments and normal forces was controlled as well.

New Swiss Code SC 5 for the design of timber structures (R. Steiger)

Since 1989 Swiss Engineers design their concrete, steel and masonry structures using a coherent system of level-1-design codes (limit states design and partial coefficient methods), whereas the design of timber structures is still based on allowable stresses. At the end of 1997 the project "Swisscodes" was started, whose attempt it is to publish a new generation of design codes for all building materials and for foundation engineering, which shall combine the principles of Eurocodes with the latest results of scientific work and with the well introduced traditional standards in Switzerland.

In comparison to the other materials the design code for timber structures SC 5 will look completely different to the known Swiss standard SIA 164 since limit states design and partial coefficient methods will replace the design based on allowable stresses. The Wood Department of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) is in charge of the following parts of the new design code, which shall be published at the end of 2001:

- Chapter 1: Introduction, normative basis
- Chapter 2: Basis of design (Limit states, partial safety factors, influence of time, temperature and moisture content, durability)
- Chapter 3: Material properties (solid timber, glulam, wood based materials, adhesives)

- Chapter 4: Design (bending, tension, compression, shear, torsion, buckling, lateral buckling, combined bending and normal force, vibrations, fatigue, fire safety design, timber-concrete composite constructions, earthquake)
- Annex A1: Strength grading (strength classes, visual grading, machine grading)
- Annex A2: Mechanically jointed beams
- Annex A3: Built up columns
- Annex A4: Timber-concrete composite beams
- Annex A5: Designing based on test values

Advanced wood assembly systems and reinforcing of timber elements using high-tech fibres (U. A. Meierhofer, R. Steiger)

The use of modern materials like fibre reinforced plastic (FRP) offers new possibilities for structural systems of wood. As these possibilities have hardly been exploited up to now, the Wood Department of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) is undertaking research and development projects for the combined usage of FRP and timber:

- Possible fields of application, lack of knowledge
- Development of an optimised tension test specimen
- Tensile deformation tests at various temperatures
- Tensile tests on timber joints with FRP-lamellas (small and structural-sized specimens)
- Tensile and bending tests on glued laminated specimens with FRP-splices
- Short and long term bending tests
- Evaluation and optimisation of various adhesives and glueing techniques

Beside the test series in the laboratories there are quite a lot of practical applications mainly the strengthening of old timber structures by bonding FRP-Lamellas in the weak zones.

Damages caused by 1999's hurricane "Lothar" (M. Arnold)

The Wood Department of the EMPA is engaged in a scientific project, which deals with collecting and documenting knowledge about the damages caused by 1999's hurricane "Lothar". The main fields of activity are:

- Compression/tension damages of fibres caused by wind pressure
- Long-term storage of logs

Regarding COST Action E 24 the problem of compression/tension damage of fibres caused by wind pressure is of interest. During a storm significant bending deformation of trees can occur. If the deformation reaches a certain level, the compression strength parallel to the grain might be exceeded. Such zones of fibrous damage are weak points, which show characteristic short-fibered brittle fracture at a low level when stressed in tension. The range of application for this kind of damaged wood is reduced due to the safety risk. Fibrous fracture caused by wind pressure is not a new phenomena and there exist some earlier studies about. The owner of sawmills know how to deal with this problem and they are very careful in processing wood with possible fibrous fractures. Nevertheless it would be of great interest to recognise fibrous fracture as early as possible. Visual detection of zones of fibrous fracture is only possible if the timber is sawn and planed and if the zone of damage is rather significant. Techniques should therefore be developed to reliably determine fibrous fractures on logs and on sawn but not planed timber. The problem not only concerns thrown and broken trees. It's even more dangerous, if the hurricane has damaged the tree locally but did not fell it. Using such timber for structural purposes without a reliable grading covers a rather high risk.

The purposes of the scientific project therefore are to determine / evaluate:

- the level of damages in trees and sawn timber
- the influence of the fibrous fractures on the strength of timber in structural sizes
- methods to detect fibrous fractures as early as possible (trees, logs, sawn timber)

Supervision of weather-exposed timber structures

(F. W. Kropf, R. Steiger)

Most exposed timber structures that have disappeared with time did not fail due to faulty structural design, but to decay. The major risk factors for weather-exposed timber are rain and direct sunshine, which causes the opening of cracks. When water penetrates into the cross section and cannot dry out rapidly enough, fungi develop and decay the wood quite fast and unnoticed until damages are beyond repair. Therefore the most effective wood preservation will always be a complete cover over the entire structure. With such an "umbrella" the supporting system is completely protected from rain and sunshine and thus not subject to degradation. Hundreds of "covered bridges" in Europe and North America were built more than 100 years ago. Some are up to 200 years old, are still in use, and will remain in use for as long as a minimum of maintenance is provided.

Today covered bridges (and houses) are considered "old-fashioned". The architects don't care too much about life-time-behaviour ("function has to follow form") and therefore their timber constructions often lack of the "umbrella" mentioned above. Chemical treatment of wood could help but this way of solving the problem is not adequate because of ecological reasons. However, for timber to be accepted as "modern engineering material", the service-time of weather-exposed timber structures must be comparable to that of concrete or steel.

During the last 15 to 20 years the Wood Department of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) is supervising different timber constructions, which are exposed to weather. As a result, we got experience in:

- Long-time-reliability of weather-exposed timber structures
- Adequate protecting measures and detailing
- Additional measures (decay-resistent wood species, localised chemical protection)
- Inspections and periodic maintenance
- Upgrading of old timber-structures with high strength-fibres

Long Term Perfomance of Timber-Concrete Structural Elements

(A. Kenel, U. A. Meierhofer, R. Steiger)

The results of an early extensive research and development work on Timber-Concrete-Composite Structural Elements (TCCs)-system, mainly short and medium term withdrawal-, shear- and bending tests, have been described in the research report EMPA 115/30 [Timmermann, Meierhofer 1993]. The report also contains some information on the development and the conception of the new building system. One of the most important results of the early tests was the realisation, that the behaviour of TCCs is not governed by strength considerations but by deformations, particularly the deflections under long term bending loads. Due to the fact, that any experience was lacking in this context, long term bending creep tests with TCCs have been initiated in 1992 and shear creep tests in 1993. While the shear tests have been performed under constant climatic conditions, the long-term bending test have been built up outside under roof i.e. under relatively unfavourable conditions with natural temperature changes and drying and wetting cycles.

At the end of 1996 the creep tests have been terminated and the results consolidated within the framework of a thesis. The present report summarises the results of the creep tests and the conclusions to been drawn of them: As expected, the moisture conditions, i. e. the initial moisture content and the moisture changes proved to have a very dominating influence. The maximum bending creep factor within the five years test period was about 3.1 for the test specimen exposed to high moisture content and about 2.2 for the other ones. In spite of these high creep factors the ratio between deflection and span proved to be still acceptable (<1/300).

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