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A. Coull

R. T. McCrone

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By

A. Coull* and R. T. McCrone**

## INTRODUCTION

Timber frame construction is particularly suitable for low cost housing, since most of the work can be carried out in a factory atmosphere unhampered by weather conditions. By the use of jigs and fixtures, much of the work is of a repetitive nature, which can be tackled by either male or female labour using easily acquired skills.

Erection on a site platform, which itself must be constructed accurately, is easily carried out by a team of erectors without great skills in joinery. The work is facilitated if little or no variation is made to a standard internal layout. The construction of the platform can be a fairly simple undertaking if accurate formwork is employed, and due care is taken in the placing of the concrete, or other foundation groundwork.

In the construction of timber-framed houses, the method most frequently adopted is to nail to timber joists or studs sheets of resin-bonded plywood. In one standard design, the outer layer of an ornamental grade plywood acts both as a sheath and cladding, the panels being generally vertical with battens or mouldings covering the suitable sealed joints. Unfortunately, the majority of timber and plywood frame types of structures depend on some additional form of covering overlay for decoration and weathering protection, and the maintenance of such surfaces can be costly.

The other recognised methods of providing the outer cladding are by using brickwork, hung tiles, or pebble dashed cement rendering on wire mesh. All these methods have their own advantages and disadvantages; however, none is suitable for industrial fabrication, and none may be used easily to stiffen and strengthen the frame by providing an integral form of structure and cladding.

At present, because of unfavourable cost comparisons with other methods of construction, smaller erections than domestic dwellings, which would still require to have an overlay for acceptable appearance, are seldom constructed from plywood.

This paper describes a simple technique which has been devised to produce cladded plywood panels which present an exterior surface of aggregates, or pebbles, which have been resin bonded to the plywood sheet underneath. The method is particularly suitable for single-story houses and similar structures which have a design basis which permits the plywood to have a combined sheathing and cladding function. It is also very suitable for structures such as house extensions, garages, sheds, holiday chalets, etc.

## BASIS OF DESIGN

In order to take full advantage of the repetition necessary for minimising production costs, the design can be carried out on a modular basis. Using British sizes, a suitable module for the construction of single story dwellings could be based on the commercially available standard sheet size, viz. 8 x 4 ft., but this could easily be altered to suit local conditions.

*Dept. of Civil Engr., University of Strathclyde, Glasgow, Scotland
**Dept. of Civil Engr., University of Strathclyde, Glasgow, Scotland

If the module size is accepted as 8 ft x 8 ft., any door or window opening can be incorporated within a single panel. The plain panel, without a door or window cut-out, consists of two 8 ft x 4 ft. sheets butting together, with a vertical stud, to which both sheets are nailed, behind the join. If it is desired to increase the length of the panel, for example in order to increase the ceiling height, a horizontal joint may be made in a similar manner, as shown in Fig. 2B. The resin-aggregate overlay conceals the joints between the sheets.

The panels can be constructed and 'rendered' under controlled conditions in a factory, and delivered on site in a finished condition. Panels of 8 ft. square modular size, whilst allowing all doors and windows to be incorporated, are small enough to be handled without expensive lifting equipment. When constructing panels with doorway or window openings, the timber surround acts as a 'dam' during the pouring of the resin.

If due care and attention is given to the detail design, the in-situ joints, which are reasonable widely spaced at 8 ft. centres, need not present an ugly appearance. The wide variation in materials and range of attractive finishes which may be employed on the panels themselves can do much to offset the drab uniformity which is often obtained in a large scale mass-produced housing scheme.

A suggested standard layout for a three-bedroomed house is shown in Fig. 1. The design utilises three panels along one side, and four along the other, and incorporates three bedrooms, kitchen, bathroom, and living/dining room. A greater variety of layouts is possible if 8 ft x 4 ft 'half-panels' are used.

## CONSTRUCTION OF RENDERED PANELS

In its cheap form of a planed but unsanded surface, complete with knot holes, Canadian Douglas Fir presents a particularly suitable surface for this form of treatment.

The stiffened panel or combined panels are easily manufactured by placing the joist or stud reinforced plywood or asbestos sheet horizontally, and then applying a coating of synthetic resin to the upper face. Aggregate or pebbles are then spread over the coating and become embedded in the resin, which is allowed to set. The process is most easily carried out by locating the panel in a surrounding frame, the walls of which project several inches above the surface of the sheet. The aggregate can be heaped on in excess of that required, so that its weight assists in embedding the first layer. After hardening, the excess aggregate is removed simply by upending the panels, allowing the surplus to fall off and be reused.

By suitable selection of materials, an attractive surface appearance can be achieved. For example,

(i) Colouring pigments or suitable agents giving a desired colour or shade may be added to the resin.

(ii) Any type of shape or colour of aggregate or pebble may be used. Within reason, there is little limitation as to size, as in the conventional pebble dash type of finish, which relies on aggregate being thrown against the mortar covered wall. Fairly large stones may be used if desired for ornamental effects.

(iii) Blendings with traditional finishes such as roughcast are easily achieved.

(iv) Mixed sizes of stones or colours may be achieved by a random placing of one size or colour, and the spaces filled up with another variety.

(v) Portions of the plywood or asbestos may be blocked off for additional design effects such as mosaic application.

The finish should require little or no maintenance over a long period of time. Little skill is required on the part of the labour force involved in the production of the panels.

Plate 1 shows a 5 ft x 3 ft plywood panel before and after rendering with a $\frac{3}{8}$ in to $\frac{3}{4}$ in aggregate.

## SITE CONSTRUCTION

The site jointing of the modular units may be effected by the usual means of nailing stud to stud, with plates top and bottom to additional joining plates, or by coach bolts if future dismantling is envisaged. The top and bottom plates can be set back sufficiently from the edge of the plywood as shown in Fig. 2A (diag. 4) to allow an overlap of the foundation plinth or wall, and at the top for the additional long top plate crossing the panels.

Possible details of the external finishing of the vertical joints are shown in Fig. 2A (diags. 1, 2 and 3). Diagram 1 shows a mastic butt joint, to whcih can be added some form of overlay if desired. The alternative form of butt joint shown in diagram 2 uses additional strips nailed to the vertical studs; these could be similarly rendered strips of wood, or some other suitable form. This form of joint has the advantage that the studs act as boundary walls for the resin when it is being poured. If an overlay strip is considered undesirable, the method of diagram 3 can be used to make a positive gap which can be subsequently filled with an elastomer sealer or a suitable resin filler in which matching and concealing aggregates may be embedded by hand placement. Whilst the third method might be considered most attractive in presenting a homogeneous surface, such are the powerful effects that can be obtained with coloured resins and aggregate variations that a bold join, or thin line discontinuity, can be aesthetically acceptable.

## WEATHERING PROPERTIES

Since the outer surface facing the elements consists of more than 80 percent aggregate, the combined outer areas present a large wind drying area. (In traditional Scottish houses, builders have relied on this factor in the rough casting process to assist in preventing moisture penetration). The resin itself forms a waterproofing medium, and with the deep penetration into the 'crushed fibre' of the plywood surface makes an excellent seal. The aggregate in conjunction with any suitable filling agents, protects the resin from the ageing effects of the sun's rays.

Some accelerated tests have been carried out on panels using soaking freezing and heating cycles of greater severity than would normally be encountered in urban environments. No dislodgement of the aggregates occurred.

The panels shown in Plate 1 have been exposed for some 18 months to atmospheric conditions in the West of Scotland. Although the edges are unprotected, no visible signs of deterioration are yet evident. However, since earlier inferior resins, with no protective aggregates, have been used satisfactorily under exposed conditions in boats, it must be expected that weathering properties should be very good.

## COMPARATIVE COSTS

Comparative costs will depend on the particular country and location, and no firm figures can be given.

In Britain, the costing must be based on imported plywoods and home-produced resins. In that case, the plywood sheet with resin/aggregate surface compares favourably with a primed but unpainted weatherboarding, and is cheaper than the skilled process which it resembles most closely, pebble dashing on cement rendering hung on wire mesh, yet it has much greater scope for aggregate sizes and background colourings. It is also a cheaper process than using ornamental timber overlays.

## INFLUENCE OF SURFACE FINISH ON STIFFNESS OF PANELS

If the strength and stiffness of the panels can be increased by the surface finish, it might be feasible to reduce the thickness of the plywood sheet employed, and hence reduce costs. Consequently, tests were carried out to determine the influence of the aggregate rendered finish on the stiffness of a plywood sheet. For simplicity, since these were preliminary investigations, tests were carried out on beam specimens subjected to pure bending.

The plywood used in the investigation was a Canadian exterior grade plywood having three resin-bonded lamina of equal thickness. The average thickness of the section was 0.27 in. and the average thickness of each Douglas Fir veneer 0.09 in.

A series of beam specimens, 24 in. long and 2 in. wide, was cut from a standard 8 ft. x 4 ft. sheet. The samples were taken at random, and divided into two groups of specimens with the grain in the outer veneers running respectively parallel and perpendicular to the span. The finished surface was not sanded or prepared in any way after cutting, as this tends to reduce mechanical adhesion, which might be of importance where neither heat nor pressure is applied to the resin film.

The adhesive used was a commercial general purpose polyester resin, applied in a layer of average thickness 0.04 in. In order to maintain a sensibly constant film thickness during the series of tests, a small formwork was constructed. This took the form of a perspex frame which could be fitted around the sample and wedged tightly to form a tank about an inch deep. A measured amount of resin was poured on to the sample, and allowed to settle over the surface. The aggregate was then poured into the tank, and the resin allowed to set for twenty minutes, after which the frame was removed and the loose aggregate shaken off. The samples were then allowed to set for three days before testing.

The aggregate used was a washed pit gravel passing a $\frac{3}{8}$ in. sieve and retained by a 3/16 in. sieve. A visual examination indicated that the presence of this aggregate did not produce a total discontinuity in the resin film, and it was assumed that, for theoretical calculations, the section consisted of a plywood base with a resin outer veneer. However, during the first series of tests, there was some indication that some of the pebbles on a compression face, might be coming into contact. As a result, further samples were prepared using similar gravel passing a 3/16 in sieve and retained by a $\frac{1}{8}$ in. sieve, in order to examine the effect of aggregate size.

The beam specimens were supported on knife edges, 16 in. apart, in a test frame. Equal dead weights were applied at the quarter-span positions to give a state of pure bending over the central semi-span, and the central deflection measured by dial gauge. Readings were taken both when loading and unloading, and the stiffness deduced from ordinary beam theory.

In all, forty specimens were tested, as follows: twenty with grain parallel to span and with $\frac{3}{8}$ in. aggregate ; ten with grain perpendicular to span and with $\frac{3}{8}$ in. aggregate, and ten with grain perpendicular to span and with 3/16 in. aggregate.

Each specimen was tested initially with each face in tension. One surface was treated, and the tests repeated with the treated face in both tension and compression.

All tests were non-destructive in order that comparative results could be obtained, since the production of identical samples was impossible, and a very large number of tests would be required to give statistically significant results for destructive tests.

The average test results were as follows:

TABLE 1. Experimental Values of Flexural Stiffness EI (lb in$^2$).

| Test | No. of Specimens | Untreated Face in Tension | | Treated Face in Tension | | Percentage Increase | |
|---|---|---|---|---|---|---|---|
| | | (a) | (b) | (a) | (b) | (a) | (b) |
| 1 | 20 | 6410 | 6250 | 8390 | 9840 | 37 | 63 |
| 2 | 10 | 440 | 460 | 1330 | 2500 | 214 | 449 |
| 3 | 10 | 440 | 440 | 1660 | 2450 | 280 | 454 |

Notes:

Test 1 : Outer Veneer grain direction parallel to span. Face (a) treated with resin and $\frac{3}{8}$ in. aggregate.

Test 2 : Outer Veneer grain direction perpendicular to span.Face (a) treated with resin and $\frac{3}{8}$ in. aggregate.

Test 3 : Outer Veneer grain direction perpendicular to span.Face (a) treated with resin and 3/16 in. aggregate.

## DISCUSSION OF RESULTS

The tests indicate that a substantial increase in stiffness is produced by the rendering process, the increase being most marked in the weaker direction. The increase in stiffness is always greater when the treated face is on the compression side in bending. The ratio of the stiffnesses of the specimen when the outer grain lies respectively perpendicular and parallel to the span increases on average from 1/14.4 to 1/5.8 or 1/4.0 (the two figures referring respectively to the cases when the rendered face is in tension or compression). Consequently, the effect of the treatment is to produce a much more isotropic and homogeneous panel.

If the same increases in stiffness were to be produced by increasing the thickness of the plywood panel, increases of some 12-17% would be required for specimens with outer veneer grains parallel to the span, and some 45-75% with outer grains perpendicular to the span.

Although, in view of the scatter obtained, the results cannot be regarded as conclusive, slightly lower stiffness values are obtained with the larger-sized aggregate used. This may be due to a reduction in the thickness of the resin layer.

The results refer only to the preliminary series of tests. Further investigations are planned to examine more thoroughly the influence on both direct and flexural stiffness and strength of resin thickness, plywood thickness, and type of aggregate.

## OTHER MATERIALS

Although discussion has centred on rendered plywood panels, the same technique could be used to produce a similar aesthetically pleasing surface to asbestos sheets. These may be used in a corresponding manner for structural purposes.

## CONCLUSIONS

A description has been given of a simple technique for producing resin-bonded aggregate-rendered plywood exterior wall panels for domestic structures. The panels are suitable for low-cost housing designed on a modular basis, since they can be manufactured quickly and cheaply under factory conditions. They are easily erected, require little maintenance, and produce aesthetically pleasing appearances. Little skill is required either in the production or the erection of the panels, and their use obviates the need for any skilled finishing trades for the walls.

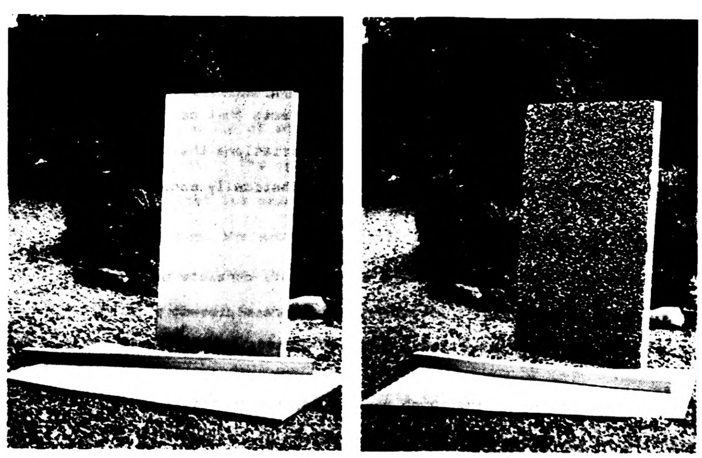

Plate 1. Plain and Rendered Plywood Panels.

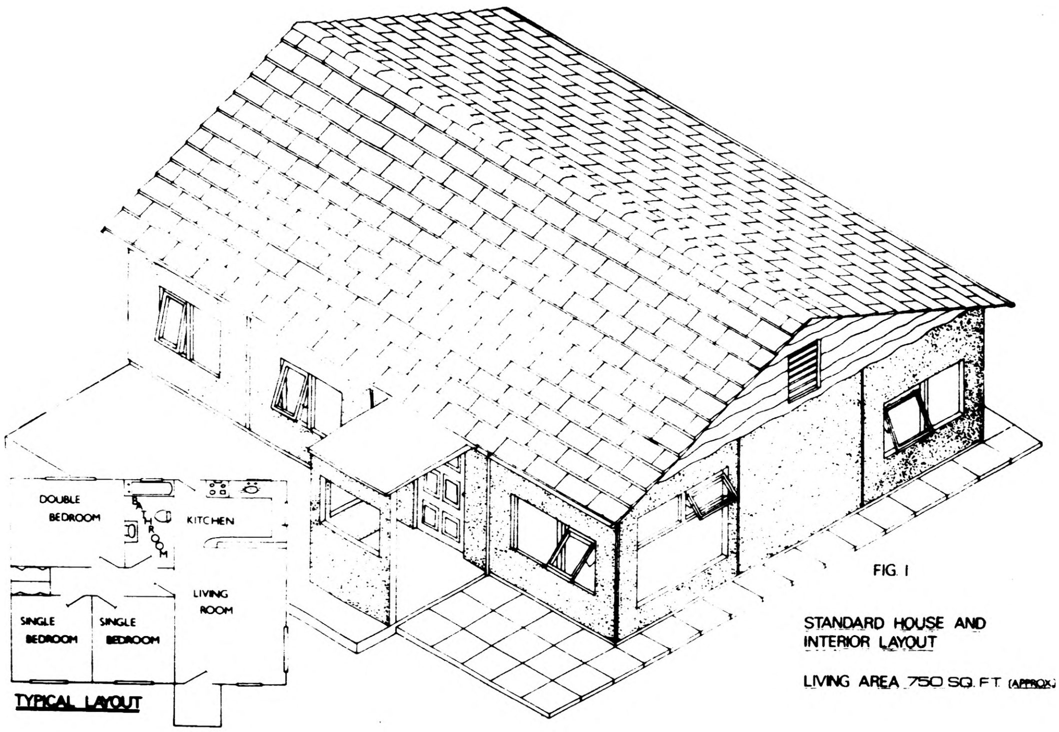


Fig. 1. Standard Modular House and Interior Layout.

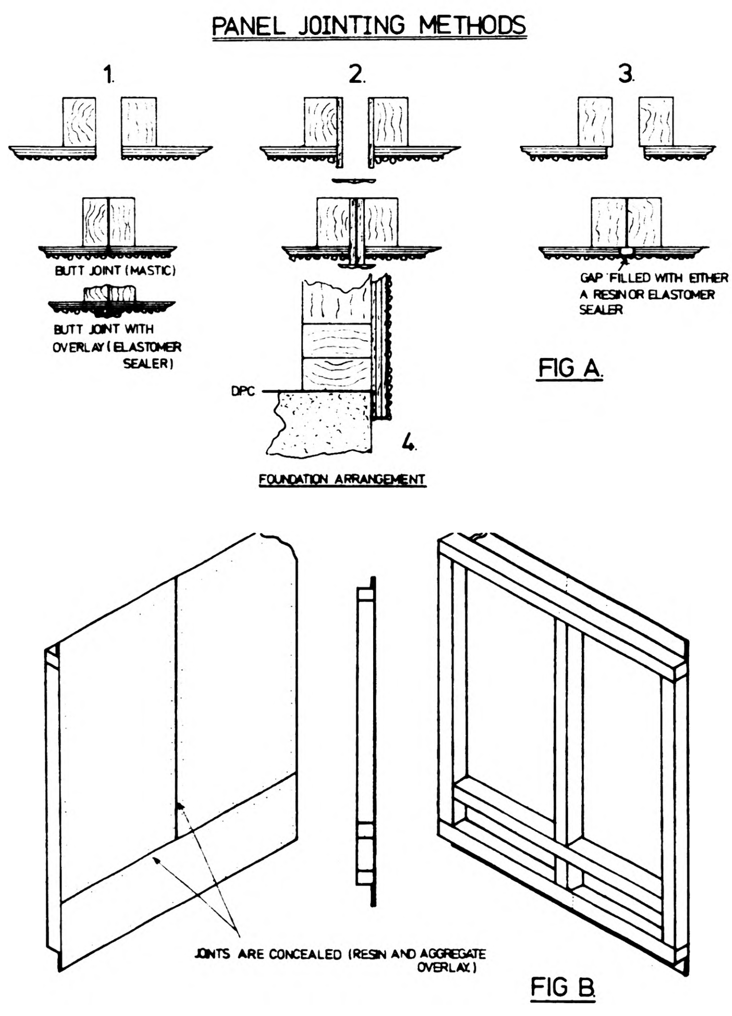


**Fig. 2 (A & B) Panel Jointing Methods.**