DIMENSION PANELS IN A MODULAR SYSTEM
OF SMALL HOUSE CONSTRUCTION
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SCHOOL OF FORESTRY
OREGON STATE COLLEGE
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UNITED STATES DEPARTMENT OF AGRICULTURE
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FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin
The Forest Products Laboratory has been exploring the possibilities of a shop-made building panel producible from low grade and waste timber. Experiments have been made with a system of employing such a panel in house construction so as to realize low cost with good serviceability and attractive appearance. The system is especially directed toward the employment of men and types of timber that in some areas cannot be fully utilized by present methods. The results to date are indicated in the accompanying photographs. No complete house has been built by this method and no manufacturing tests have been made to determine its practicability or cost. Ways and means of making such tests on a semi-commercial basis are sought, but have not yet been worked out. The basic idea is extremely simple, but this may be a liability instead of an asset if it is assumed that details of construction and workmanship can be disregarded. Successful application is largely dependent upon intelligent regard for important details, especially those relating to moisture and shrinkage control. Hasty trials that do not take advantage of the information and experience that the Laboratory has already accumulated are to be strongly discouraged. Assistance will be given by the Laboratory as freely and fully as possible to those who wish to investigate further.

Emphasis here on important details does not mean that there is but one way to handle the features incorporated in this type of construction. As a matter of fact there are several alternatives and variations and considerable flexibility within the main pattern of the basic system so that what is shown here is really only suggestive rather than a description of the one and only way.

Gradual development of the possibilities rather than general promotion has been looked upon as a wise procedure. A self-contained plant to produce the panels from local material not suitable for standard grades of lumber, especially in connection with the utilization of hardwoods, has seemed a logical application. However, other applications may be as good or better through the manufacture of the individual pieces of the panels as standard sawmill items, especially in the case of softwoods, and shipment to
panel-assembly shops near the centers of consumption. Any application to emergency housing projects would probably follow this pattern. Although not intended for temporary or demountable construction, the fact that all parts of the house except the framing and roof are of uniform sized panels which are fastened to the framing with little nailing and no face-nailing means that a building could be disassembled without much damage to the re-use value of the material.

To the individual who might be interested in this method of construction for his own home there is no application at the present time because the panels are not available on the market and the component pieces from which the panels might be made are not standard mill patterns and sizes.

The general aim is to reduce the present high handling costs of using short lengths individually by assembling them into convenient-sized panels under conditions where machinery, conveyors, and jigs can take the place of excessive hand labor. Extending the acceptability of hardwood species in house construction depends largely on substituting mechanical and shop work for manual work on the building site. It is the aim of this development also to avoid the rough, cheap, and outmoded appearance ordinarily associated with the use of short lengths in building and to suggest forms for wood products from low grade that are in line with trends in present day architecture.

Technically, the aim of the development is to provide inexpensive and rapid assembly of solid wood cuttings into shop-made panels, and of panels into wall and floor structures for both exterior and interior coverage primarily without gluing; to provide methods of compensating for the deleterious effects of swelling and shrinking that take place in solid wood, especially in panel form; to provide proper protection to the increased amount of end grain wood that is exposed to the elements when short lengths are used on exteriors; to provide an insulated, moisture-resistant panel and wall assembly with surfaces suitable for exterior and interior use; by means of as complete fabrication as possible at centralized plants to facilitate the technical control of the finer points of construction detail and carry out operations not feasible with the use of stock items of lumber, viz., where desirable the application of preservative treatments, aluminum priming, end grain and joint coatings, predrilling, prefinishing, etc.

In essence the system illustrated in this report involves the use of shop-finished building panels of uniform size for all parts of a house except the framing and roof.
The individual panel is two stud spaces in length and the width of one, or typically 16" x 32". A certain proportion of half panels, 16" x 16", would be used. The panels are made of relatively narrow cuttings nominally 1 inch in thickness. They are of nonglued construction (except as an alternate for painted walls where, under certain conditions, edge-glued assembly may be used) with special treatment of joints to provide weather tightness for exterior walls and decorative appearance for interior surfaces. The fact that relatively small cuttings are used in the panels means that a wide variety of low-grade and lesser-used species as well as standard species can be brought into utilization in this form of construction, either in natural or painted finish.

The panels are for use in so-called curtain wall construction where conventional framing erected on the site is braced sufficiently to carry the full load without reliance on the coverage material. They are further intended for use in a modular system of building layout in which spacing of framing members, dimensions of rooms, location and size of openings conform to the standard module of 16 inches.

Pertinent features of the structural system may be outlined as follows:

(a) The use of shop-made panel units for exterior and interior walls, ceiling, and floor, typically 16" x 32"* (plus certain proportions of half-panel units, 16" x 16").

(b) The exterior panel as shown is made up of 3-inch strips tongued and grooved to special water-resisting joint at edges and ends; assembled by two cleats on the back near the top and bottom edge. The panel reaching across two stud spaces is locked to the framing by the horizontal mullion bars. Although additional fastening is probably not necessary, if desired the panels would be face-nailed to the studs at six points.

(c) The horizontal mullion bars of random lengths lock the panels together at the top and bottom edges and pitch the water away from the top and bottom of the panels.

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* A wider unit; viz., 24" x 32" or 48", may prove advantageous under some conditions.
(d) Conventional framing is used, except for minor features, with particular attention to the size and location of window and door openings so that the standard spacing of studs and joists (consistently on 16-inch spacing) will be maintained as uniformly as possible to minimize cutting of panels on the job.

(e) For small one-story houses no sheathing or subflooring is used. Diagonal bracing of the framing according to good present practice is contemplated for purposes of stiffness.

(f) The window construction is important in order to adhere to the 16-inch module and avoid necessity of cutting panels. There are various alternatives, but thus far a bank of narrow casement sash has been used, let in between the studs without the usual framing. The stud is used as a part of the window jamb and the balance of the window frame is simple and economical. From several points of view this window treatment appears to be flexible and satisfactory.

(g) For the fullest realization of the economies accruing to this system of house construction the 16-inch module must be adhered to in planning the building. Adherence to such a module brings up both advantage and disadvantage according to the point of view. Although the system is flexible with respect to size and shape of building and permits numerous variations in design it is not adapted to some of the architectural features, such as built-up entrance features, bay windows, complicated dormers, circular windows, and blinds and fancy shutters, that builders oftentimes put into small low-priced houses to give them so-called individuality and dressed-up appearance. To some this will be a disadvantage. Others will consider it an advantage in that it will encourage the elimination of imitative and relatively costly "frills." This type of house will look better without frills than with them, relying for its attractiveness on simple lines and good proportions. However, the pattern lends itself to various treatments in design which architects seem to favor in modern construction. It is believed that one of the advantages of this panel form of product is that it permits designers to create new effects in wood construction and to use wood "set off" with new products that have undoubted appeal, such as glass brick, plastic tiles, chromium strips, etc., that are rather incongruous with traditional wood construction.
(h) In all cases the finish, at least in part, is better and more cheaply applied in the panel-assembly shop than after installation on the walls. Prefinishing is especially advantageous in solid wood panels because it permits the use of special and coatings where necessary and the tongue and groove can be finished the same as the face, hence the opening of joints does not expose raw wood and is not so disfiguring as in the present conventional methods of handling lumber for paneling.
PLANT REQUIREMENTS AND COSTS

In general the most favorable conditions for the application of the method would appear to be those of a small strictly modern plant designed particularly for the purpose of building-panel manufacture, equipped to handle low grade lumber, logs, or bolts efficiently, and located within or close to the consuming territory which it is to serve so that there can be a close association between supplier and builder. It appears to be an undertaking for numerous, scattered plants. If it proves successful advantages should accrue to the buyer of a house, to the employment of labor, and to utilization of low quality timber.

Without having made any close analysis or study of this phase of the subject it seems reasonable to assume that a plant adapted to production of the panels on an efficient basis would have the following equipment:

- Dry kiln
- Cut-off saw
- Ripsaw
- Jointer
- Shaper
- Moulder
- Drum sander
- End matcher
- Variety bench saw
- Painting and finishing room facilities

This is in addition, of course, to the ordinary saw-mill equipment.

A nailing machine might or might not prove more efficient on a moderate production basis than simple table templates and jigs for hand nailing. A glue spreader and clamp carrier would be necessary, of course, if any panel stock were to be produced by edge gluing.

All new equipment of the above items, including building and power, would probably cost in the neighborhood of $45,000 for a plant capacity of approximately 15,000 square feet of finished panels per day or sufficient to build three five-room houses. Roughly a five-room house will require 5,000 square feet of panels for inside and outside walls, ceiling, and floor, not including framing and roof structure. A made-over plant or one with good used equipment would represent a substantially smaller investment, perhaps as low as $15,000,
Along with the panel plant a sawmill would be required for a self-contained unit unless the plan were to operate on low grade lumber from mills already in the vicinity. A new small sawmill with the equipment required for the efficient handling of bolts and short logs along with the building and power unit would perhaps cost $5,000.

If the component pieces of the panels were purchased worked to pattern from a sawmill-planing mill and shipped in bundles to a panel-assembly shop, the equipment requirements at the fabricating end would be substantially less than above.

It is virtually impossible for us in the present status of knowledge of the panel construction project to venture any close estimates of production costs and savings in building costs.

As rough indication of what the manufacturing costs may be, the following figures are used:

- Rough lumber per M. .................. $15
- Seasoning ................................ 5
- One-third waste on the above ........ 7
- Cutting and ripping .................... 5
- Dressing and moulding ................ 3
- Assembly into panels .................. 7
- Prefinishing ............................ 8
- For exterior, mullion bar per M feet of panels .................. 7
- For interior panels, sanding .......... 3
- For interior panels, insulation and building paper ............. 10

The interior panels, insulated, will cost somewhat more than the exterior panels plus the mullion bars. Not all the interior panels will require insulation, but for rough calculation let us assume that, including the mullion bars, all panels will average $60 per M prefinished.

The exterior panel at $60 per M board feet would be somewhat more than the cost of the sheathing material, outside the lumber-producing territories, that would be used in a small conventionally-built house. Within a lumber-producing territory it might be $30 more than the cost of sheathing for those who can buy direct from a small mill. Under most conditions the $60 would be perhaps half
the cost of the sheathing, siding, and paint (not installed) that would normally be used. This comparison, of course, is on the basis of present prevailing construction -- not on merely a drop siding or weather-board house without sheathing such as is used in the very cheapest construction in some parts of the country.

The interior panel at $60 per M board feet would be perhaps a third of the cost of the lath, plaster, paint, and trim (all in place) that would normally be used on an interior wall and about a third of the cost of a hardwood floor installed, sanded, and finished in the conventional way. It will be noted that the costs of the panels as used here do not include distribution and installation. No attempt is made here to estimate these costs. The indications are that the costs of installing the prefinished panels, if the modular system of layout be followed, are substantially less than the costs of installing standard unfinished materials in the conventional system of building.

From the differentials indicated above must come the margin for distribution costs, savings to the builder, and profit to the producer.

Only a pilot plant test, or its equivalent, including the actual construction of houses that people can see and react to, can establish the validity of any of these points.
PLATE I

A. Framing erected on the building site in the conventional way after wall dimensions and size and location of window and door openings have been laid out to maintain the 16-inch module of standard stud and joist spacing. A special placement of exterior corner post members and interior partition corners is necessary to maintain the 16-inch module. Casement windows are let-in between the studs without cutting away any of the studding.

B. Close-up of an exterior panel.

C. Exterior view of an experimental one-story corner section showing panels and mullion bars in place; shingled hip roof; screened openings in the soffit with provision to ventilate the interior of the wall and roof against condensation within the insulation in cold weather, against retained heat in warm weather, and against moisture that during bad storms seeps in or is driven into any exterior wall construction that the Laboratory has investigated.

D and E. Interior views showing various types of hardwood panels in natural and painted finish. Sidewall, ceiling, and flooring panels are all of the same general type of construction. The joints within and around the panels (except floor panels) are deliberately emphasized to produce a tiled design. There is no face-nailing through any of the interior panels. Each panel is tongued and grooved around the edges. In fastening to the wall one end of the panel merely fits into the tongue of the preceding panel and the other end is nailed to the studding through the protruding cleat. This provides rapid installation and secure fastening with no surface disfigurement due to nailing.

Although only hardwoods are illustrated here very effective results are obtained also with a variety of softwood species, especially in the three-piece panel type producible from standard 6-inch yard lumber widths. In a full-painted or in a wiped-painted finish the coarser-grained, as well as the finer-grained, softwoods can be used for panels with new appeal and attractiveness.

F. Sketch of a one-story house suggestive of the flexibility in design permitted by the panel system of construction.
Plate I.
PLATE II

A. Section view of exterior panel, cleats, and horizontal mullion bar in place against the face of the stud wall. The photograph shows the mullion bar and portions of two exterior panels — one above and one below. The vertical edge joint between the individual pieces in the panels is a close-fitting tongue and groove somewhat wider than normal and sufficiently close to the face side to shed water to the front instead of the back of the tongue on the top side of the horizontal mullion bar. The edge joints are coated with white lead paint as they are assembled in the shop. The panel may be face-nailed through the cleat to the studs, but this is not essential. The mullion bar is securely toe-nailed to the studs. The detail of the tongue and groove joint on the sides and ends of the strips is highly important and cannot be disregarded. The cut-back on the lower edge of the panel where it rests on the mullion bar is to minimize moisture absorption during rains. This cut-back edge should be end-coated with aluminum paint or white lead as part of the shop-fabrication process.

The mullion bar if made from sapwood or a wood of low durability may well be given a hot and cold bath treatment in a suitable preservative after machining to pattern. As the panels are put in place on the mullion bar a setting in white lead or caulking compound is advisable for maximum tightness.

B. Details of interior panel showing face side of two and back side of one in which built-in insulation is added in the space formed by the cleats. The placement of cleats is best illustrated in the center panel.

The interior panel may be shop-insulated substantially as illustrated with any one of several locally available fibrous materials, viz., sawdust and shavings, rock wool, cotton, peat moss, etc.; or commercial blanket insulation may be installed within the framing of the house according to conventional methods.

C. Close-up detail of joints and floating, decorative spline used to cover joints between pieces within the interior panel and produce uniformity in appearance as the wood swells and shrinks with moisture changes. A 1/32-inch saw kerf is made at an angle to the face as shown preferably by a supplementary cutter on the moulding.
machine when the piece is tongued and grooved. A thin, narrow strip is then inserted as the pieces are assembled into the panel. A wide variety of inexpensive materials in various colors and textures is available for this joint treatment, such as thin metals or foils, celluloids, wood veneers, fiber boards, etc.

This detail can be eliminated, but it adds so much to the up-to-date distinction of the panel that retaining it at a minor increase in manufacturing cost seems well worth while except for the cheapest type of construction in order to give the public something besides the usual "cracks" in wood construction.

D. Back view of exterior wall construction with particular reference to ventilation. The design of the panels and their method of application in wall construction lend themselves to a practical application of the idea of a ventilated-insulated wall. The advantages and objectives of a ventilated wall in combination with insulation largely center around the prevention of the accumulation of free water in an insulated wall caused by moisture vapors from the interior of a building condensing within the wall during cold weather. Another source of moisture in a wall is that due to rain driven in by the wind through the joints in the siding. Where accumulations of water do occur they (1) minimize the efficacy of the insulation, (2) create decay hazards in both trim and framing members of the building, and (3) cause blistering of paint on the exterior surfaces and discolorations. The above conditions are now well established by laboratory research. Another advantage of a ventilated wall in combination with insulation, which is not generally recognized in its application to summer comfort, is that the temperatures within a wall exposed to the sun during hot weather are higher than the outdoor temperatures. This condition is also general in attics. Ventilation lowers the temperature within the wall and reduces the exchange of heat accordingly. The effectiveness of insulation against summer heat is thus enhanced. Regardless of other considerations, the ventilated wall feature is particularly advantageous to the panel type of construction since numerous joints are necessary, and should some water gain entrance ventilation provides a means for rapid redrying.
The open spaces in the wall incident to ventilation are, of course, more favorable to spread of fire if it gets inside the wall than would be the case in a wall that is tightly closed and firestopped. The ventilated wall, however, has no more connection to the inside of the house or the basement than does good conventional construction, and hence should not have any bearing on spread of fire originating inside the house unless it gets into the wall space. It is felt that the economic advantages of the improved ventilation are sufficient to compensate for such adverse effect as there may be on fire spread. If desired, however, the vertical circulation of air into the attic can be stopped and dependence placed on horizontal openings only, or the ventilation feature can be dispensed with altogether and reliance for some of the benefits placed on other measures.

The specific measures whereby ventilation within the wall in the panel type of construction is accomplished consist of the horizontal cleats on the back of the exterior type of panel which set the panel out from the studding and thus permit unobstructed passage of air not only up and down the stud spaces but also crosswise from one stud space to another. This is particularly important above and below window and door openings. Such ventilation cannot be obtained in conventional construction without adding materially to the expense of construction and to the thickness of the wall. At the sill line the horizontal cleats on the exterior type panels would normally come in full contact with the sill and thus shut off passage of air. For this reason the panels from the floor line down are made according to the interior panel type where the cleats are vertical and thus do not shut off the passage of air. The stud spaces at the top of the wall are open to the chamber formed between the roof rafters and ceiling joists and to the attic space. Ventilators on the four sides of the building are provided through the cornice soffit and facilitate circulation of air.
Plate II.
PLATE III

(Possible alternatives as subjects for further study)

A. An alternative interior panel for painted walls. This panel is constructed exactly like the other interior panels except that the strips are edge-glued. This produces more conventional appearance than the "Tiled" panel. The technical disadvantage with it is that swelling and shrinkage control is more difficult because the unit of shrinkage is that of a 16-inch width instead of that of a 4-inch or 5-inch width. However, where a wall is to be painted and if aluminum primer is used not only on the face side but on the back and edges, then the shrinkage factor can be taken care of with species of only moderate shrinkage. The cleat construction on the back is retained in the glued panel just as in the nailed panel for purposes of keeping the panel flat and for blind nailing to the studs. In the glued panel the cleat should be provided with slotted holes so that the panel can come and go without undue restraint.

Where the edge-gluing of random widths according to box factory procedure is preferred by the manufacturer in lieu of using narrow fixed widths, it will be safer with most woods to rip the glued-up stock and use in connection with the 3-piece tiled panel type rather than as a unit in the one-piece type illustrated here.

B. and C. Alternative exterior panels with horizontal strip construction similar to interior panel type for use with horizontal mullion bars and vertical battens let in between and covering the end joints. The nailing to the studs is through cleats that protrude at both ends of the panel instead of only at one end as in the case of the interior panel construction. This means that the horizontal pieces do not come in direct contact end to end under the batten, and consequently a T-shaped rather than a flat batten is used over the joints.

B is edge-glued construction in a one-piece panel. If a good water-resistant glue is used for the edge gluing and if the panel is painted with an aluminum primer on all sides, it should prove as satisfactory as the one-piece construction for the
interior panel referred to in A. In this case the lower side of the horizontal mullion bar is routed out sufficiently deep to allow for both expansion and contraction in the width of the panel itself without either crowding the mullion bar or coming loose from it.

C is simple tongued and grooved construction (oil, stained finish with painted mullions). The lower half of the wall shows end joints covered with battens as already described in B. The upper half of the walls shows flush batten construction.

D. Detail of flush batten construction in which the face of the batten is a strip of thin noncorrosive sheet metal, such as copper or aluminum, that slides into a thin, shallow groove cut at a 45-degree angle similar to that for the floating spline in the interior panel construction shown in Plate II, C. The metal batten construction is for the purpose of greater resistance to infiltration of water under the batten. The flush surface is also advantageous from the standpoint of appearance.
Plate III. Possible alternative panels.
A. Interior panel of edge-glued strips with painted walls. B. Exterior panel of edge-glued strips and vertical battens. C. Exterior panel of tongue and grooved strips. The upper two panels are here used with flush battens. D. Detail of metal batten strip.
PLATE IV

A. Cross-section through wall, and two alternative methods of insulating panel construction.

(a) Blanket insulation of recent commercial type (extra thick, but competitively priced) tacked to the studding.

(b) Shop-installed insulation as a part of the prefabricated interior wall panel, filling in between the cleats on the back of the panel (3/4-inch thick). Rock wool fill is shown here, but several other inexpensive materials can be used (chemically treated against fire, decay, and insects if desired), viz., raw cotton, sawdust and shavings, peat moss, etc.

In both (a) and (b) a vapor-barrier (moisture-resistant paper) intervenes between the insulating material and the back of the interior panel. A non-moisture-resisting sheet (for breathing) is used between the insulating material and the wall cavity. Low cost cotton cloth is used in (b) for this sheet and a low cost paper in (a).

The tongue and groove in the exterior panel, as shown, are intentionally wider than normal, and have a full contact, flat bearing surface rather than a one-point contact and rounded bearing.

B. Alternative type of interior wall paneling with vertical joints and horizontal flush connector strips. As in the other types, the unit panel size used here is 16" x 32". The decorative spline in the vertical joints in this instance is a glossy plastic material. Either in a painted or natural finish the possibilities of attaining an attractive appearance are promising, especially with a contrasting color for the horizontal strips. Aside from permitting some variation from the effect produced by the other types of interior panels, this type may hold distinct advantages from the standpoint of manufacture and installation.
Plate IV.

A. Cross-section through wall showing two alternative forms of insulation.  B. An alternative form of interior panel -- size 16 by 32 inches like other panels.