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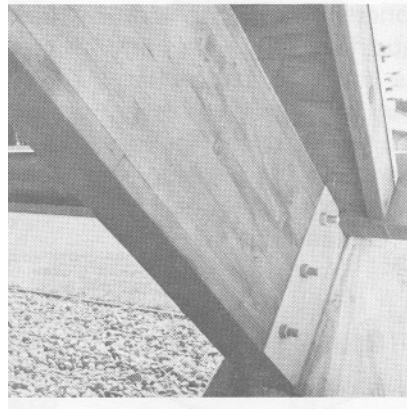
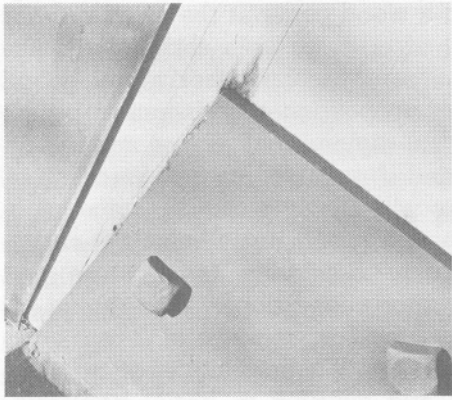


Figure 37-15  
(left).--Water entrapment causes ironwood oxidation reactions. The flashing on top surface of glulam arch (upper left) did not prevent water entrapment at steel plate. (South face shown.)

Figure 38-2  
(right).--Arch-buttress ground support totally protected by roof overhang. (South exposure.)

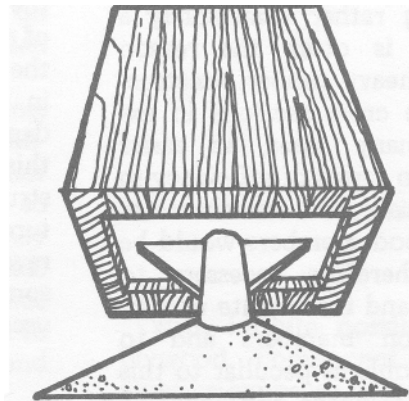
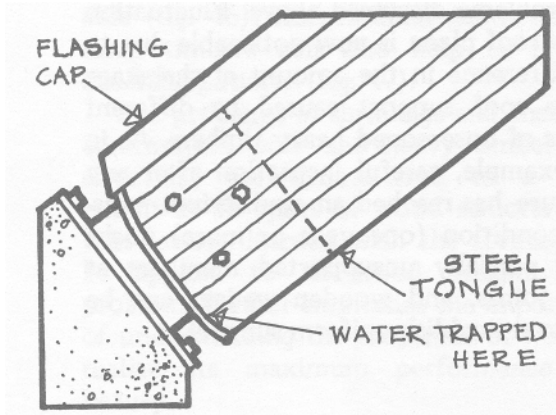


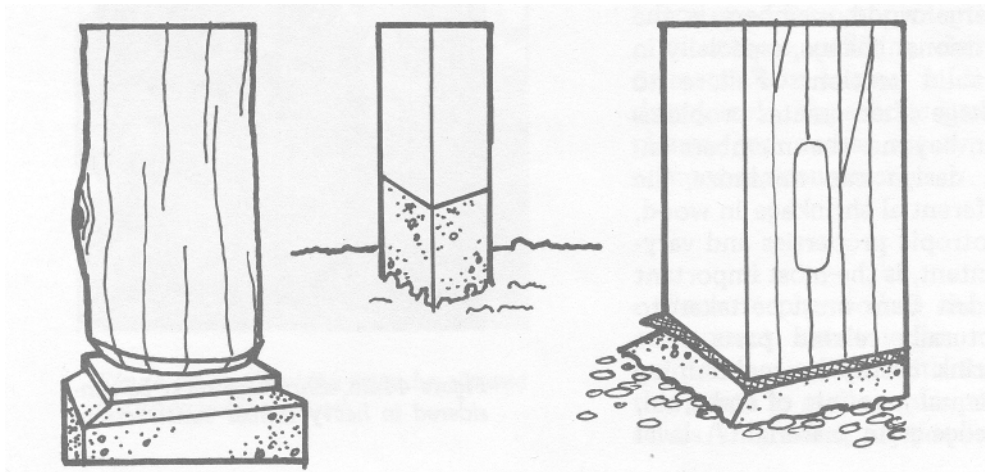
Figure 39-19  
(left).--Steel tongue eliminates exposed vertical joints, but horizontal joints still trap water.

Figure 40-2.5  
(right).--Wood totally shelters steel plate in this optimum solution.

Figure 41-11.--Cedar pole rests on steel plate.

Figure 42-21.--Concrete base can trap water.

Figure 43-25.--Reduce moisture transfer by providing barrier between concrete and wood.



wood arches can be bolted directly to vertical surfaces of concrete buttresses with the help of shear plates (fig. 34-5); no end grain is touching the concrete, and water can only be trapped by capillarity between the wood member and the buttress. Placing 1/4-inch washers between the two surfaces might further improve this connection by ensuring complete separation of the surfaces.

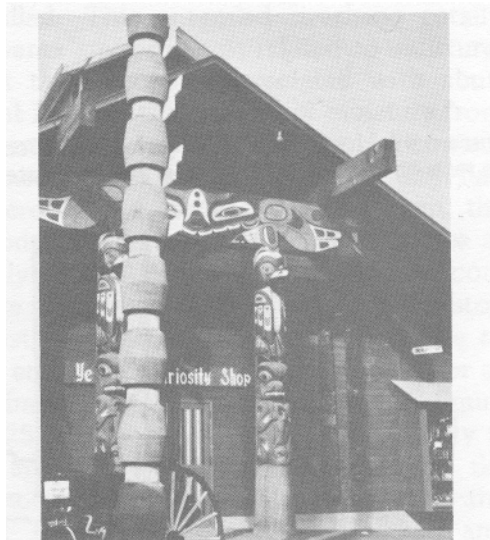
## POLE AND HEAVY TIMBER CONSTRUCTION

Consider the performance requirements of large-section members in the form of poles or cut timbers. Creation of a certain architectural feeling rather than solely a structural solution is often the reason behind the use of heavy timber construction involving large cross sections in exposed areas. In many cases, an easier structural solution in terms of efficiency in design might be used, but the character created by large wood members would be destroyed. It is therefore necessary to recognize adequate and inadequate uses of exposed large-section members and to point out design problems peculiar to this type of structure. Shrinkage and checking are the two basic problems to consider in this method of construction.

### Shrinkage

An important consideration in the performance of large wood members is the inevitable dimensional change, especially in nonlaminated solid sections. Failure to allow for shrinkage often creates problems that spread far beyond the members involved. Proper design can minimize the difficulties. Differential shrinkage in wood, due to its anisotropic properties and varying moisture content, is the most important aspect to consider. Care must be taken to allow all structurally related parts of a structure to shrink evenly by maintaining approximately equal amounts of end-grain, flat-grain, and edge-grain material. A level

beam supported by a wood column at one end and a wood girder at the other will not be level after cross-grain shrinkage in the wood girder. Stacking horizontal wood members proportionately increases potential vertical dimensional change and should be avoided if possible. Proper seasoning of members will alleviate the shrinkage problem although it will not eliminate it entirely because of varying temperature and water vapor conditions. Kiln-drying is generally used for members of 2-inch cross section or less. The possibilities of twisting, bowing, and cupping in heavy nonlaminated timbers must also be considered. The heavy timber sections in the structure shown in figure 44-26 demonstrate some of the problems discussed above. Fluctuation of the roof plane is now noticeable due to the difference in the amount of shrinkage in the roof support caused by different depths of unseasoned heavy timbers. As in this example, careful inspection after any structure has reached an equilibrium moisture condition (one year or more) might reveal partially unsupported members at some joints, and wooden wedges can be used to reestablish uniform support.

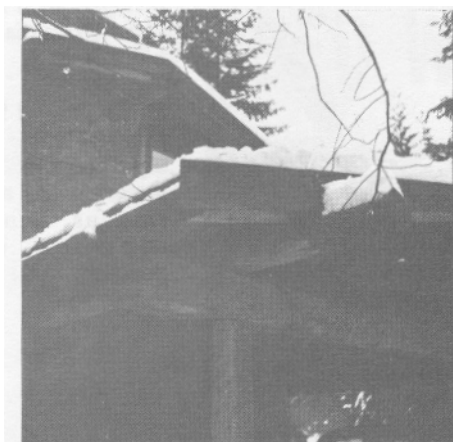


*Figure 44-26.--Shrinkage must be considered in heavy timber construction.*

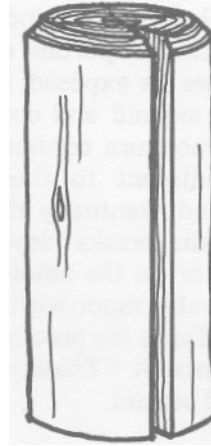
## Checking

The second major problem in heavy timber design is checking. This also results from differential shrinkage, and it can be minimized in heavy timbers by long airdrying, and in thinner lumber, by kilndrying. Pressure treatment with preservatives will reduce the chance of decay in existing checks. Checking of poles in construction, as in figure 45-3, must be accepted at times. However, it can be reduced by relieving the stresses with saw kerfs. For centuries, Japanese craftsmen have used longitudinal saw kerfs, cut to the pith of the poles, to provide a single uniform "check" where it is least noticeable (fig. 46). Longitudinal dado relief on sawn timbers can also help to preplan checking patterns (fig. 47).

The problems of shrinkage and checking, common in pole and heavy timber construction, are encountered to a lesser extent in all types of wood structures, so that lessons learned with the former may be applied to all wood design. These problems further emphasize the importance of understanding the properties of wood to realize its maximum performance and beauty.



*Figure 45-3.--Checking must be allowed for when poles are used.*



*Figure 46.--A single saw kerf can reduce checking in poles.*



*Figure 47.--Dado relief reduces visible checking.*

## PLYWOOD COMPONENT

### CONSTRUCTION

With infinite possibilities available for plywood component structural design, exterior exposure deserves increasing attention and study. Plywood, when used to form structural units, is often exposed to totally unprotected conditions, and only integral protection can offer resistance to weathering and decay. However, independent protection incorporated in the design should be considered before complete reliance upon integral protection is made.

Structures utilizing delta box beams, diamond box beams, folded plates, stress skin panels, hyperbolic paraboloids, space planes, and domes are types of plywood component construction.

### Joint Integrity

Because plywood is the "skin" for all component construction, it must be a continuous surface with total integrity at the joints as well as over the sheets themselves. In general, plywood exhibits greater

stability than lumber. However, its individual plies still retain the properties of wood, and when their edges are exposed, as in open joints, they will expand and contract with variations in moisture content. Finishes and coatings adjacent to these joints are then stressed, and eventually the continuous protective skin breaks down either at the panel edges or on the adjoining faces, where trapped water vapor within the panel causes blisters. Tapes are presently used to seal these joints. A "Thiokol" bead would also be a good sealant.

### Surface

Plywood surfaces are not suitable for exterior exposure without frequent main-

tenance, unless a continuous coating or skin that will adhere to summerwood is used to reduce surface checking. The ends of the diamond box beams shown in figure 48-21 are coated with plastic resin. The domes of the classroom units, shown in figure 49-18 were covered with a vinyl coating which, after 5 years of exposure, developed leaks. Fiber and paper overlays are often used to provide better surfaces for paint on plywood, but additional protection from water is often necessary for lasting durability.

Plywood component systems are being used in greater numbers to meet increasing needs for efficient use of materials and labor. Therefore, proper design is a necessity for good performance.

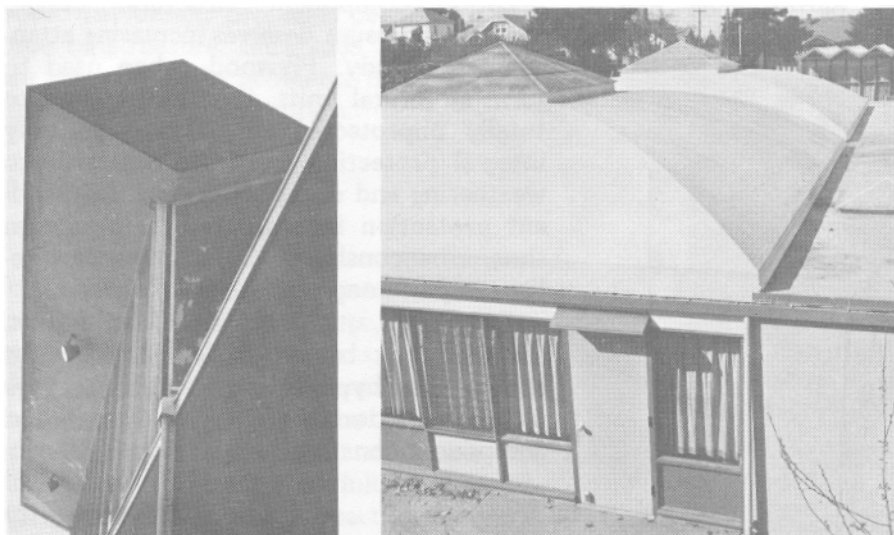


Figure 48-21 (left).--Plastic resin protects wood components, such as the ends of this diamond box beam.

Figure 49-18 (right).--Vinyl coating provides joint integrity and a continuous skin for plywood components.

# **METHODS FOR IMPROVING EXPOSED WOOD PERFORMANCE**

INTERACTION OF  
PROTECTION METHODS

WHAT TO CONSIDER IN  
EXPOSED WOOD DESIGN

FUTURE STUDIES IN  
EXPOSED WOOD PERFORMANCE

The architectural design of a structure directly affects performance in service. To insure permanence and safety, architectural as well as structural design must be considered. An understanding by the architect of good design practices is essential for structural protection of exposed wood members.

## **INTERACTION OF PROTECTION METHODS**

Since no single method of protection can solve all exposure problems, the most basic and important concept is the interaction of various methods of protection. Therefore, all protection methods should be considered in a design problem. The combination of the methods selected should reinforce each other and collectively provide the required protection.

In reviewing the observations made on methods of protection and their associated problems, we found independent protection (i.e., protection of the immediate environment) provided the better answer to most performance problems. Excess moisture causes most performance difficulties, and generous roof overhangs are the greatest deterrent to trouble from this source. Other independent protection techniques complement overhang protection in specific and general situations. For example, shielding and flashing protect specific structural surfaces not sheltered by roof overhangs, and peripheral protection and building orientation provide overall shielding from the effects of moisture and subsequent entrapment. The proper- design

of fastenings and careful erection procedures also provide overall protection and are important in all wood construction. Further, the properties of the material itself must be considered. Species durability, grain orientation, and the nondurability of sapwood under exposed conditions must be recognized. The important concept to remember is that any species, regardless of grain orientation or sapwood content, will provide optimum performance if given good protection.

To supplement independent protection, integral protection may be used. This implies the direct application of protective materials to the wood member by treating, coating, or modification of the material itself. Although integral protection is subordinate to independent protection, new techniques will make this a more attractive alternative in the future. For good performance, treatments and coatings will not require independent protection because they will be more resistant to the effects of time under exposed conditions. This radical change will bring about an entirely new set of design criteria. Current research and development directed at improved mechanical treatment as well as other methods illustrate the accelerated interest in integral protection techniques. Saw kerfing of beam ends and use of "clean" pressure treatments with preservatives are examples. For the present, however, only partial reliance should be placed on integral protection. Buildings totally dependent on integral methods clearly show performance below the standard of buildings with independent protection unless frequent, high-quality maintenance is practiced.

## **WHAT TO CONSIDER IN EXPOSED WOOD DESIGN**

To relate exposure problems and protection methods to design procedures and maximum performance expectation, a list of important considerations has been developed. First, an understanding of the factors

affecting wood is necessary. With this background knowledge, any architectural expression desired may be developed utilizing the properties of wood in the best possible manner. Next, all existing protection techniques should be evaluated and considered for possible application, singly or in combination. And, finally, planning for the upkeep of the building should be a determinant during the design stage. The following points are intended to amplify many of the considerations discussed and are not intended as clear-cut rules which should be rigidly followed.

### **Wood Characteristics**

#### **MOISTURE MOVEMENT:**

1. Moisture movement and resulting moisture gradients occur in exposed wood members. If movement is rapid and frequent, internal stresses result which often cause checking, splitting, and warping.

2. Moisture travels much faster along the grain than across the grain. Therefore, exposed end grain maximizes the effect of moisture movement and makes endchecking difficult to prevent, even in laminated beams.

3. Flat-grain boards experience greater dimensional change than edge grain boards. Checking is most likely on exposed flatgrain surfaces.

4. Checking provides easy access for additional moisture. And, the high moisture content, deep in an exposed check, may exist for extended periods of time and lead to decay.

#### **NATURAL DURABILITY:**

1. Toxic extractives and resistance to moisture changes increase the decay resistance of some species. Redwood and western redcedar are excellent examples.

2. Heartwood is more durable than sapwood in most coniferous species, due to the presence of extractive materials. For-

tunately this is true of Douglas-fir, the most common species for structural use. Sapwood in all species is nondurable if conditions favor decay.

#### **BIOLOGICAL DETERIORATION:**

1. Air must be present for decay to occur. Submerged timbers lack an air environment and therefore don't decay.

2. Suitable temperature must be present. (About 80° F. is optimum.) Cold climates reduce or prevent decay.

3. An adequate food supply must be present. Toxic extractives in some species impart decay resistance to the wood, as do wood preservatives.

4. Suitable moisture must be present. When the moisture content of wood is under about 20 percent, decay is not active.

5. Wood-destroying insects also have rather specific requirements, but their tolerance level varies greatly with the type of insect. Absence of moisture will usually keep them in check.

### **Location Considerations**

#### **EXISTING PROTECTION:**

1. The local climate is an important aspect of protection requirements. The conditions of old buildings provide clues as to whether the climate is favorable or unfavorable to biological deterioration.

2. Site conditions must be considered. Sites should be checked for exposure, terrain, and surrounding environment.

#### **PERIPHERAL PROTECTION:**

1. The protection afforded by trees may improve building performance. Existing trees may provide a high degree of protection from sun, wind, and rain.

2. The location of other nearby structures should be considered with respect to the possible protection they might give.

Their permanence, of course, must be taken into account.

3. By planning the structure and landscape together, allowance can be made for a "dry belt" around exposed wood. Irrigation or sprinkler systems can be kept at a safe distance, and smooth hard surfaces near exposed wood can be eliminated to minimize splashback and heat reflection.

### **Overall Design Considerations**

#### **INDEPENDENT PROTECTION:**

1. If possible, roof overhangs should be designed for critical areas. Most important are the exposed wood surfaces on the west and south sides of the building.

2. Consider orienting the building to provide maximum protection. The largest areas of structural and surface exposure might be placed on the north and east sides of the building.

3. Use flashing and shielding if other protection is not adequate for critical areas. Divert all water away from wood surfaces and allow adequate air space between wood and the protecting material.

4. Provide for supervision to eliminate prolonged exposure of unprotected structural members and excessive tightening of fastenings by the erection crew.

### **Joint Design**

#### **WATER ENTRAPMENT:**

1. Minimize intersurface contact (wood-wood, wood-metal, and wood-concrete) where moisture can remain in the interface to induce decay.

2. Protect end grain from direct exposure, if possible, to reduce end-checking and subsequent moisture entrapment.

#### **FASTENING DESIGN:**

1. Specify suitable sizes and types. Large washer sizes help to reduce local crushing of wood. Two shear plates, back to back, provide more space between wood members than a ring connector and minimize moisture retention.

2. Fastening material should also be protected. Exposed metal must be well galvanized, or well painted, to prevent rust from contacting the wood.

### **Structural Member Design**

#### **INTEGRAL PROTECTION:**

1. Specify proper moisture contents for wood members; use kiln-dried lumber for laminating to prevent initial checking; allow for shrinkage in all deep sections, especially where air-dried sawn timbers are used. Ideally, the moisture content of the member at the time of erection should approximate its average moisture content in service.

2. Specify proper preparation of the wood surface for paints and stains. Also, specify only high-quality formulations by reputable companies.

3. Reduce end checking if critical. Independently protect the member, cut back the beam end to reduce exposure, or use a deep saw kerf pattern; or coat the end with well-adhering elastic material, but protect severely exposed sides of the member, also.

4. Remember that any species may check when not fully protected independently, and decay may eventually begin. Pressure-treat or flood the surface and checks with preservative, perhaps combined with a stain, on a continuing maintenance and inspection schedule.



## Maintenance Considerations

### MAINTENANCE AVAILABLE:

1. The building use must be considered from the maintenance standpoint when in its design stage. For example, residences may receive more careful maintenance than schools.

2. For the owner's benefit, the architect might suggest budgeting a fixed percentage of building cost for optimum maintenance.

### MAINTENANCE NEEDED:

1. To adjust for uneven shrinkage of structural members after the moisture content of wood members is stabilized, wooden wedges can be used, equalizing loading on purlins and stringers and reducing any annoying deflection or vibration.

2. Schedules should allow for more frequent maintenance of areas with south and west exposures.

3. The maintenance of structural members requires more frequent attention than other surfaces such as the siding. Douglasfir structural members do not hold finish as well as cedar siding, for example.

## FUTURE STUDIES IN EXPOSED WOOD PERFORMANCE

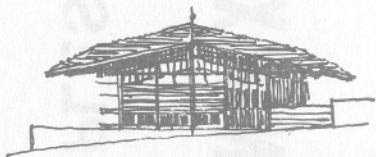
Often, research leads to new ideas for future study. Future research on the effects of caulking, preservative pads, or surface-to-surface spacing on the performance life of structural connections would provide useful new design alternatives to the architect. Other important areas to consider include: proper treatment of exposed beams with deep checking present, long-term analysis of moisture movement in exposed building members, the effectiveness of windbreaks (trees, sunscreens, etc.) on reducing rapid moisture content changes, and proper maintenance techniques for extended optimum performance. Equally important is the task of assembling and presenting the findings to inform and assist those who design in wood.

## LITERATURE CITED

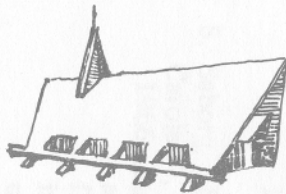
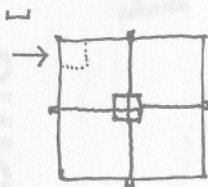
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# **APPENDIX**

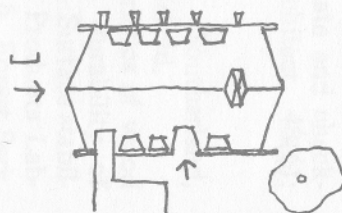
## **BUILDING EXAMPLES**



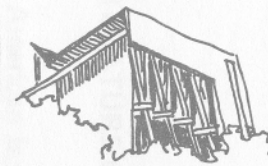
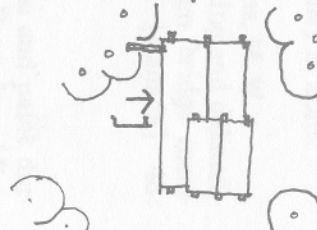
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 JOHN HARRISON RUDOLPH  
 POST AND GLULAM BEAM S-MIN.



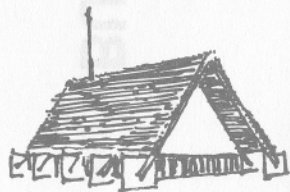
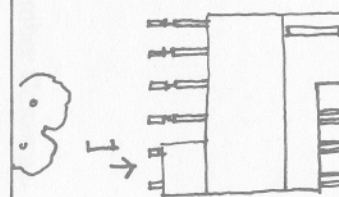
**CALVARY LUTHERAN CHURCH**  
**2** BELLEVUE 1965  
 GRANT, COPELAND, & CHERVENAK  
 GLULAM A-FRAME S-MIN.



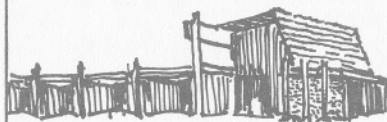
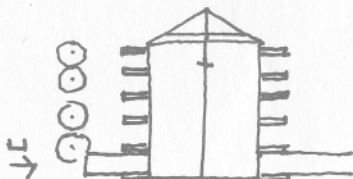
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**3** BELLEVUE, 1955  
 BUILT BY OWNER  
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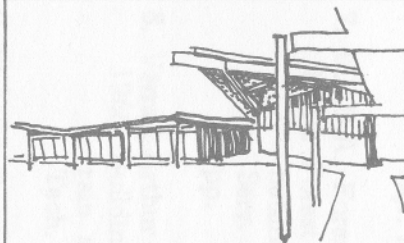
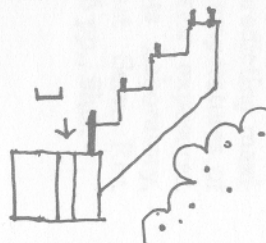
**CHRIST THE KING CHURCH**  
**4** EASTGATE 1956  
 GRANT, COPELAND, & CHERVENAK  
 HEAVY TIMBER P-MAX



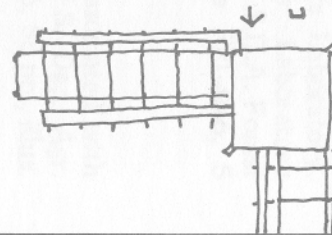
**EMMANUEL EPISCOPAL CHURCH**  
**5** MERCER ISLAND 1959  
 WALDRON & DIETZ  
 GLULAM A-FRAME S-MAX



**FEDERATION FOREST INFORMATION CTR.**  
**6** STATE PARK - MT. RAINIER AREA, 1964  
 ROBERT JORGENSEN  
 POST AND GLULAM BEAM S-INT.



**HILLAIKE ELEMENTARY SCHOOL**  
**7** BELLEVUE 1960  
 JONES, LOVEGREN, HELMS, & JONES  
 GLULAM POST AND BEAM S-INT.



## Legend



NORTH  
ALL PLANS

SCALE: L = 10 FT.

ENTRANCE = →



TREES

REF. NO. BUILDING NAME  
 LOCATION YEAR BUILT  
 ARCHITECT

STRUCTURAL MEMBERS

INTEGRAL PROTECTION

[S = STAIN, PRES. = PRESERVATIVE]  
 [P = PAINT, PC = PLASTIC COATING]

INDEPENDENT PROTECTION

[MAXIMUM, INTERMEDIATE, OR MINIMUM]

Building Information

APPENDIX

CONTINUED