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Factors which Influence Durability of Wooden Structures

Facteurs affectant la durabilité des structures en bois

Einwirkungen auf die Dauerhaftigkeit von Holzbaukonstruktionen

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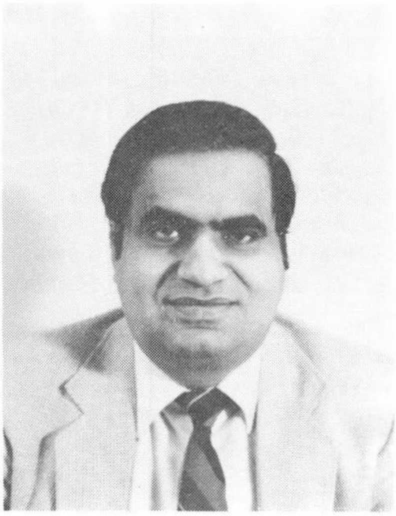

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SUMMARY

Various factors affecting the serviceability and durability of wooden structures are briefly discussed. Discussion is focused on the following factors: loading (man-made loads and forces due to natural hazards); time (duration of load, fatigue and creep); cyclic environment; weather exposure; decay due to fungi, insects and marine organisms; chemicals; and fire. A review of the manner in which these factors are accounted for in the current design codes for wooden structures is given.

RÉSUMÉ

Plusieurs facteurs ayant un effet sur l'aptitude au service et la durabilité des structures en bois sont examinés avec soin: charges dues à l'homme et à la nature; durée (durée du chargement, fatigue du bois et retrait); effets saisonniers; effet des conditions climatiques; effet des moisissures, des insectes et des organismes marins; produits chimiques; et feu. L'article présente la façon dont ces éléments sont pris en compte dans les normes pour les constructions en bois.

ZUSAMMENFASSUNG

Verschiedene Faktoren, welche die Gebrauchstauglichkeit und die Dauerhaftigkeit von Holzbaukonstruktionen beeinflussen, werden diskutiert. Es handelt sich dabei um: Einwirkungen (menschliche und natürliche), Zeitdauer (Einwirkungsdauer, Ermüdung und Kriechen), zyklische Beanspruchungen, Bewitterung, Zersetzungen infolge von Pilz- und Insektenbefall sowie durch marine Organismen, Chemikalien und Feuer. Es folgt eine Uebersicht über die Berücksichtigung dieser Faktoren in den heutigen Holzbaunormen.

1. INTRODUCTION

To carry out effectively the task of evaluation, maintenance, rehabilitation or upgrading of wood structures, it is imperative that the influence of various factors on the performance of these structures be understood. The factors discussed in this paper are: loading; time; temperature; moisture content; cyclic environment; weathering; insects, fungi and other organisms; chemicals; and fire.

2. LOADING

A structure must be designed to carry all man-made and natural hazard loads. Man-made loads generally include the dead and live gravity loads, constraint forces and accidental loadings such as from fire and blast. Live loads correspond to the intended use of the structure and to the occasional extrodinary loadings. One should design for possible changes in occupancy that might result in heavier loads than does the intended use. Constraint forces arising from differential settlement and due to temperature, creep, chrinkage, warping and other similar effects, should be considered in the design.

Depending on the location of the structure, loads resulting from hazards for a wood structure generally consist of forces due to wind, rain, snow, flood, earthquake, ponding and expansive soil. Critical areas for damage against wind forces are attachment of cladding and anchorage of the roof to the walls and the walls and floor system to the foundation. Anchorage must resist uplift, overturning and sliding. A dynamic analysis or wind tunnel testing may be needed for a structure potentially very sensitive to wind forces. Aspects to be considered in the design for earthquake forces include ductility in members and connections, limited strength loss with load reversal, compatible ductility between elements, and alignment of the massed and rigidity centers to avoid torsion.

Snow loading is dependent not only on geographical location, but also on local terrain effects and structure geometry. Wind-blown snow can cause large accumulations or drifts to develop which result in loads of intensity far in excess of those normally anticipated from annual precipitation records for a region. A taller structure in the close vicinity to the roof being considered, combined with high winds, will sometimes result in heavy snow loads in limited areas of the roof. The National Building Code of Canada [1] has recognized this phenomenon for several years and has developed guidelines for the designer to consider.

Ponding can be a serious hazard with flat roofs when there is inadequate strength or stiffness and insufficient roof drainage. Roofs should be designed either to ensure adequate drainage or to support the additional loads due to ponding.

3. TIME (DURATION OF LOAD, CREEP AND FATIGUE)

It is well recognized that the ultimate strength of wood decreases as the time of fracture increases, that is wood members can withstand higher loads for a shorter duration of time than the loads for a longer period. Therefore, the effect of duration of load on wood properties is an important aspect to be considered in the design of wood structures. To account for this effect, structural design codes, such as the National Standard of Canada [2] classify loads into a number of categories according to their duration and provide adjustment factors for use in design for these various durations. Presently, research on the influence of duration of load on wood structures is being carried out in Canada, U.S.A. and many other countries to study this phenomenon in depth.

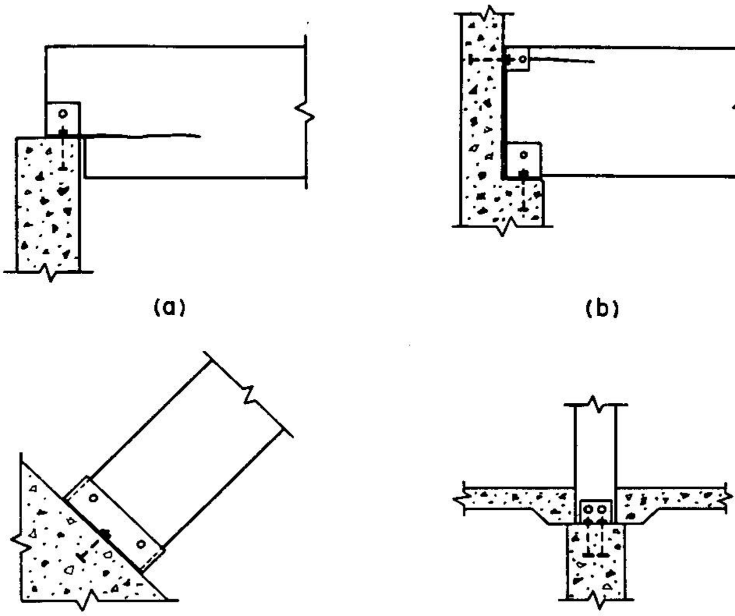

Fig. 1 Some Illustrations of Possible Problem-Type Connections

It has been observed that cyclic relative humidity and temperature affect the relation between loading and time-to fracture. Hearmon and Paton [3] have noted that the time-to-fracture for small, clear wood specimens in bending could be drastically reduced if the specimens were subjected to cyclic changes in relative humidity. Further research by Schniewind and Lyon [8] has shown that this reduction in time-to-fracture is dependent on specimen size. Design for fatigue in wood structures is generally considered to be not so important as in many other structural materials. However, research of fatigue fracture in wood indicates that the possibility of fatigue fracture under cyclic loading conditions should not be ignored in situations when it is anticipated that the structure will be subjected to a very large number of cycles.

4. TEMPERATURE, MOISTURE CONTENT AND CYCLIC ENVIRONMENT

It is commonly accepted that exposure to high temperature for a limited period usually has no permanent effect on strength properties, although strength properties are temporarily reduced while wood is at an elevated temperature. However, high temperatures associated with high moisture content may require a reduction of strength values.
The change in moisture content affects almost all mechanical properties of wood. The generally accepted relation between moisture content and strength is that a reduction in the moisture content of wood results in its higher strength and less deflection at a given stress level [5,6].

Wood is dimensionally quite stable as long as its moisture content is above the fiber saturation point. Wood shrinks as it dries below the fiber saturation point. Shrinkage of wood in structures in service causes several problems, particularly in connection details. As lumber dries more rapidly through the ends than through the sides, more serious splitting occurs at the ends where connections are located. This can cause loosening and failure at joints by splitting between fasteners.

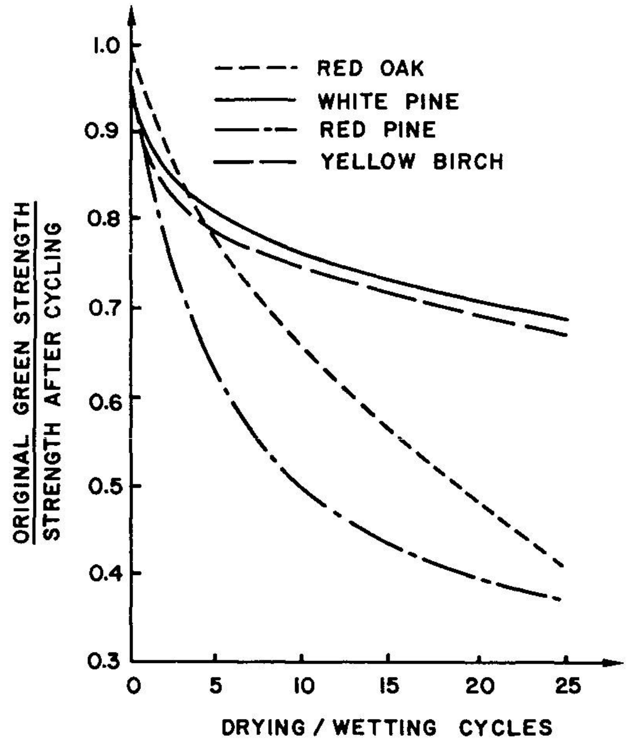

Fig. 2 Influence of Drying-Wetting Cycles on Shear Strength

Good construction practice is to retighten bolts in bolted joints and in joints with split ring connectors after a structure has been in service for some one year or so.

Special care must be taken to avoid problem-type connections. Figures 1(a) and (b) give illustrations of two possible problem-type connections. The clip angles or concealed internal anchors as connected to the beam enhance the formation of a split when wood shrinks, thus reducing the effective strength of the connection and effect shear strength of the member.

It should be mentioned that the strength and stiffness of a nailed joint is reduced if there is a gap caused by shrinkage between the component members [7]. This effect should be considered in the design process.

Wood being rheological material, may behave somewhat differently in each successive cycle when used under cyclic environmental conditions. The effect of repeated wetting and drying cycles can be quite severe on some strength properties of wood and on deflections in trusses. For example, Fig. 2 illustrates the reduction of shear strength measured during 25 drying-wetting cycles for 4 different species of wood [4]. Hearmon and Paton [3] have shown that cyclic exposure to changes in moisture content significantly reduces wood strength. They observed a creep failure at loads only 3/8 the maximum load a matching specimen would sustain if maintained at a constant moisture content. The effect of moisture cycling can be quite significant and should be accounted for in design when structural members are expected to be exposed to cyclic moisture contents.

Another aspect, associated with moisture content effects, that should be considered is the influence on the time-dependent properties of wood when moisture changes occur while wood is under load. When wood is under constant load and a sudden change in moisture content takes place, a large increase in creep deformation can result.

5. WEATHERING, INSECTS, FUNGI AND OTHER ORGANISMS, AND CHEMICALS

Wood exposed outdoors without protection, is subjected to physical and chemical changes as a result of weathering. These changes usually affect only the surface of the wood and the wood under this relatively thin surface is essentially unchanged and unaffected. In the absence of decay, wood exposed to the weather can last for a very long time. Good engineering and construction practices for wood structures to protect them from prolonged wetting and use of finishes to protect them from weathering effects, should eliminate weathering as a cause of serious damage of wood structures.

Wood, a biological material, is susceptible to degradation by organisms, most of which require oxygen, moisture, food and a favourable temperature. Bacteria and fungi induce a bio-chemical attack while insects destroy wood by mechanically biting off bits of wood tissue. The initial effect of bacteria infestation of wood generally results in an increase in permeability. The increase in permeability makes bacterially-degraded wood especially susceptible to increased moisture absorption. Long-term bacterial action may cause significant reduction in wood strength properties.

Critical locations for moisture absorption and decay are connections, exposed end-grain surfaces and splits and checks. Care must be taken to avoid problem-prone connections. Figure 1(c) and 1(d) show, respectively, a connection with wood column (or arch) in closed steel box and a connection where the base of the wood column is concealed by placing concrete around the connection. The problem in Fig. 1(c) can be avoided by providing weep holes in the box and that in Fig. 1(d) can be prevented by setting the column base on a pedestal above the floor slab.

Treatment of wood with preservative chemicals contributes to resistance against wide spectrum of bacteria, fungi and insects. Adequate pressure treatments with preservatives significantly extend the service lives of many species of wood.

Wood is generally considered to possess a high degree of resistance to attack by a wide variety of chemicals. The adverse effect of acids and bases on strength properties of wood is greatly influenced by wood species. Generally, hardwoods are more susceptible to chemical degradation than are coniferous species. Alkaline solutions, which dissolve some of the hemicelluloses and attack lignin in wood, have a greater effect on wood strength than do acids. Acids make the wood more brittle and reduce its strength. Some salts may increase certain strength properties of wood and others may significantly reduce strength.

6. FIRE

The loss of load-carrying capacity of wood components under the action of fire is the result of two major causes: Namely, the formation of charcoal in the outside portion of the member and the weakening of a thin layer that is immediately beneath the charcoal. The basic effects of fire on a wood member are the reduction in cross section (only cold wood core area is effective) and the weakening of metalic fasteners in the member.

Fundamental to the problem of incorporating fire safety in structures is the way in which fire, heat and smoke spread. There could be several building design deficiencies which contribute to the spread of fire, heat and smoke throughout a building or from one building to another. Designing to minimize damage by fire must be incorporated in the architectural planning process as early as possible.

It has been noted that open doors and stairs, together with lack of firestopping in concealed spaces are responsible for spread of fire and smoke in a high percentage of fires in dwellings. Fire spread from one area of a building to another through open concealed spaces is a major problem. The National Building Code of Canada [1] stiplulates requirements on where and how much firestopping and draftstopping are to be used.

Treatment of wood with fire-retardant chemicals is an effective means of preventing flame spread. Fire resistance of wood structures can also be improved through good design and construction details. In heavy timber construction, fire resistance is provided by massive wood and the avoidance of concealed spaces in which fire may originate and spread undetected. As light-frame wood construction, most residential dwellings belong to this category, do not have the fire resistanace provided by heavy timber construction, special attention should be given to good construction details to delay the spread of fire and reduce hazards to occupants. Firestops should be provided at exterior walls, at each floor level and at the level where the roof connects with the wall.

7. CONCLUSIONS

The effects of various factors which influence the performance of wood as structural material were reviewed in the paper. Current design specifications and codes on engineering design in wood deal with usual service environments (dry condition, wet condition, various durations of loads, etc.), but other extremes in the environment, such as severe variations in temperature, cyclic moisture conditions, changes due to weathering, biodegradation, chemical degradation, are not adequately dealt with. The problem of interaction of various environmental factors needs to be addressed, with respect to their combined effect on wood properties.

Wood, one of the world's principal construction materials, is dependable, versatile, economical and energy-efficient. With the proper understanding of the material behaviour and with the adoption of good engineering design and construction practices, wood structures can be built economically to provide many, many years of durable service life.

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