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Progress in Codes and Standards for Timber Construction

Progrès dans les normes et recommandations pour la construction en bois

Fortschritte in Baunormen und Empfehlungen für den Holzbau

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SUMMARY
In recent years, and currently, great efforts are being made to create a foundation for internationally agreed uniform structural design codes for all materials based on so-called "limit state methods". This Paper gives some of the background which has led to these developments along with an indication of some of the proposals which are likely to be included in timber codes and some of the outstanding research problems which need to be done to enable this to be carried out satisfactorily. It should be emphasized that because of current discussions taking place many changes and amendments are likely before this Paper is considered.

RESUME
De grands efforts ont été accomplis ces dernières années – et le sont encore actuellement – pour établir le fondement d'un règlement de construction international pour tous les matériaux, qui soit basé sur la "méthode aux états-limites". Ce rapport en mentionne quelques aspects et énumère quelques propositions susceptibles d'être incorporées dans les normes de construction en bois. Certains travaux de recherche sont encore nécessaires pour réaliser cette norme. Il y a lieu de souligner que de nombreux changements et corrections se produiront avant le congrès.

ZUSAMMENFASSUNG
Dieser Bericht erläutert die bisherige Entwicklung und erwähnt einige Vorschläge, die in künftigen Holzbaunormen berücksichtigt werden sollten. Zugleich werden noch offene Forschungsprobleme aufgezeigt. Infolge der laufenden Diskussionen sind noch vor dem Kongress in Wien Änderungen und Anpassungen zu erwarten.

1. BACKGROUND

In most countries it has been convenient in the past to consider the design of timber structures in four stages:

- assumed loading
- design stresses for the materials (usually based on some form of testing materials)
- methods of analysis
- required performance (e.g. how much deflection should be permitted)

The various structural codes in most countries have not been concerned with loading. This is usually covered by other codes independent of the various materials. Until recently most of these codes were based on the assumption that loads could be defined precisely by values which would not be exceeded in practice. More recently, they have become based on measurements, particularly the natural loads such as wind and snow, and have been subjected to statistical analysis.

In addition, most codes have only contained limited information on design analysis of structures and it has been assumed that generally acceptable principles of structural engineering would be followed. Design has only been mentioned when modifications have been necessary to account for particular characteristics of materials or when the design is preculiar to one material. In these instances modification factors are usually given in the relevant codes.

Timber codes were therefore chiefly concerned with laying down permissible stresses for timber and plywood and various jointing devices and giving modification factors to enable these to be adjusted to particular design situations.

For example, the first edition of a timber design code in the United Kingdom was published in 1952 (called CP 112 'Structural Use of Timber'). This code was based on the use of notional loads given in another code applicable to all materials. With timber the required safety was obtained by limiting the design stresses to values which were approximately one fifth of the ultimate strength of the constitutent materials. In fact, two design stresses of 5.5 and 6.9 N/mm^2 respectively were laid down for two groups of species of similar quality. It is interesting to understand how these stresses were derived. They were based on a study of current experience up to that date. The sizes of members used in various constructions were found by survey and by using the assumed code loading and normal simple structural design Stresses were then derived which the timbers were obviously capable of sustaining. A similar action was taken with regard to the derivation of deflection limits, which are usually limited to a fraction of the total span, e.g. L/300. Until about 1965 no allowances were made for variations either in load or the material itself. Most North American and Western European codes followed a similar process. Generally, the Nordic codes were a little more advanced and in fact a 'partial factor code' was introduced in Denmark at a very early stage.

2. VARIABILITY IN MATERIALS

In the 1960's some attempt was made in many codes to make allowance for the real behaviour of timber by taking into account its natural variability. This was done by using the measured distribution of various strength properties and using a minimum calculated value (say 1 or 5%) as a starting point before the application of safety factors to these values. (Distributions were assumed to be 'normal' or occasionally 'log-normal'). Safety factors of the order of three were quite common! In recent years there has been a move to derive design stresses from tests on full sized graded material. Generally, non-parametric methods of analysis (e.g. 3-parameter - Weibull) have been found appropriate.

3. VARIABILITY IN LOADING

A combination of assumed load and design stresses determine what size of members will be used in a construction. Hence, it is impossible to separate these two variables in consideration of drafting suitable design codes. For example, it was found in a survey carried out 10 years ago that some countries have twice the design floor loads of others and at the same time are using stresses about twice as high also. Hence, they arrived at similar designs whereas a consideration of loading alone would have led one to believe their values were twice that of another country.

It is very apparent that many loadings cannot be defined with great precision and some loads are easier to estimate than others. Thus, dead or permanent loads such as weights of building materials show variations which are generally less than those due to the climate. e.g. wind and snow loads.

However, statistical information on climatic loading is available and it is now possible to predict at any required probability level the maximum wind load likely to occur on a building during its assumed life, which is often taken as 50/60 years. A statistical approach has therefore been adopted in current revisions of many national and ISO wind loading codes. Such information is not yet available (and may be very difficult to obtain), for imposed loads caused by the type of occupancy and storage and therefore it may be some considerable time before it is possible to specify these loadings in true statistical manner. Other considerations are that dead loads will generally show less variation than live ones and that the extremes of loading caused by people, snow and wind, are unlikely to occur simultaneously.

It is therefore fairly easy to see that the safety of a structure (or the probability of it failing) depends on both the variations in applied loading which are likely to occur and on variations in material from which they are constructed. Good design seeks a balance between allowing adequately for the load which might occur, whilst keeping the amount of material in the structure to a minimum by trying to ensure an acceptable consistent risk of failure throughout the whole structure.

4. LIMIT STATE DESIGN

Some confusion exists between the definition of 'limit state design' and the introduction of probabilistic methods. It happens that both methods are being brought to the forefront simultaneously and many of the suggested changes due to statistical methods are being attributed to limit state design. Generally, limit state design is nothing to do with the particular safety method being considered and can be just as appropriately applied to full statistical methods or the 'partial co-efficient' safety load factor methods currently being suggested. Limit state design is purely a systematic treatment and a somewhat theoretical clarification of the subjects rather than any new ideas in the subjects.

A limit state design is reached when a structure becomes unfit for its intended use. There can be a number of reasons why a structure becomes unfit for use and each one of these is termed a 'limit state'. The most important limit states in timber design are those of ultimate collapse and excessive deformation.

Other confusing problems have been caused by the fact that attempts have been made to draft model codes purely for the use of code writers, and practitioners in design have assumed that the codes have been written for their use and tend to complain about their complication.

In considering the progress in codes and standards for timber it is convenient to divide the subject into three areas:

- the obtaining of necessary research information to permit sensible harmonisation of codes and standards
- the development of acceptable test methods to enable the material properties to be obtained satisfactorily, linked with agreed methods of sampling and evaluation of 'characteristic' values
- the development of an international design code of timber engineering, including material properties, safety concepts and design methods (whenever these are peculiar to timber).

5. HARMONISATION

More international harmonisation through international standards and regional directives (EEC, CMEA) is inevitable. In some respects this will represent a major step forward, in others it will offer short term disadvantages to their particular materials, and in other cases it probably will not matter apart from obtaining a neat and tidy solution. In the latter cases, it is important that the cost of design is not added to or the final results will be found unacceptable.

The increasing cost of research makes international co-operation highly desirable to obtain maximum benefit from the world research resources available. Generally, testing standards are desirable since they cut the cost of testing and particularly avoid repeat testing in different countries.

Sometimes it can be a local or national short term disadvantage to harmonise regulations, since they can reduce technical barriers where a country has more to lose than gain. This is why ultimate initial harmonisation is more likely to occur on a regional level since they have the power to remove trade obstacles. Both EEC in Western Europe and CMEA in Eastern Europe regarding the removal of trade obstacles by having similar building codes and safety systems as a prime object.

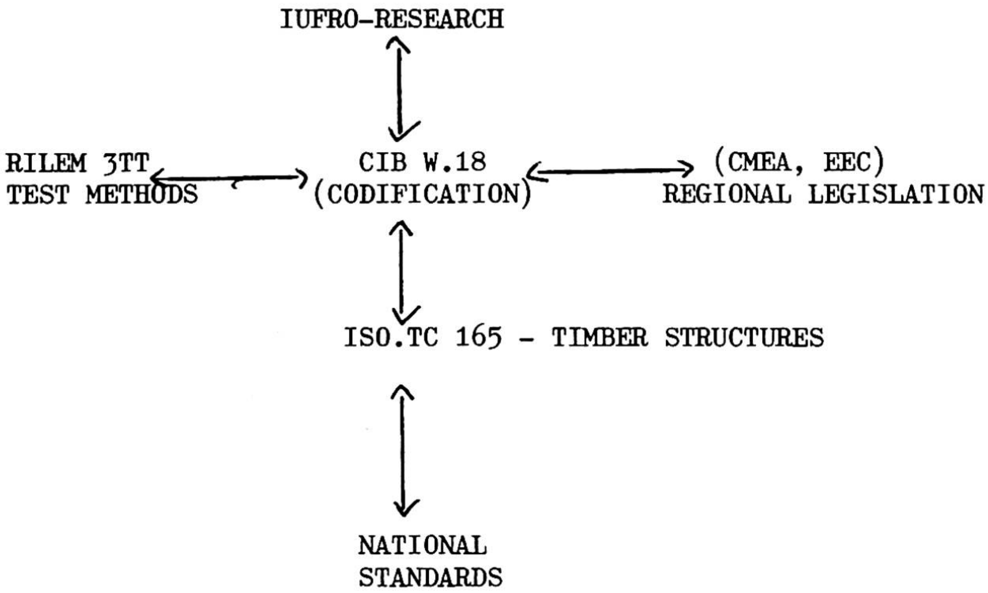
6. THE WORK OF CIB W.18 'TIMBER STRUCTURES'

CIB W.18 'Timber Structures' was reformed in 1973 with the following terms of reference:

> "To study and highlight the major differences between the relevant national design codes and standards and suggest ways in which the future development of these codes and standards might take place in order to minimise or eliminate these differences."

CIB W.18 is constituted by leading timber research and code engineers from most Western, Northern European and Northern American countries, with some representation from other countries such as Poland, Australia, South Africa, etc. It has emerged at the right time as a leading Forum in the world on timber structures to provide maximum assistance for harmonisation of codes and standards and in this work has been recognised by ISO, ECE and EEC as a major Forum and to provide them with drafts and to assist them with the harmonisation of Building Regulations and Structural Codes.

The diagram below illustrates the relationships CIB W.18 has with these other organisations.



The work of CIB W.18 is implemented in three main ways:

- as an independent group of timber engineering experts who publish their own recommendations through CIB so the rest of the world is aware of their views and of recommended ways of dealing with timber in structural codes.
- by ensuring that the recommendations of CIB W.18 are made available to the appropriate organisations who wish to use them (e.g. ISO, ECE, EEC, etc.). Also to ensure that the recommendations are correctly used, members are encouraged to take part in the activities of these organisations.
- individual members are able to report back to their national organisations and encourage the adoption of CIB agreements and recommendations.

CIB W.18 has completed a fourth draft of a CIB code which, with suitable editing, could link in with other structural codes on any sensible safety system. Appendix 1 gives a list of chapter contents for the fourth draft CIB code.

7. TIMBER ENGINEERING RESEARCH

In drafting a CIB code and considering its application alongside other materials, many research gaps have been identified. For this reason CIB W.18 has forged links with IUFRO Division 5.02 'Timber Engineering'. This is a worldwide organisation concerned with timber engineering research.

In the development of suitable timber engineering codes and in particular the CIB code, it has become apparent that if timber is to remain competitive with other materials a large amount of information is necessary on timber properties, etc. For example:

- in new codes it is essential to be able to estimate 5% minimum or 'characteristic strengths' of materials. To be able to do this, much data is necessary and methods of analysis have to be developed. For this reason the IUFRO Timber Engineering Group has been co-ordinating and encouraging work which has been carried out in many countries in deriving timber strength properties on a logical basis.

Other points which have to be considered are concerned with timber's response under long term loading and moisture content. In previous codes fairly high factors of safety have been used and these have included factors for effects of long term loading and moisture content. Recent information would indicate these factors are too large and put timber in a bad competitive position with other materials. If realistic timber codes are to emerge more information on the true long term loading factors and how these have been affected by moisture content is essential. The IUFRO Engineering Group is again co-ordinating work in this field.

Modern methods of limit state design tend to separate loading and the necessary factors to be considered from the material resistance side. If all materials are to be dealt with in a similar fashion with regard to loading, it is essential that the material resistance side is adequately dealt with. Other research work necessary to accommodate these problems is to consider how far the strength of timber is affected by size. Currently, fairly large 'depth effects' are assumed in timber design. Here again if an accurate estimate of the resistance of timber to loading is to result, realistic information on depth or volume effects is essential. Similar problems also occur with the stability of various timber and timber-based beams (plybox, plyweb, etc.).

Timber grading is an important subject which still needs further consideration. Timber requires a different philosophy in this respect from most other constructional materials. Most other structural materials are manufactured products (e.g. concrete, steel, masonry, aluminium, etc.). Timber, however, grows as trees and one has to accept the natural products which emerge. The logical way of dealing with such a natural product and overcome some of its variability, is to divide it into grades. With structural timber this is called stress grading. It is obvious that a balance between number of grades and some reduction in natural variability has to be achieved. Therefore, it is inevitable that there will be much consideration of stress grading as a way of utilising such a natural product. This is also why stress grading machines for selecting timber of required strength value may offer much potential for the future.

The ECE Timber Committee has recently made a significant contribution to harmonising grading and encouraging international trade by the publication of stress grading rules.

8. TEST METHODS

There is a small committee, which is a joint committee of RILEM 3TT Timber and CIB W.18, which is chaired by Dr. Kuipers from the Netherlands, which is trying to agree test methods for timber engineering properties. Subjects under which agreement has already been reached are concerned with testing solid timber, testing timber joints and methods for structural plywood. It is obvious that agreed test methods are essential as the necessary base in the development of structural codes, since the properties which emerge are affected by the strength of the timber. It is now necessary to develop realistic sampling techniques and methods of analysing the test results so that acceptable characteristic strength values are obtained.

9. TIMBER STRUCTURAL RESEARCH

There is still a large amount of timber structural research necessary. For example, it has recently been found in the United States that they feel their estimates of design strengths of timber are too high and yet when they test their structures they are very conservative. This means there is a considerable amount of work done on the prediction of structural strength in the form of complete structures, that is in the structural design field. It is obvious this work should be concentrated on the major timber structural items of floor, wall and roof construction.

10. CONCLUSIONS

Although a natural material whose use has evolved over the centuries, timber is nevertheless a material fully capable of meeting all modern requirements.

Research is necessary, but is taking place, which should enable timber to find its correct place alongside other structural materials as limit state design loads are developed.

The main organisation carrying out harmonisation work on Structural Timber Design Codes is CIB W.18 'Timber Structures'. Their links with ISO and Regional Standardisation Organisations should enable substantial progress to be made in Modern Safety Concepts.

Briefly, a fourth draft of an internationally agreed CIB Timber Code has been drafted and is now being considered by ISO.

The CIB is supported by Stress Grading Rules developed by the ECE Timber Committee.

Internationally agreed test methods for solid timber, plywood and timber joints have been agreed by a joint RILEM/CIB Committee. Research is in progress which will enable material resistance effects to be better understood in such matters as long term loading, moisture and size effects.

<u>APPENDIX 1</u> (List of chapter headings for the fourth draft CIB code)

1. INTRODUCTION
- 1.1 Scope
- 1.2 Conditions for the validity of this document
- 1.3 Units
- 1.4 Notations
- 1.5 Definitions

2. BASIC ASSUMPTIONS
- 2.1 Characteristic values
- 2.2 Climate classes
- 2.3 Load-duration classes

3. BASIC DESIGN RULES

4. REQUIREMENTS FOR MATERIALS
- 4.0 General
- 4.1 Solid structural timber
- 4.2 Finger jointed structural timber
- 4.3 Glued laminated timber
- 4.4 Wood-based sheet materials

5. DESIGN OF BASIC MEMBERS
- 5.1 Solid timber members
- 5.2 Glued laminated members

6. MECHANICAL FASTENERS
- 6.0 General
- 6.1 Joints with mechanical fasteners
- 6.2 Glued joints

7. DESIGN OF COMPONENTS AND SPECIAL STRUCTURES
- 7.1 Glued components
- 7.2 Mechanically jointed components
- 7.3 Trusses

8. CONSTRUCTION
- 8.0 General
- 8.1 Materials
- 8.2 Machining
- 8.3 Joints
- 8.4 Assembly
- 8.5 Transportation and erection
- 8.6 Surface treatment

Annex 7A: Mechanically jointed beams and columns with I-, T- or box cross-sections

Annex 7B: Spaced columns wuth nailed or glued packs or battens

Annex 7C: Lattice columns with glued or nailed joints

Current list of CIB W.18 Technical Papers