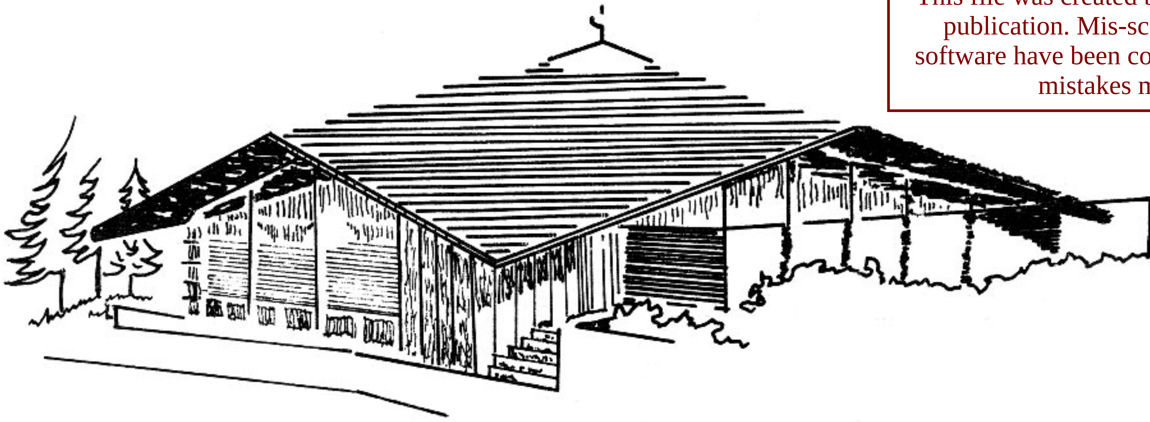

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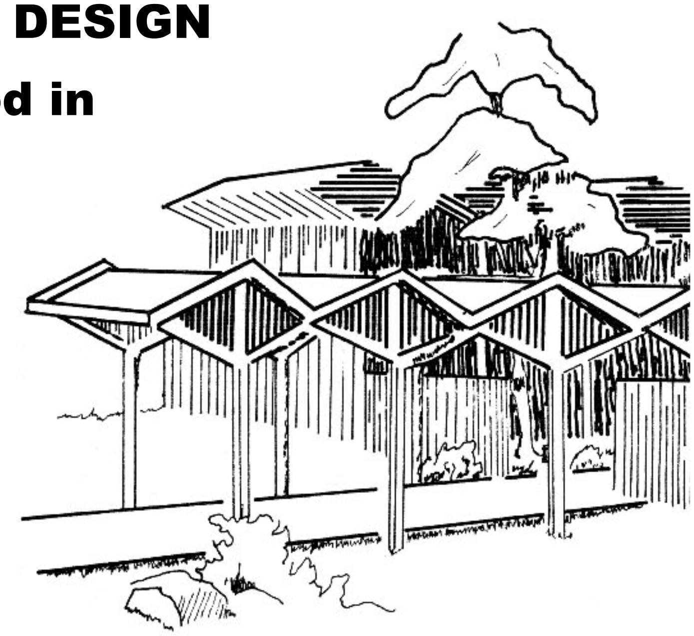

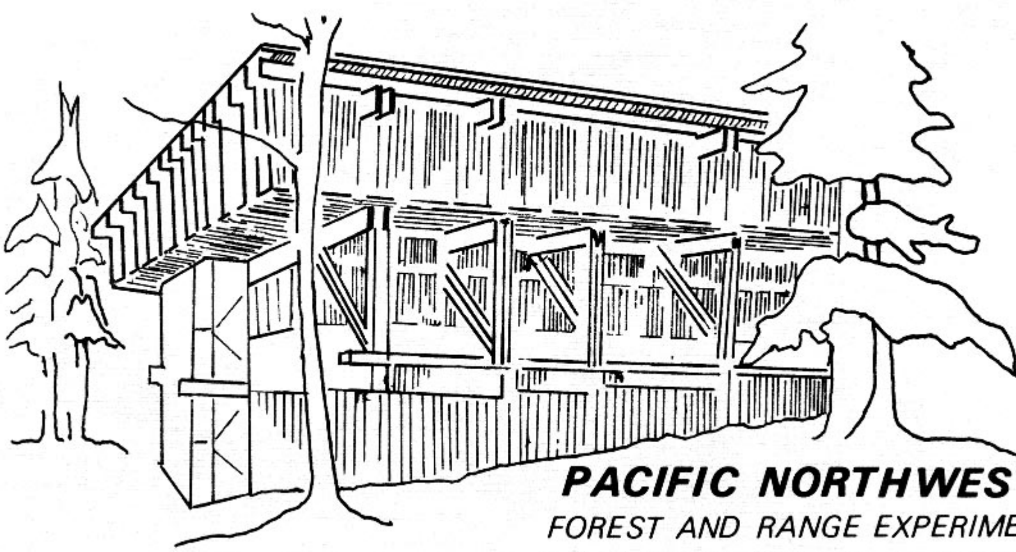

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
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The Influence of DESIGN on Exposed Wood in Buildings of the Puget Sound Area

by

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FOREWORD

In this publication,[1] Edward Schein summarizes a field survey of the performance of exposed structural wood members.

The study included a survey of 175 buildings in the Puget Sound area of the State of Washington, using a detailed inspection check list. Examples for study were compiled from architectural periodicals, the College of Architecture library slide file, and persons engaged in building construction, use, or maintenance. Building designers, owners, and custodians were consulted for details of construction and maintenance. Though the primary concern was with contemporary structures, the influence of design was also observed in some older examples. Twenty-seven representative buildings were selected for analysis from the original survey list, and sketches of these are contained in an appendix. Illustrations accompanying the text are keyed to these by suffix number.

The objective of the study was to identify the best existing design solutions to exposure hazards. From this base, a continuing research program aimed at new or improved solutions is planned by the Pacific Northwest Forest and Range Experiment Station.

[1]An abridged version of a thesis submitted in partial fulfillment of requirements for the degree of Master of Science in Forestry at the University of Washington, 1967. The program was conducted under the guidance of Dr. Ben S. Bryant of the University staff and with the financial assistance and cooperation of the Pacific Northwest Forest and Range Experiment Station.

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WOOD STRUCTURES TODAY

In the Pacific Northwest, architects have employed the unique character and great versatility of wood in many successful designs. As production and engineering methods advanced and an increasing variety of laminated shapes and sizes and plywood constructions became available, heavier framing systems have replaced traditional light frame construction for many applications. Greater freedom of design and dramatic esthetic effects have come from this revolution in technology, resulting in exposed structural members with the warm beauty and touch of wood.

Contemporary architects are using wood structures more boldly, with structural members exposed to view and often to the weather. This new freedom carries with it both new and old problems of adapting this hygroscopic, organic material to a severe environment.

THE NEED FOR DESIGN SOLUTIONS

To assure the maximum in performance and appearance of wood members exposed to the weather, special attention to design conditions and details is needed. Many designers lack the technical information needed to recognize exposure problems and to provide adequate solutions. This condition may be partly attributed to poor communications between wood technologists and the design professions. Although considerable information on exposure problems is published by various government and private research groups, it frequently does not find its way into programs of architectural schools or publications which the architect uses for reference or reading.

Good practice recommendations and design details published by the American Institute of Timber Construction carry the considerable weight of the combined experience of the timber fabricators, but these data are often unsupported by adequate field studies of performance and are limited to current methods which are believed to be most effective. There is an opportunity to develop improved methods supported by adequate field inspections and communicated to the practicing designer. This study is evidence of the need for information on exposure problems, as well as a review of the principal considerations affecting performance.

FACTORS AFFECTING PERFORMANCE

Basic factors affecting the performance of exposed wood members are climatic and biological. The character and structure of the wood itself reacts to these influences in varying degree and may be used to some extent for design control. Briefly, these factors may be outlined as follows, and are discussed at greater length in the U.S. Department of Agriculture Wood Handbook (7)[1] and in other texts on wood technology:

1. Climatic factors.
   a. Moisture.--Atmospheric moisture in the form of liquid or vapor is the most important environmental influence on the performance and appearance of exposed wood members. Repeated absorption and drying of wood causes dimensional

[1]Underscored numbers in parentheses refer to Literature Cited, p. 40.

changes resulting in mechanical stresses and splitting, checking, or warping. Moisture changes occur rapidly at end-grain surfaces, or where splits, checks, or pockets admit and retain water (fig. 1-24),[2] and more slowly in side-grain surfaces. Excessive moisture content reduces strength and rigidity and contributes to the development of decay organisms.

b. Heat.--Solar heat affects vapor pressure and the migration of moisture. The rapid heating of ends of a timber may cause rapid drying and high surface stresses that result in large checks. Although prolonged high temperatures can produce chemical changes, and favorable temperatures are a factor in decay, the significant effect of heat on performance is its influence on moisture changes.

c. *Light.--Ultraviolet light* is a factor in the photochemical degradation of unprotected wood surfaces. This is accelerated by moisture and is responsible for the surface color changes in wood exposed to weathering.

d . Erosion. --Rain, hail, sand, and freezing cycles very slowly erode unprotected wood surfaces and act with mechanical strains due to moisture and photochemical changes to produce a weathered appearance.

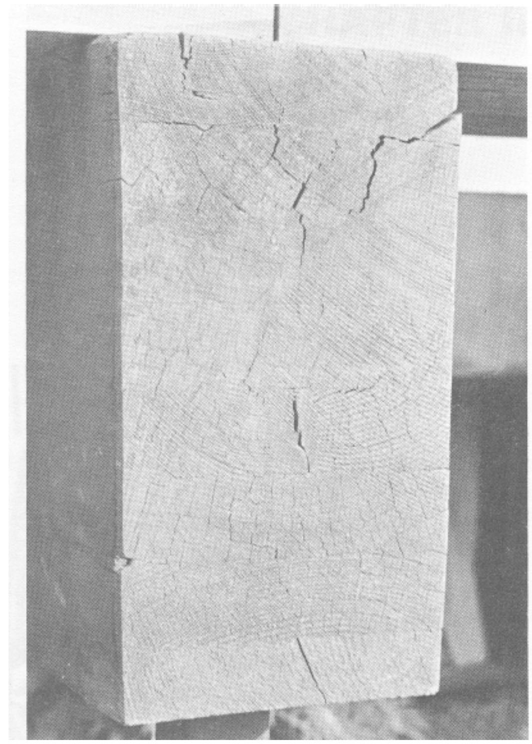
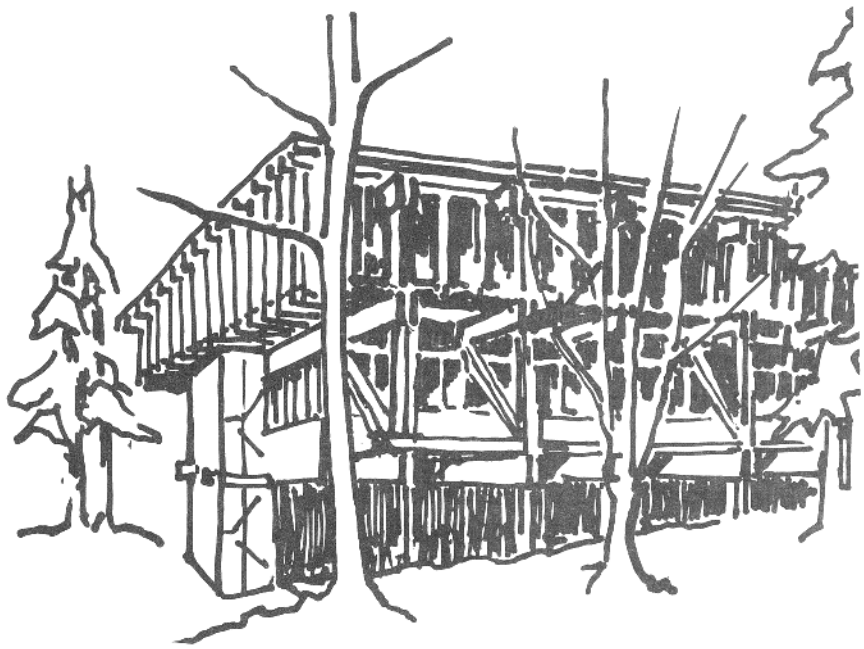


Figure 1-24.--Checks cause moisture

2. Biological factors.
   a. Decay.--Moisture contents of exterior wood members may become high enough to permit the growth of decay organisms in humid climates. Decay fungi also require favorable temperatures, oxygen, and food--the latter from the wood--to survive. Termites and certain other insects are also capable of destroying the structure of wood under conditions favoring their presence.

[2]Figure references are keyed to sketches in the Appendix; for example, figure 1-24 is text figure 1 with reference to Appendix sketch 24.

CHAPTER II



INDEPENDENT PROTECTION

ROOF OVERHANGS

BUILDING ORIENTATION

PERIPHERAL PROTECTION

FLASHING AND SHIELDING

FASTENING AND ERECTION PROTECTION

To provide acceptable performance, exposed structural members depend upon protection. Satisfactory performance may be influenced by design, or constructions independent of the wood member, or by coating, treatment, or fabrication of the member itself. These two forms of protection supply the definitions for major categories in exposure protection; viz., independent and integral protection. In providing weather resistance without intimate contact with structural members, independent protection includes many elements associated with total building design such as roof overhangs, building orientation, and peripheral protection. Individual member protection includes shielding, flashing, fastenings, and erection procedures. All of these independent protection methods play important roles in determining the performance of exposed structural wood members.

When a wood structure is erected, members should also be protected from severe conditions such as prolonged hot sun or excessive moisture where eventual independent protection will be added. Otherwise, unnecessary checking will occur, and the members will have to readjust in moisture content and in dimension when they are finally protected.

Independent protection of structure includes many areas in and around a structural wood building. No single form of protection can solve all the problems of exposed wood, but the proper combination of several methods that fit the individual requirements of a building and its environment can lead to highly successful performance with minimum maintenance.

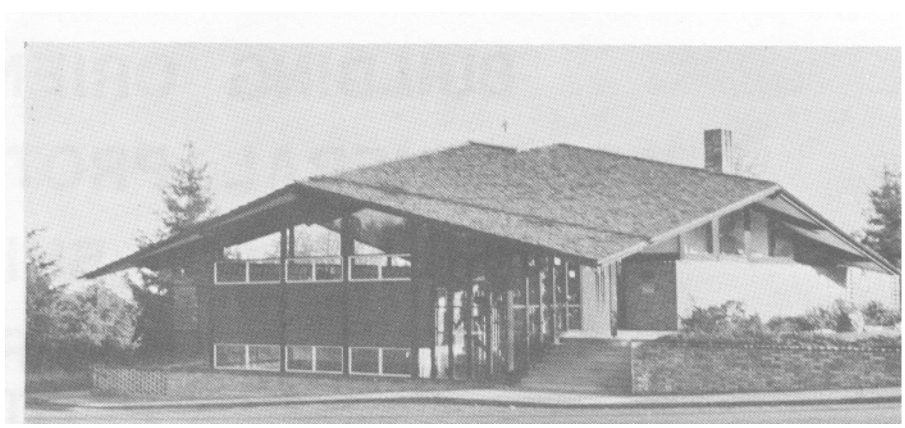
ROOF OVERHANGS

Roof overhangs, perhaps, are the most familiar example of independent protection. They protect structural connections, critical weathering areas, integral finishes, and structural extremities (fig. 2-1). If thoughtfully designed, they provide the necessary cover for the structure to assure maximum performance with minimum maintenance. Several objectives of overhangs are apparent in the buildings examined. The architectural and economic advantages, in light of other alternatives, often are obvious.

Roof overhangs have existed in the architecture of wooden structures since primitive man. In wood structures hundreds of years old, they are still one of the primary reasons for structural endurance.

Some climates require the use of overhangs more than others. For example, overhangs are vital in the tropics but not as necessary in arid regions or in alpine areas. Because decay must be accompanied by suitable temperature and moisture, rain or high relative humidity during warm weather causes an optimum condition for fungal

Figure 2-1.--Corners are subjected to severe weathering in unprotected instances. Photo illustrates how corners may best be protected by large overhangs. This building is 6 years old.



activity in unprotected wood. A warm, dry season limits fungal growth. The geographically limited examination of wood structures in the Puget Sound area, reported here, merely adds to the proof of existing examples the world over that overhangs are an important protection feature for structures of wood.

Column-beam joints can collect water that may lead to decay. With adequate roof overhangs, these joints remain free of water. Water entrapment between surfaces of wood members is also prevented. Therefore, structural connection performance is influenced by roof overhangs (fig. 3-l).

Dry soil condition due to generous overhangs will minimize the hazard of accidental soil contact with wood; if the soil remains dry, living organisms are less likely to remain active and cause decay.

Overhangs may be regarded as environmental equalizers, minimizing effects of both rain and sun--south and west building exposures benefit the most. By reduction of waterflow over exposed surfaces, moisture gradient fluctuation is lessened, with a consequent reduction in checking and the possibility of decay.

Wall surfaces as well as exposed structural members are shaded by overhangs. Because ultraviolet light is the greatest cause of breakdown in clear finishes, shade is important for minimum maintenance. (Finishes are discussed in more detail under "Integral Protection," chapter III.) Shade also reduces temperature differential occurring over a 24-hour period, and therefore reduces change in moisture content.

Column ends at roof, floor, and ground levels are protected by roof overhangs. At roof level, an extension of the overhang beyond the beam ends protects against normal weathering. Ground- and floor-level extremities lack full protection from such overhangs, but water runoff is reduced.

Overhangs may be used to protect structural extremities only. Figure 4-2 shows such a solution where the architect was able to express the church's structural system and yet fully protect all critical portions of the structure. This is positive protection at its best.

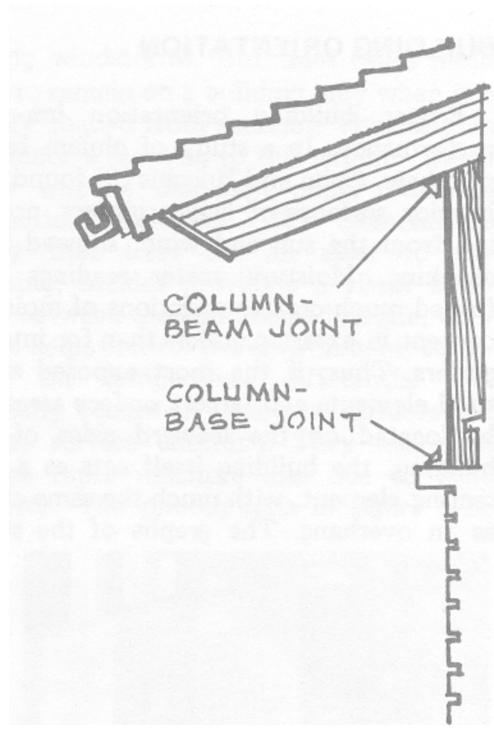
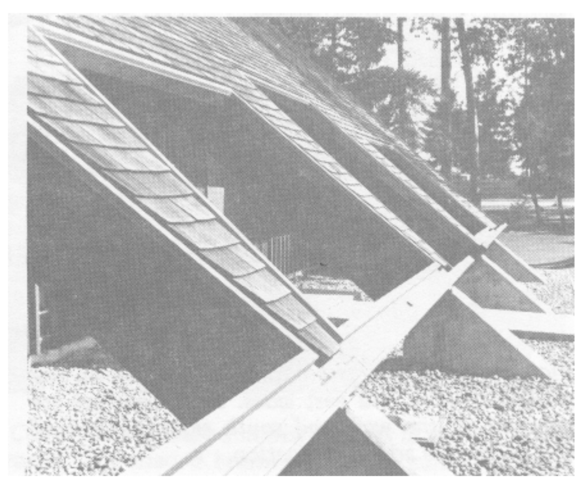


Figure 3-l.--Overhangs protect structural joints.

Figure 4-2.--Arch-buttress connection protected by an overhang.



BUILDING ORIENTATION

Proper building orientation improves performance. In a study of glulam bridge members, Aplin and Huggins (2) found that interior surfaces of bridge girders, protected from the sun and wind, showed little checking. Moisture meter readings confirmed much greater variations of moisture content in exterior girders than for interior girders. Thus, if the most exposed structural elements and largest surface areas can be located on the leeward sides of the building, the building itself acts as a protecting element, with much the same effect as an overhang. The graphs of the study showed further that bridges oriented east-west showed less checking and delamination than north-south oriented bridges. The north-south oriented structures had greater quantities of morning and afternoon sunlight striking the faces of the exterior members at a greater angle of incidence, whereas the east-west bridges had little sunlight striking the north exposed faces and the angle of incidence of the sun on the south face was much less. This reduced the heating effect on the girders which limited differential shrinkage and subsequent checking (2, 9). Figure 5 illustrates this point in buildings examined.

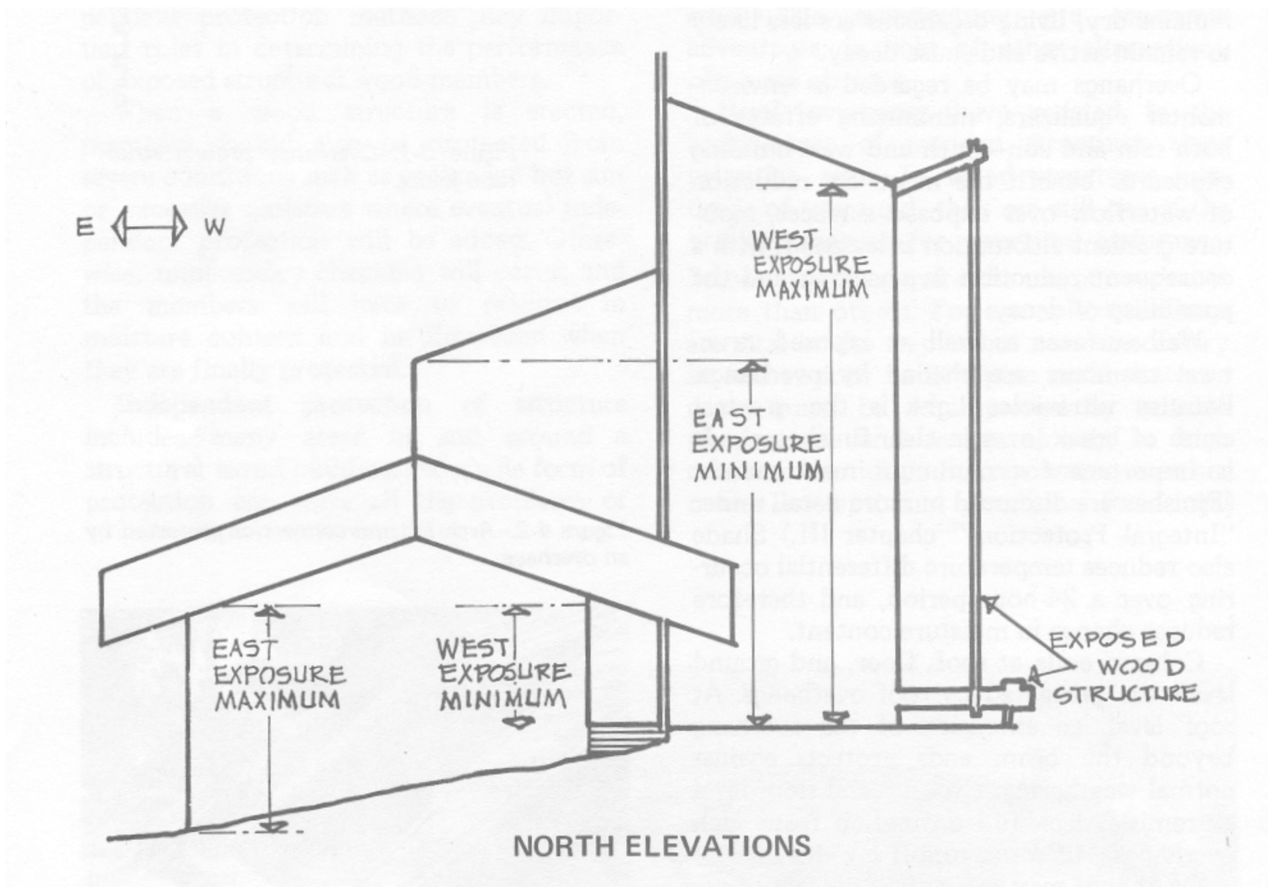


Figure 5-1.--The largest exposed areas are on the sheltered north and east sides. Few members are exposed on the west and south sides. Large roof overhangs give added protection.

Figure 5-24.--The majority of exposed structure and the largest exposed areas occur on the west side. Few members are exposed on the sheltered sides. No roof overhangs are present.

PERIPHERAL BUILDING PROTECTION

Peripheral building protection offers other solutions to the problem of independent protection. Proper utilization of trees, other buildings, sunscreens, and landscaping, can contribute to the maximum performance of exposed wood structures.

Peripheral protection is provided by objects totally independent of the structure. A frequently overlooked element of peripheral protection is trees. Often trees are considered a detriment to buildings: they shade the structure, thus causing moss to form in damp areas, and are a hazard during windstorms. But trees cause moisture to remain on a building only when it is totally shaded from sunlight. They seldom dominate a building to this extent. (Damp areas will be discussed under "Integral Protection," chapter III.) Observations verify that trees are an asset to any building; besides providing a visual backdrop between the building and its site, their shade helps control the environment, equalizing the temperature differential that normally occurs on structural surfaces and causes surface checking. They may also reduce rapid moisture loss due to wind velocity. The photographs in figure 6-25

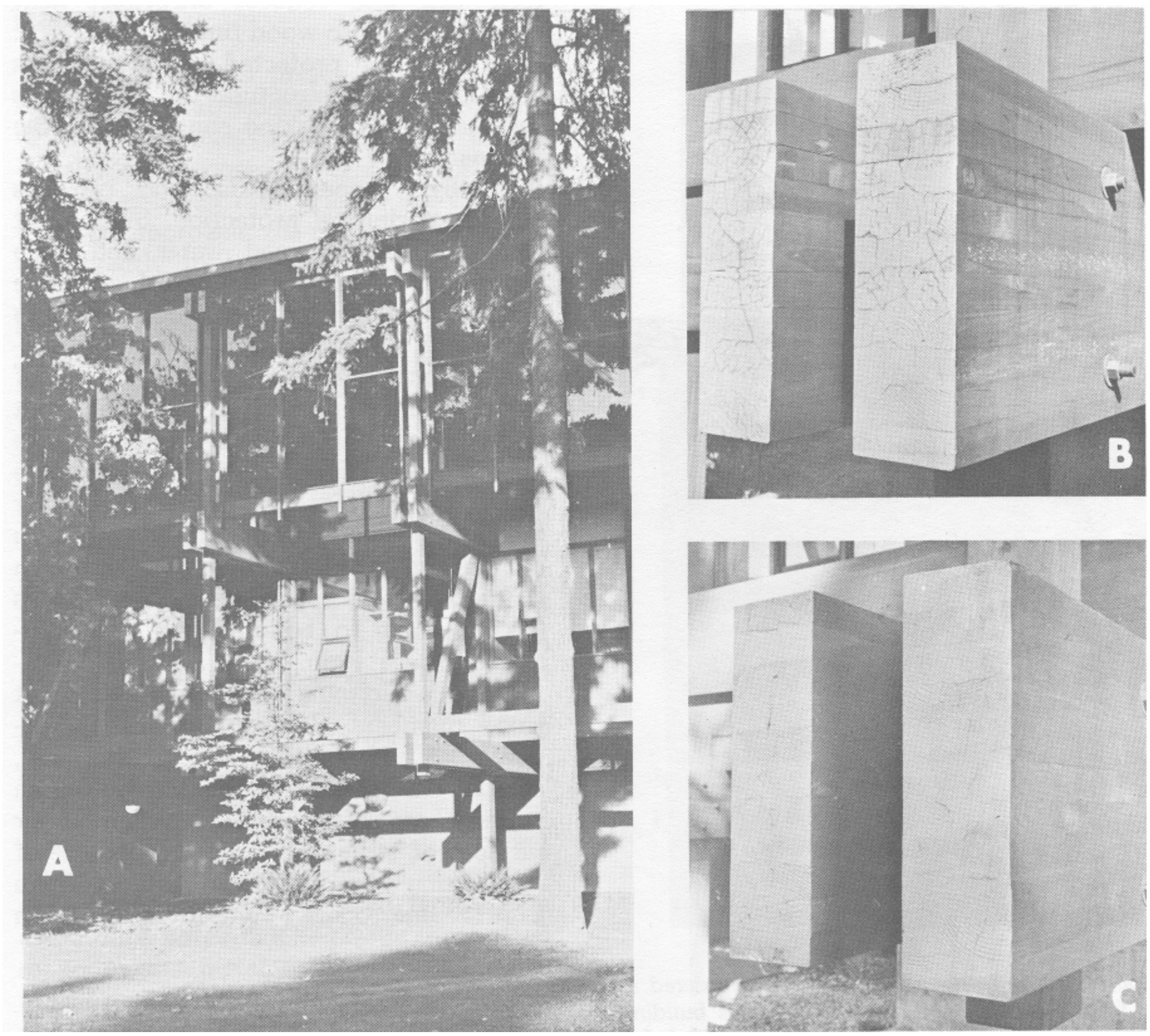
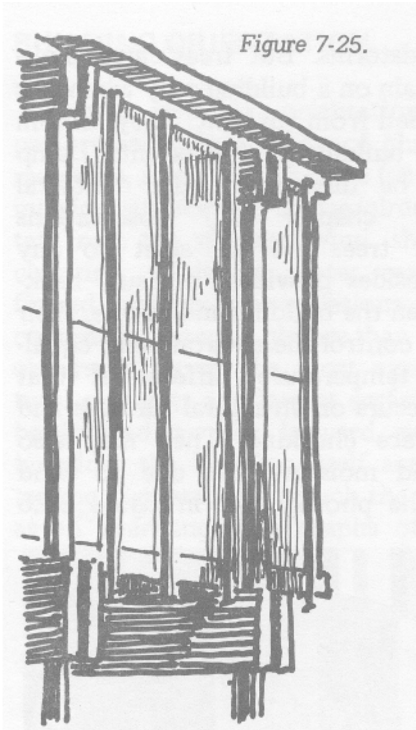


Figure 6-25.--Trees provide peripheral protection (A). Continual moisture-content changes in the unshaded beam ends (B) caused end checking due to internal stresses. The shaded beams (C) on the same west side showed little effect.

Figure 7-25.



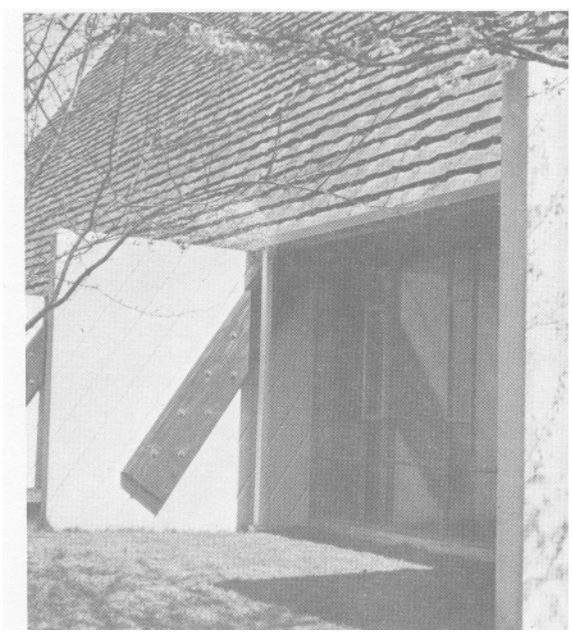


Figure 8-5 .-- Landscaping must be considered as a form of peripheral protection. At this building, watering the grass causes a decay hazard for the glulam arches during the summer months due to optimum temperatures and moisture.

clearly show the difference between unprotected and tree-shaded beam ends. Other buildings also act as protecting elements. A courtyard situation has this advantage. With the additional protection from a courtyard, south and west exposures can be protected from the full duration of sun and wind-driven rain.

Sunscreens give peripheral protection to a building. Their function is similar to that of trees, providing added uniform protection where they are used with roof overhangs. Glass sunscreens are functioning well at the Winkenwerder Forest Sciences Laboratory, University of Washington, and their tint also reduces ultraviolet light transmission onto wood finishes (fig. 7-25). Here again, a protected environment is beneficial to the structural life of wood as well as to the working conditions of the occupants.

Finally, proper landscaping provides indirect peripheral protection. Since most grass and shrubs need water and since watering is often hard to control, adequate distance between exposed wood structure and plants is essential. If automatic sprinklers are located to minimize the wetting of wood, built-in control is provided, but poorly planned irrigation systems can cause serious decay problems if they sprinkle wood as well as grass. Warm summer temperatures and continuous high moisture contents in the glulam arch ends shown in figure 8-5 could initiate decay. Gravel beds (moats) next to buildings are one alternative to vegetation.

Various surfacing techniques also affect wood members. Concrete surfaces in particular reflect sunlight and radiate heat, creating a severe environment. Splash patterns are often prominent on lower surfaces of structural members because of rain hitting a hard, uniform surface. Where a drip line occurs, gravel again is an alternative.

Continued