

# Explorations of Roundwood Technology in Buildings

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**Abstract**—A report and critical commentary is presented on the use of small diameter roundwood in building construction in the United States and England. Examples are discussed of roundwood joinery being evaluated at the USDA Forest Service's Forest Products Laboratory, and joinery developed by the British engineering consulting firm Buro Happold, working over 15 years in the development of roundwood use in Europe. Three buildings constructed at Hooke Park in Dorset, England, using small diameter roundwood thinnings as the structural members are profiled, demonstrating the range of applications from small domestic scale to a very large enclosed workshop space. These precedents will inform the construction of traditional Navajo hogan shaped buildings in northern Arizona in the development of local roundwood industries.

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## Introduction

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Roundwood is the original forest product for building construction from the most ancient of human times to today. Whether heavy logs or thin scantlings, the natural form of timbers and saplings has been the traditional geometry of construction. But since the industrialization of forestry and lumbering, especially in the milling of lumber, a prismatic mentality has dominated thinking and practice. Flat surfaces are easiest to join to flat surfaces. But with milled material there is both material and structural loss in trimming a round log into a rectangular cross section.

This exploration paper is part of a comprehensive program to develop a use for the forest thinnings of the northern Arizona ponderosa pine (*Pinus ponderosa*) forest. The project involves the design of a modernized traditional Navajo home, a single room octagonal "hogan," using precut and fitted roundwood parts. Perhaps small industries could be developed locally that would also meet a strong housing need not currently addressed.

Obviously a house is more than a roof. Roundwood and thin logs are undoubtedly best suited to structural frames, trusses, and skeletons. But these need continuous panels or

infill if used for shelter. When used as solid walling, or as panel materials, roundwood seems less appropriate. Thus the challenge is to find the most obvious economic uses of these small timbers in small buildings.

## Forest Products Laboratory, Madison, Wisconsin

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Within the U.S.A., the Forest Products Laboratory at Madison, WI, run by the Department of Agriculture Forest Service, is a national center for research in timber applications to building construction. Experimental, testing, and computational activities are conducted both at the laboratory and by contracted researchers. A personal visit there February 3–5, 2000, allowed intensive discussion with Ron Wolfe, the investigator, about the current technical status of roundwood applications, as well as a review of recent experiments in joinery and fastening. Because wood is strong in tension, but weak in shear, considerable attention has been focused on methods to allow the joint to transfer the potential full strength of the member.

The most thorough recent experiment has been with a "dowel-nut connection" at the end of a piece of roundwood that was conducted by Ron Wolfe. A cylindrical 44.5-mm (1.75-inch) diameter dowel is fitted across the member or strut. A distance of some 7 diameters from the end is recommended. This dowel is tapped and becomes the nut for a threaded rod that extends from the center of the roundwood to connect to a hub, or other transfer point or joint. A tight steel strap or sleeve around the roundwood holds the fibers together to control splitting. Although the experiments were made on 127 mm (5 inch) diameter Douglas-fir (*Pseudotsuga menziesii*) peeler cores, by adjusting structural data the technique could be applied to other wood types, other diameters, and to debarked but untrimmed roundwood, according to the researcher.

A building project of special interest is the design and construction of a full sized circular pavilion of roundwood 7.5 m (25 feet) in diameter, a dimension similar to a hogan, a traditional Navajo dwelling. A 12.5 mm (1/2-inch) steel cable around the perimeter makes a tension ring for the truss ends. The roundwood pieces 150 to 200 mm (6 to 8 inches) in diameter are joined by "timber rivets," a steel nail with a wedged head used with a flitch plate. While apparently over designed, the pavilion is both a confidence builder and the subject of full sized monitoring. In addition, at the Forest Products Laboratory a number of other building products are at various stages of development and commercialization that have special interest to those interested in innovative forest products. Trade names such as "fast wall," "tectum," "bison pressed board," and "compreg" are among the many of these upcoming materials.

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## Hooke Park, Dorset, England

The Parnham Trust, Beaminster, Dorset, UK, was founded in 1977 as a nonprofit educational charity by John Makepeace, perhaps the best known furniture designer and maker in Britain. It has been primarily concerned with the teaching and development of the design, production, and business skills needed for the establishment of new enterprises using timber as a primary material. Both forestry and furniture-making skills are taught in apprentice-like settings. Thus Hooke Park was founded as a demonstration forestry tract and test site of 132 ha (330 acres) of Dorset woodland, which contains at its center, a workshop/training facility in the use of roundwood, as well as student residences—a miniature college in the woods.

The educational facilities at Hooke Park consist of a series of custom designed experimental buildings that explore uses of roundwood, a sustainable crop, together with test forests that provide the outdoor classroom. Roundwood has been recognized as a viable construction material worldwide and throughout history. However, it is the use of immature thinnings of little commercial value that is innovative at Hooke, and of most interest elsewhere.

Leading British architects have been involved in the design of each building at Hooke Park. However, the common technical consultant for all structures has been Buro Happold, Bath, with Ted Happold personally involved with carefully engineered high-tech ideas of joinery. Since his death, the home office staff from Bath have continued technical support of structural and services engineering for this program. All buildings demonstrate ideas of what can be achieved with round poles, particularly the first two where details use epoxy plugs, wrappings, and adhesives.

### The Prototype House

Richard Burton, of Arends Burton, Koralik, (ABK) Architects, of London designed this single story domestic building (figs. 1 and 2) in 1983, which was completed in 1986. The internationally known partnership of ABK founded in 1961 has been the source of major architectural designs for four decades. The house is used as a seminar room and for

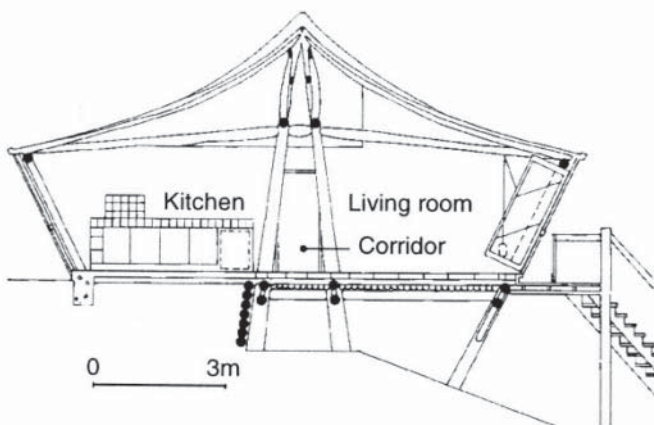


Figure 1—Prototype house, Hooke Park, UK: section.

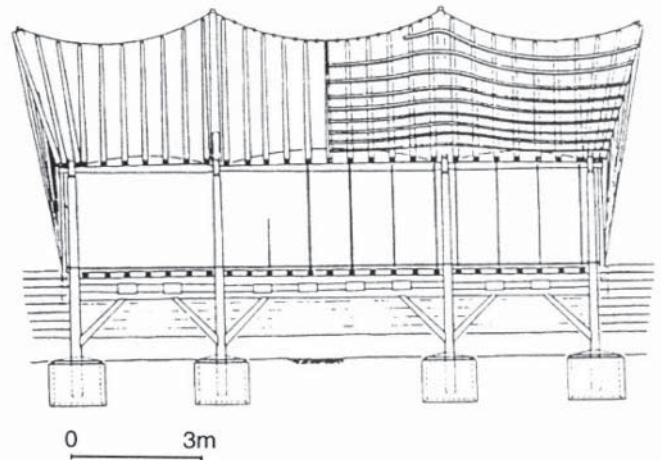


Figure 2—Prototype house, Hooke Park, UK: longitudinal section.

administrative offices. It has a size of 11.2 by 8.5-m (37.3 by 28.7 feet) and the material used was Norway spruce (*Picea abies*). A series of A-frames support a doubly curved roof structure using 5.5 m (18.3 feet) long, 60 to 90 mm (2.4 by 3.6 inch) diameter hanging rafter poles with an initial sag of 20 mm (0.8 inch). Thus the roof load is carried in tension and taken out of the poles by epoxy threaded 12 mm steel rods, connected to tension eyes.

The decision to use the thinnings structurally in tension led to the resin joint. To use roundwood only 50 mm (2 inches) in diameter, a very efficient joint was required (fig. 3). This is achieved by drilling a conical hole in the end of the timber and

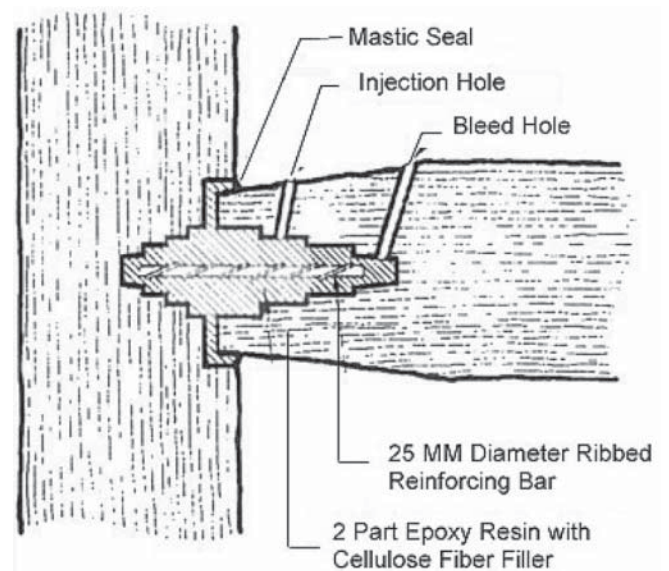


Figure 3—Prototype house, Hooke Park, UK: roundwood design joint.

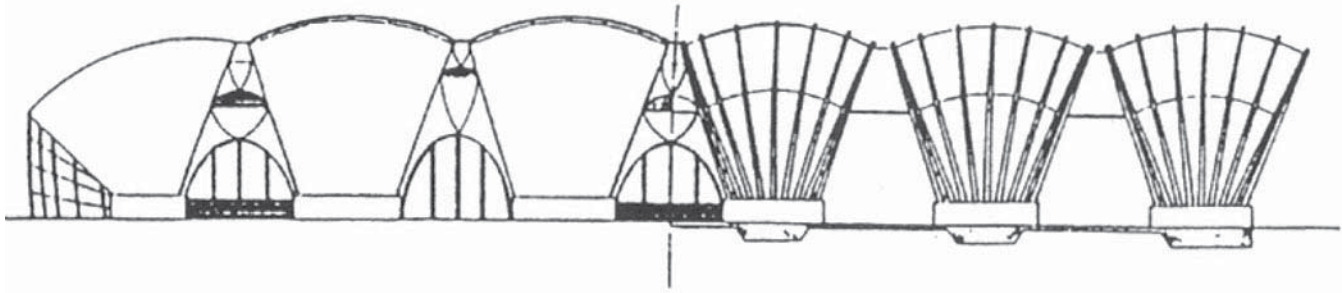


Figure 4—Wood workshop, Hooke Park, UK: elevation/section.

filling it with epoxy resin. The conical hole exposes all the fibers, which are oriented longitudinally, and maximizes the efficiency of the joint. A threaded steel rod is bedded in the resin to enable a connection to be made. In the case of this house, roof timbers hang from the ridge cable. An additional benefit is to avoid metal-to-wood contact, a common area of building material failure. Similarly, the same joint is used in the compression joints as the resin plug helps to bind the center fibers of the roundwood and prevent them splitting apart under pressure.

With the initial sag set at 200 mm (8 inches), the design sag for maximum load is 300 mm (12 inches), which gives a tension force of 7.2 kN. This tension is transferred into the building structure at the ridgeline through a tension joint attached to a wire cable hung between the heads of four A-frames. The tension at the eaves is transferred into a cable spanning between inclined side posts, resisted in turn by a roundwood header beam joining the tops of these posts as a “burnished compression spar.” The symmetry of the cross section avoids structural eccentricity.

The outside walls lean outward to help resolve structural, thermal, and rainwater problems, and to provide solar

control. An overhanging eave was considered but rejected on the grounds that it is undesirable to have rafters projecting outside the insulated skin and be subjected to different temperature and moisture conditions. This solution also avoided having to cut the vapor barrier around rafters and also avoided wind penetration.

## The Wood Workshop Building

The training Wood Workshop (figs. 4 and 5) was also designed by Richard Burton of ABK, and was completed in 1990. It is a 15 m (50 foot) span vault roof using wet Norwegian spruce (*Picea abies*) two bent poles 10.5 m (35 feet) long tapering from 180 mm to 70 mm (less than 8 inches to less than 3 inches) in diameter. A crown section of two poles was used to connect the bent poles through lapping bolted joints. At the base, the poles were fixed to concrete walls using grouted-in-place bolts and plates.

The final building has three shells spanning 15 m (50 feet) wide, forming a total structure 42.5 m (142 feet) long and 7 m (23 feet) high. The shells are formed using thinnings of

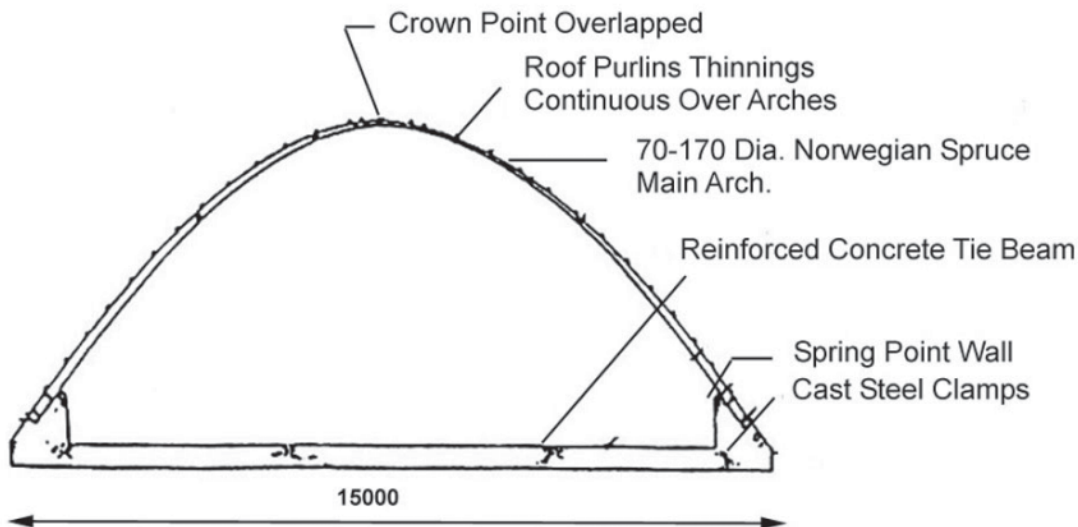


Figure 5—Wood workshop, Hooke Park, UK: structural section.



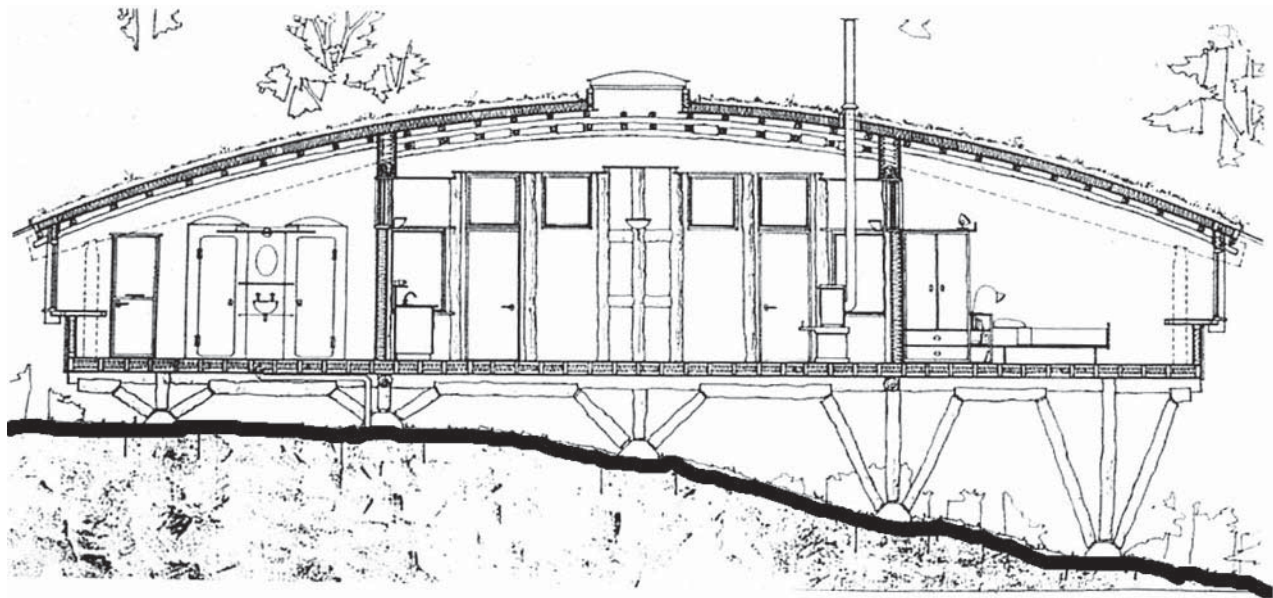


Figure 6—Westminster Lodge, Hooke Park, UK: construction section.

nominal diameter 155 mm (6 inches) at the base to 65 mm (2½ inches), approximately 9 m (30 feet) long, joined at the crown by a laminate crown arch member. Access for visitors is by a bridge that enters the building at mezzanine level between the workshop and teaching areas. Two of the shells form the workshop area. The third contains the library, seminar rooms, teaching area, and offices, all arranged both at ground floor and mezzanine levels.

The most labor-intensive part of the work involved fitting the plywood edging strips for the membrane and fitting the windows and doors to the complex shapes of the frame on the end walls. This work required several skilled carpenters and took several weeks.

### Westminster Lodge

The Westminster Lodge (fig. 6) by architect Edward Cullinan was opened in April 1996. It provides student accommodation with four pairs of private rooms around a central common space. The floor is raised above sloping

ground and the load-bearing walls are made from clad roundwood. The main feature of the Lodge is the two-way spanning Vierendeel truss roof (fig. 7), which required eight 3 m (10 foot) long poles to be spliced together to form the top chord. The poles were approximately 100 mm (4 inches) in diameter and were used in four layers to span the 8.4 m (28 feet) in two principal directions. Blocking pieces provided shear connections between the top and bottom layers adding stiffness in the central part of the span.

Named after the Duke of Westminster, who provided substantial funding, the most interesting roundwood element again is the roof. The two-way spanning roof has a large number of alternative load paths to allow for problems with isolated timbers. Using this strategy the variable properties of the roundwood can be exploited without the need to downgrade the stresses to the level that the statistical variation in strength might imply.

The solution was to develop a joint, which could easily be made in the forest, with simple, readily available tools. This joint was a combination of a scarf joint and finger joint. The

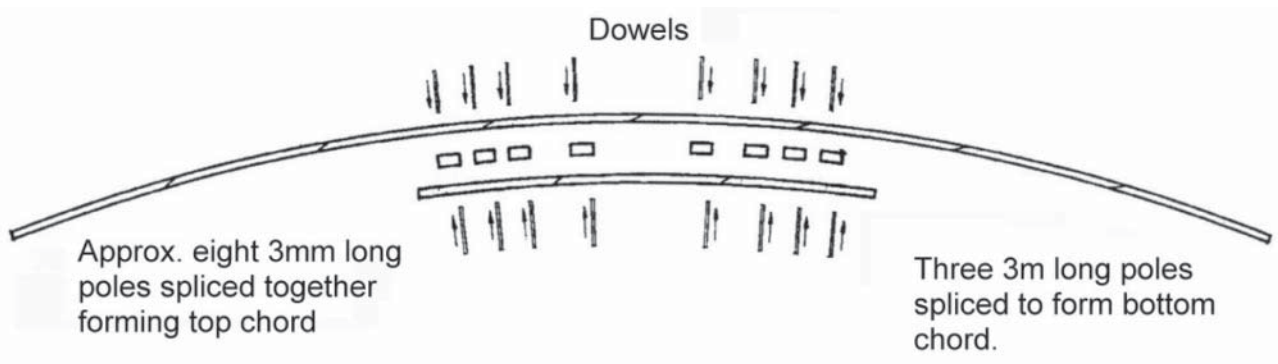


Figure 7—Westminster Lodge, Hooke Park, UK: structural assembly.

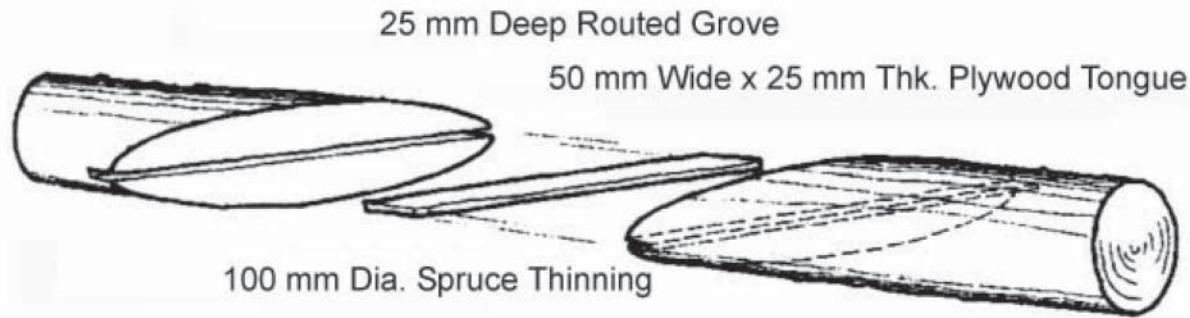


Figure 8—Westminster Lodge, Hooke Park, UK: Roundwood end joint detail.

normal scarf joint is weak and unreliable; the normal finger joint is difficult to make in the forest. By cutting a plywood tongue or key into the roundwood scarf joint diagonally, a simply made, strong, and reliable field joint was achieved by increasing the surfaces of the epoxy glued end joint as shown in figure 8.

By using this joint any length of 100-mm (4 inch) diameter could be produced. Long lengths were used top and bottom with two intermediate layers to span across the 8.4-m (28 ft) roof space. Blocking pieces were used to generate a shear connection between the top and bottom layers, creating the two-way spanning Vierendeel trusses. The continuity of one layer over the side span gives added stiffness to the central span. It also enables a single layer of timbers to span one way across the 3 m (10 ft) between the walls of the side rooms. Instead of steel bolts, 25 mm (1 inch) oak dowels connect the top and bottom chords through a spruce shear block 400 mm (16 inch) long and 80 mm (3 inch) thick that serves as a spacer.

A secondary connector of some interest is the wrapped straps of stainless steel, a standard product, here used to hold two roundwood perkins together as they pass at right angles.

## Construction Summary of All Three Buildings

On all three buildings, the roofing materials allow for the variability in form and surface natural to roundwood. On the first two buildings, a flexible membrane surface on a soft insulated blanket was used that fits to the profile shape of the roundwood as well as the double curved surfaces. On the Lodge, boarding was used to support the heavier “green” roof surface of living grass turf, which has already been replaced once. Since the sod is not very thick, it apparently cannot survive even in the damp English climate.

Floors were more difficult to detail. They needed to be covered with level boarding or surfacing and this cannot be achieved with tapered elements. A possible future development would be to use *in situ* concrete on roundwood with shear connectors. Thus the roundwood would act as permanent formwork and as tension reinforcement, with concrete providing the compression element and the finished floor surface.

## Evaluations

The UK visit to the University of Surrey (of an international European technical team) concentrated on a tour of Hooke Park in Dorset, where John Makepeace of the Parnham Trust had set up a school for woodland industry. All the buildings and structures for the school, situated deep in woodland, featured round-pole technology. The buildings are an interesting combination of forestry thinnings with very high-tech ideas carefully engineered by Buro Happold in Bath. They demonstrated ideas of what can be achieved with round-poles particularly when reliance can be placed on epoxy gluing. However, they were seen by the project team to be one-off developmental structures, with only limited relevance to the low-cost higher volume uses required for the round-pole project... (Ranta-Maunus).

This reviewer has similar observations. Although structurally successful, all buildings demonstrated intensive investments of human ingenuity and labor, as well as expensive fasteners in complex high technology joining systems. The similarity of the Happold epoxy resin plug to the American “dowel-nut connection” demonstrates two parallel technical solutions to the same engineering problem. Unfortunately neither seems appropriate to the design of the hogan roof structure. None of the buildings demonstrated use of roundwood for cladding or panel systems. Thus they all have limited lessons for the design of small span, small scale climatically adapted Navajo hogans for northern Arizona. But they are experiments that do not have to be replicated in northern Arizona. Of all those roundwood building ideas that have been built, it is the wrapped straps, and the multi-layer trussed roof at Westminster Lodge that appear to be the most transferable.

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