



THE JAMES COOK UNIVERSITY OF NORTH QUEENSLAND
CYCLONE STRUCTURAL TESTING STATION

CYCLONE TESTING STATION

CONNECTIONS and FASTENINGS for DOMESTIC CONSTRUCTION

TECHNICAL REPORT NO.7.

September 1978

DEPARTMENT OF CIVIL & SYSTEMS ENGINEERING
POST OFFICE JAMES COOK UNIVERSITY
TOWNSVILLE QLD 4811

CYCLONE TESTING STATION

CONNECTIONS AND FASTENINGS

G.F. Reardon

TECHNICAL REPORT NO. 7

Department of Civil and Systems Engineering
James Cook University of North Queensland
Townsville, Australia

ISBN

No. 0 85874 060 5

This Report is a reprint of a paper presented by the author as part of the Cyclone Building Construction Seminar organized during November 1980 in Townsville by the Cyclone Building Research Committee. Other papers presented at the seminar are listed below

Introduction to Wind Loads
Roof and Wall Cladding
Bracing
Wall and Roof Framing
Windows and Doors
Brickwork and Blockwork Theory
Practical Brickwork and Masonry
Building Regulations

A bound set of all the papers may be purchased from the Secretary,
Cyclone Building Research Committee, P.O. Box 707, Townsville, 4810.

CONNECTIONS AND FASTENINGS

G.F. Reardon

1 INTRODUCTION

A building is only as strong as the fasteners that hold it together!

This fact has been reasonably well recognized throughout the traditional cyclone belt of Australia. It has been common practice for many years to use cyclone bolts to reinforce external walls against uplift forces. In the light of current knowledge however, the old fashioned practice of using half inch diameter rods spaced at ten foot centres (Queensland Housing Commission, undated) would have been inadequate to resist the full wind forces developed during cyclone Tracy or even during cyclone Althea. In fact one of the conclusions reached after the investigation into damage caused by cyclone Althea (James Cook University of North Queensland, 1972) was "Cyclone bolting practice currently in use is inadequate to protect roof structures if windows fail". The same report concludes that the principal mode of failure was through loss of roof sheeting and/or roof structure. Similar field investigations after other wind storms have made the same conclusions. (Reardon, 1975a; Leciester and Reardon, 1976). So, although the problem has been recognised for some time it has not been completely solved.

Current methods of building in Australia do not lend themselves to a single solution of how to keep a house roof secure during a cyclone. The practice of fastening one piece of timber to the one below it is equivalent to a series of links between roof and ground. Obviously if any of these links is weak the whole roof structure can be sucked off. A better proposition therefore is to eliminate as many joints as possible. This is already done to some extent in the cyclone belt by the use of anchor rods which extend from the wall top plate to the bearers or floor joists, and thus eliminate uplift forces on the potentially weak stud-to-plate joint. An extension of the concept is to use overbattens on top of the roof sheeting in conjunction with anchor rods, thus eliminating more joints. This practice is often

used in the Western Australian cyclone belt. Possibly the best solution is the use of a structural anchor frame which is designed to resist wind forces without the assistance of architectural features such as claddings. Details of such a concept are outlined by Leceister and Reardon (1975).

2 TYPES OF FASTENERS

In areas not subject to tropical cyclones the traditional fastener used for domestic construction is the 75 mm nail. It is used in the construction of most joints, and is often skew driven through the corner of one member into supporting member. Framing anchors are sometimes used, and bolts are rarely used except to attach ceiling joists to rafters. The philosophy behind the extensive use of nails is that they are needed only to locate the different members in position, and prevent sideways movement. There is very little thought given to resistance against uplift forces.

In cyclone-prone areas a considerably wider range of fasteners is used. As well as the traditional nail screws are commonplace, as are bolts of various lengths, anchor rods, framing anchors, metal straps and masonry anchors. It has been accepted that in many instances, nails cannot provide joints of sufficient strength to resist the uplift forces developed by cyclonic winds.

All the abovementioned fasteners are installed on site. There is another group of fasteners that are used in the factory fabrication of engineered components for domestic use, namely toothed plate connectors. These toothed plates are predominantly used in the manufacture of roof trusses, and as such do not directly contribute any strength to the line of joints holding the building down. Some truss manufacturers are expanding their interests and producing prefabricated wall frames using toothed plates to join studs to wall plates. Provided the tooth plates are of adequate size they will produce a structural joint between stud and wall plate, which may be used as an alternative to anchor rods in resisting uplift forces. Of course such a system provides security only between top and bottom wall plates. The bottom plate still has to be anchored to the slab or sub-frame structure.

Glue is occasionally used as a structural jointing medium, such as for glued laminated beams, finger jointed framing or to attach plywood gussets to truss members. The disadvantage about glued joints is that their strength cannot readily be assessed by visual inspection. Therefore they should only be made using the most favourable conditions, such as are found in a factory. It is difficult to ensure that field fabricated glued joints will give a satisfactory performance.

3 TESTING OF FASTENERS

3.1 Research

A considerable amount of research has been carried out into the strength of nailed joints in Australian timbers. Most of this work has been directed towards the effect of lateral loads on nails, as in the case with a splice joint. Mack (1960a) showed that the lateral strength of a nailed joint is dependent upon nail diameter, grain direction and the number of nails per joint. For joints with a large number of nails, the load carrying capacity is not directly proportional to the total number of nails, but reduces by approximately 20 percent for every 10 nails in the joint. Mack (1960b) also showed that the ultimate strength of laterally loaded nail joints is not affected by a previous history of cyclic loading for the loading regime tested.

Less research has been done on the withdrawal strength of nails. Mack (1961) showed that the strength of a nail in withdrawal is approximately proportional to the diameter and depth of penetration. However the series of tests were very limited as they involved only one type of nail and one species of dry timber, radiata pine. Swane (1965) investigated the effect of heat on the withdrawal resistance of nails from three different species of timber, radiata pine, blackbutt and messmate. His control specimens (unheated) verified Mack's withdrawal results.

The test results discussed above were for nails withdrawn immediately after they were driven into the timber. This is not a realistic test, because in practice such forces are usually exerted some considerable time after the house has been built, and the timber has dried out. Mack (1969c) tested a series of nailed joints in which nails were withdrawn

at different time intervals after driving. The results showed a considerable loss of strength for smooth shank nails, but an increase in holding power for grooved nails. Also, grooved nails had a significantly higher immediate withdrawal strength than did smooth shank nails. Figure 1 shows the results expressed as a percentage of the immediate withdrawal resistance of the nails in green timber. It should be noted that these are the results of a limited set of tests and therefore although the trends are probably typical, too much emphasis should not be placed on the absolute values given in the graph. The results have been verified to some extent in a bachelor of engineering thesis by Che Lah (1976) but his results display a large coefficient of variation, that is they are widely scattered.

There is little research data published about the performance of screws subject to withdrawal loads. Mack (1978) shows that wood screws perform similarly to grooved nails with respect to withdrawal strength three months after being driven into green timber. On average there is no change in withdrawal strength after three months for screws driven into initially dry timber.

Reardon (1979) conducted an investigation into the strength of various fastening devices used to attach roofing battens to rafters. The tests included plain and grooved shank nails, self drilling screws, metal straps and bolts. Plain shank nails were used at the control specimens and the other fasteners were tested because there was no information readily available on their holding power. The test program included withdrawal of fasteners from both green timber and timber that had been jointed green and allowed to dry out. These tests demonstrated that not all timber species follow the trend shown by Mack in Figure 1. Figure 2 (a) shows that grey satinash preformed as would have generally been predicted by Mack, but the results given in Figure 2 (b) show that the holding power of grooved nails in Johnson River Hardwood deteriorated as the timber dried out. It is therefore apparent the holding power of nails is dependent not only upon density of timber but also upon other parameters such as fissility.

As a result of these tests a further investigation into the holding power of Johnson River Hardwood has been made by CSIRO, and it is probable that the timber will be allocated a lower joint strength grouping.

3.2 Cyclic Loading

After cyclone Tracy devastated Darwin it was evident that not enough research effort had been directed towards the effect of cyclic loading on building products and their fasteners. Probably the most significant findings after Tracy were those of Beck and Morgan (1975) into the fatigue failure of metal roofing. Although these failures did not actually involve fracture or withdrawal of the fastening device, failure occurred because the thin metal sheeting around the relatively small head of the screw could not sustain the continual buffetting of cyclonic winds. It is worth noting that one roof sheeting and its fasteners had been successfully tested in accordance with the specifications to resist wind forces laid down in AS1562-1973 "Design and Installation of Self-Supporting Metal Roofing Without Transverse Laps". This standard specifies only a static load test, there are no requirements for cyclic loading.

For the reconstruction of Darwin a saddle shaped washer was developed for use with steel roof sheeting. Tests proved this washer capable of withstanding the ten thousand cycles of design load specified in the Darwin Reconstruction Manual without any signs of failure to either the fastener, the washer or the metal sheeting. It is of interest to note that subsequent testing has shown that the cyclone washer need not be used provided the roofing is screwed according to new specification of batten spacing and screw spacing along the batten (Young, 1977). These limitations effectively reduce the load per fastener.

It has been shown by Mack (1960b) and by Malhotra and Ritchie (1980) that the ultimate strength of nailed joints loaded laterally is unaffected by a previous loading history of up to 10 000 cycles. Armstrong and Schuster (1979) reached a similar conclusion after a series of cyclic load tests investigating the lateral strength of nails in various building cladding materials. In all cases a significant increase in joint deflection occurred during this cycling but this apparently did not affect the ultimate load.

There appears to have been no research conducted on the withdrawal resistance of fasteners subject to cyclic loading conditions.

An investigation by CSIRO into the performance of framing anchors yielded a loss in strength with increasing number of cycles. Figure 3 shows these results.

4 PRESENTATION OF TEST RESULTS

There is a tendency for manufacturers of common fasteners, for example nails or wood screws, not to bother providing data on the strength of their product. Whilst this attitude may have been satisfactory when only steel plain shank nails were made, and there was very little difference in strength between the produce of different manufacturers, it is no longer acceptable. There is very little published data available on the strength of annularly or helically grooved nails, nor on the effect of chemical coatings on the holding power of nails. Loose claims of "up to five times the holding power of equivalent plain shank nails" are not good enough. Actual strength figures should be quoted and stamped on the packages.

The manufacturers of specialist fasteners such as power driven screws, masonry anchors and the like are more helpful in this matter. They usually have available technical literature outlining strength aspects of their fasteners. However sometimes this information can inadvertently be misleading. The usual form in which such information is provided is as the average failing load. There is some danger, although hopefully very small, that the quoted figures could be taken as safe working load. This could lead to catastrophe. It would be better for the manufacturer to publish a suggested safe working load for his fasteners rather than an average failing load.

Other aspects that must be taken into account are the number of tests conducted in order to obtain the quoted average, and the range of values obtained. For example if three tests conducted on a type of fastener yield failing loads of 1500, 2000 and 2500 Newtons, the average failing load is 2000 N. But it would also be fair to claim from that very small number of results that one third of the fasteners tested failed at only 75% of the average value. This reasoning shows the average value to be a rather dubious quantity on which to base design recommendations. It would be far more appropriate to conduct many more tests and base the design recommendations on some statistically chosen lower limit, such as the value below which only one sample in twenty would be likely to fail. Whatever way the

test results are interpreted, it is recommended that safe working loads be printed in the technical literature together, if necessary, with the value of the load factor that has been applied. It is also strongly recommended that for the benefit of the user, the safe working load of all fasteners be stamped on their packages. This will at least provide the users with an estimate of comparative strengths of fasteners of different sizes.

5 DESIGN LOADS FOR JOINTS

5.1 Nailed Joints

In the lower density timbers such as pine nailed joints are intrinsically stronger when subject to lateral loading rather than to withdrawal loads, however for the denser timbers used in North Queensland this difference is not so evident. When calculating the design load for a nailed joint there are a number of modification factors that may be applied to nails in lateral loading that are not applicable to similar nails resisting withdrawal forces. Table 1 shows this comparison using a nail 3.75 mm diameter, 75 mm long to joint two pieces of seasoned spotted gum. The loads are given in newtons.

TABLE 1
DESIGN LOADS FOR 75 mm NAILS IN SEASONED SPOTTED GUM

	Nail in lateral bearing	Nail in Withdrawal
Basic load (N)	530	520
Modification factors (based on AS1720-1975)		
(i) wind	2.0	-
(ii) moisture content	1.35	-
Design Load (N)	1430	520

This comparison may appear trivial because most joints are made to suit the intersecting members. However if one of the members in the lateral bearing joint was made of light gauge steel it would still have all the advantages over the nail in withdrawal. This is the theory behind the use of metal framing anchors (Trip-L-Grips and the like). There are considerable advantages gained by using framing anchors at the cross-over joints of battens and rafters, rather than using plain shank nails.

Apart from the few tests by Mack that have been mentioned previously there is practically no information available on the holding power of grooved nails. As it is quite likely that the grooved nails currently being manufactured are different from those tested in 1960, Mack's results are not suitable to act as a basis from which design loads could be derived. This leads to the situation where the designer must either assume no advantage is gained by using grooved nails, or he must conduct a few ad-hoc tests to provide a solution of his particular problem. Neither solution is really satisfactory. Surely it is up to the nail manufacturers to produce the required engineering data for grooved nails.

5.2 Screwed Joints

Over the last few years there has been a considerable increase in the use of screws in house construction. This is undoubtedly due to the development of self-drilling and self tapping fasteners. Such screws are usually used for attaching roof sheeting to battens or for attaching battens to rafters. In either case the screws are subject to withdrawal forces during a cyclone. Basic withdrawal loads for wood screws are published in AS1720-1975. The basic withdrawal loads for wood screws may be modified by the factors given in Table 1 for nails in lateral bearing. That is, they perform better under impact loading than do nails.

There has been a considerable amount of research work by industry in developing these screws, and summaries of pull out strengths for different type screws in different materials are readily available from the manufacturers. It should be noted that the strengths given are for failure of the fastener, and therefore an appropriate safety factor should be applied to the results before they are used for design. In order to assist in the determination of the safe working load, the range

of the test results is given. The results published for screws in timber generally agree with the recommendation for steel wood screws published in AS1720-1975.

5.3 Framing Anchors

The recommended design loads for framing anchors, Figure 4(a) are published by the manufacturers in their technical literature which is readily available.

Most framing anchors are made by manufacturers of toothed plates, and therefore have been developed to fulfil an engineering need. One point of interest is that the two main manufacturers have only one recommended design load for all species of timber. The implication of this is that their recommendation would be quite conservative for some of the dense hardwoods used in North Queensland.

5.4 Bolted Joints

The traditional use of bolts is in bearing and shear. However in house construction in cyclone-prone areas bolts are used as tension members, either as anchor rods or as long bolts securing roof framing. While acting as a tension member the design load is the maximum allowable load that can be carried at the net section of the bolt, that is at the root of the thread. If this full load capacity is needed, a large washer must be used in order to provide sufficient bearing area to transfer the load to the timber members. A simple rule of thumb is to use a square washer having a length equal to three times the bolt diameter. The washer thickness should be approximately one quarter of the bolt diameter. If a round washer is used its diameter should be approximately $3\frac{1}{2}$ times the bolt's diameter.

5.5 Bent Metal Strap

A simple method of providing a reasonably strong joint is to use flat metal straps shaped to straddle one timber member and be fastened to the lower one, Figure 4(b). The strap is approximately 30 mm wide and 1 mm

thick, and is made of galvanized steel. The nails used are usually 2.5 or 2.8 mm diameter although one commercial manufacturer of the straps is specifying 3.15 mm nails. The strap can be either purchased in standard perforated lengths or as a perforated roll and cut to length, or merely as a strip of galvanized iron. In the latter form the builder would have to drill holes in it prior to nailing. Metal straps in this form have the advantage of being versatile, as they can be shaped to suit a particular joint. The design load for such a strap depends upon the number and diameter of nails used and to a lesser extent the size of the strap. Reardon (1975) recommends a value of 1150 newtons for a 30 mm x 0.8 mm strap secured at each end by a 2.5 mm nail. It would be reasonable to increase the number of nails at each end up to a maximum of four and expect the strap to carry four times the load. It is unlikely that the load carrying capacity per fastener would be significantly increased by using the thicker strap.

5.6 Toothed Metal Plates

There are at least four different brands of toothed metal plates being used in the manufacture of trusses for cyclone prone areas of Australia. The design load for these plates has been determined by product testing and is readily available from the plate manufacturer. At least one company is using these plates to prefabricate wall frames.

5.7 Masonry Anchors

Masonry anchors are used in low rise construction to attach wall members to concrete floor slabs. In factory construction the base plate of steel columns can be secured by the anchors, whereas in domestic construction the timber or light gauge steel bottom plate can be secured by them. The anchors have the advantage that they are installed after the slab has been poured, and therefore negate the problem associated with keeping bolts properly aligned during the pour.

There are two basic types of masonry anchors, one which uses a mechanical device to grip the inside of a hole drilled in the concrete, and the other which used a chemical bond. Details of failing loads are readily available from the manufacturers. However a number of points should be emphasized about this information.

- (a) A strict interpretation of the failing loads is that they apply only to the strength of concrete tested.
- (b) The published failure loads apply only when the anchor is correctly installed, which not only includes the correct penetration but also the minimum spacing and edge distance.
- (c) As it is usual for manufacturers to provide failing loads in their literature, these must be reduced to working loads. At least one manufacturer recommends that a factor of safety of four be applied to the mean failure load.

Therefore if the anchors are installed into concrete of lower strength than that tested, or if smaller spacing or edge distances are used the published pull-out values may not apply.

In domestic construction masonry anchors are often used to attach bottom wall plates to concrete slab floors. For external walls this would usually involve locating the anchors nearer to the slab edge than is recommended by the manufacturer. The situation would apply not only to board clad walls where the plate is obviously near the slab edge, but it may also apply to brick veneer construction where the edge of the slab is stepped down to allow for the brickwork.

If a builder finds that he is constantly needing to use anchors at spacings or edge distances that are at variance with the manufacturer's recommendations, he should approach the manufacturer for further advice. It is quite probable that anchors could be safely used at spacings or edge distances smaller than recommended if lower design load values are used. Similarly if lower strength concrete is used the user should approach the masonry anchor manufacturer for lower design load values.

6 FASTENING TO BRICKWORK OR BLOCKWORK

There is very little double brick construction in the cyclone region. When this form of construction is used, the roof members must be secured to the foundations via a bond beam or top plate. It is not sufficient to anchor the roof to the cavity wall.

In concrete block construction it is normal to anchor the roof structure to a bond beam consisting of one or two courses of reinforced blockwork. The roof structure is usually attached to the bond beam using metal plates or angles that are connected to the reinforcing. The bond beam is secured to the foundations by reinforcing bars that pass through cavities in the blocks. It is common practice to use S12 bars spaced at 1200 or 1800 centres. The cavities through which the bars pass must be filled with concrete.

One other critical type of fastening used in this construction is the lap joint between the starter bars protruding from the concrete slab and the wall reinforcing bars. If this lap joint is not long enough the wall will fail. The lap length should be at least thirty times the diameter of the larger bar.

7 FASTENERS REQUIRED FOR A TYPICAL HOUSE IN A SUBURBAN ENVIRONMENT

Figure 5 shows the house that was used for this exercise, it is of rectangular plan with a low pitch gable ended roof. Pertinent details are given in Table 2. The house is to be located in a suburban environment (terrain category 3) in the cyclone region. Only the basic chain of fasteners has been calculated, no account has been taken of concentrated loads that may occur beside openings. Bracing details have not been specified, as this is the topic of another paper. Also no mention has been made of timber sizes as it is assumed that traditional sizes are adequate.

TABLE 2
Specifications of a House

Length	14 000
Width	7 000
Eaves	600
Truss spacing	900
Batten spacing	900
Roof pitch	10°
Roofing	c.g.i.

Table 3 lists the fasteners required to secure the house against uplift forces. All of the details are in accordance with the specification of the December 1979 draft edition of Appendix 4 to the Queensland Building Act 1975-1978. In order to help the reader find the details in the Appendix 4, Sub Clause numbers have been included in the table. Details of the fasteners are illustrated in Figure 6.

It should be stressed that the fastener details listed in Table 3, and illustrated in Figure 6 are not the only solution to the problem. Other types of fasteners may also be quite suitable. Indeed Appendix 4 lists a number of alternative methods of most structural details.

Table 3
Fasteners Required for House in Suburban Environment

Location	Fastener	Sub-clause in Appendix 4
Bearer to pier	1-M12 bolt	40.2 (6) (a)
Joist to bearer	1-M10 bolt through 38x38x5 steel angle	41.7 (2) (a)
Anchor rod (top plate to bearer or bridging piece below joists)	M12 rods at 1800 maximum spacing	41.8 (2) (c)
Truss to plate	1-M10 bolt through batten adjacent to truss	41.9 (2) (c)
Batten to truss	14x75 mm screw	41.9 (2) (c)
c.g.i. to batten	14x75 mm screw every second corrugation* (every corrugation at corners)	41.9 (2) (a)

*Manufacturer's recommendation

8 FASTENERS REQUIRED FOR A TYPICAL HOUSE IN AN EXPOSED ENVIRONMENT

Most construction manuals, TRADAC (1979), Reardon and Aynsley (1979), Smith and Adams (1980), Appendix 4, which provide details for domestic construction in cyclone regions relate only to construction in a sheltered environment, that is category 3 terrain. There are good reasons for this. As most houses are built in a suburban location where they gain some form of shielding from the other houses, trees and shrubs and fences, the manuals are catering for the majority. It is generally accepted that the most pressing need is to provide information for this majority. Another possible reason is that the forces involved in designing buildings for exposed terrain are considerably greater than for a sheltered location. Therefore there is a need for more innovation in solving the problem and probably a departure from some of the conventional techniques of building.

Figure 7 illustrates the fasteners and some member sizes that are required when the house shown in Figure 5 is designed to resist winds of 60 metres per second. This wind speed is just slightly above the design wind gust speed for category 2 terrain in the cyclone region. The design wind speed for category 1 terrain, very close to the seaside, is 65 metres per second.

Again it should be stressed that the details given in Figure 7 are not the only solution, but they do indicate the strength of fasteners that are required.

Conventional techniques have been followed regarding the use of roof trusses, they have been supported and anchored at their ends only. This has led to large concentrated uplift forces being applied which in turn necessitate the closing of traditional spacing of structural elements such as anchor rods and piers.

All timber must be F17 stress grade, and all bolts acting in tension must be provided with large washers to ensure adequate bearing.

The entire engineering input into domestic construction can easily be nullified by poor or incompetent workmanship. When related to fasteners this usually involves a lack of appreciation of the importance of their role. Examples of this are

- (a) the use of a lighter gauge nail or screw because it is easier to drive,
- (b) the use of a smaller size bolt because the correct size was not in stock,
- (c) an incorrect number of nails in a framing anchor,
- (d) one or more weak links in the hold-down chain between roofing and foundations,
- (e) omission of washers from bolts acting in tension,
- (f) securing roofing to unreinforced brickwork or blockwork,
- (g) the use of plain shank nails where grooved nails were specified.

It is the author's experience in having inspected storm damage on numerous occasions that most damage can be related to inadequate fastening details.

10. CONCLUSIONS

Although field investigations have shown that most damage caused to domestic buildings can be traced on the fasteners, the present system of stitching one member to another can be made to work. With the apparent exception of grooved nails there is sufficient information available for architects or engineers to correctly specify the fasteners needed for each joint in a house. The two examples included demonstrate that conventional methods of construction can still be used to provide the necessary strength to resist cyclone wind forces.

11 REFERENCES

- ARMSTRONG, L.D., and SCHUSTER, K.B., (1979) The behaviour of nailed wall cladding under repetitive loading. 19th Forest Products Research Conference. CSIRO Division of Building Research
- BECK, V.R., and MORGAN, H.W., (1975) Appraisal of metal roofing under repeated wind loading - Cyclone Tracy, Darwin 1974. Housing Research Branch, Department of Housing and Construction, Technical Report No. 1.
- CHE LAH, R., (1976) A comparison of withdrawal resistances of various types of nails in several North Queensland green and seasoned timbers, Bachelor of Engineering Thesis, James Cook University of North Queensland.
- EXPERIMENTAL BUILDING STATION (1978) Guidelines for the testing and evaluation of products for cyclone-prone areas. Technical Record 440
- JAMES COOK UNIVERSITY OF NORTH QUEENSLAND (1972) Cyclone "Althea" Part 1 - Buildings.
- LEICESTER, R.H., and REARDON, G.F., (1975) Some aspects of cyclone resistant design for houses. Seminar on Prevention of Wind Damage in Domestic and Similar Structures. CSIRO Div. of Building Research.
- LEICESTER, R.H. and REARDON, G.F., (1976) Wind Damage in Australia, CSIRO Div. of Building Research.
- MACK, J.J., (1960a) Strength of nailed timber joints. 1 Divison of Forest Products Technological Paper No. 9, CSIRO
- MACK, J.J., (1960b) Repetitive loading of nailed timber joints. Divison of Forest Products Technological Paper No. 10, CSIRO.
- MACK, J.J., (1960c) Grooved nails. The Australian Timber Journal, Vol. 26, No. 8.
- MACK, J.J. (1961) Nail size and withdrawal resistance. Division of Forest Products Technological Paper No. 11, CSIRO.

MACK, J.J., (1978) Withdrawal resistance of plain steel nails and screws in Australian timbers. Division of Building Research Technical Paper (Second Series). No. 30.

MALHOTRA, S.K., and RITCHIE, R.A.G., (1980) Behaviour and reliability analysis of nailed timber connections under cyclic loads. International Conference on Engineering for Protection from Natural Disasters, Asian Institute of Technology, Bangkok.

MORGAN, J.W., and BECK, V.R. (1975) Sheet metal roof failures by repeated loading. Housing Research Branch, Department of Housing and Construction. Technical Report, No. 2.

REARDON, G.F., (1975a) The Brisbane wind storm, November 1973. Division of Building Research Report 33. CSIRO.

REARDON, G.F. (1975b) Special fasteners and their use. Seminar on Prevention of Wind Damage in Domestic and Similar Structures, CSIRO Div. of Building Research.

REARDON, G.F. (1979) The strength of batten-to-rafter joints, Part 1, Test results and derivation of design loads. Cyclone Testing Station. Technical Report No. 2.

REARDON, G.F. and AYNSLEY, R.M., (1979) Houses to resist cyclone winds - construction details. Cyclone Testing Station. Information Bulletin No. 1

SMITH, P.R., and ADAMS, R.H.T., (1980) Domestic Construction Manual. Queensland Master Builders Association and Queensland Institute of Technology.

STANDARDS ASSOCIATION OF AUSTRALIA (1973) Design and installation of self-supporting metal roofing without transverse laps, AS1562-1973.

STANDARDS ASSOCIATION OF AUSTRALIA (1974) Determination of basic working loads for metal fasteners for timber, AS1649-1974

STANDARDS ASSOCIATION OF AUSTRALIA (1975) SAA Timber engineering code, AS1720-1975.

SWANE, R.A., (1965) A study of the effects of heat on the static withdrawal of timber fasteners in some Australian timbers. Master of Building thesis, University of New South Wales.

THE QUEENSLAND HOUSING COMMISSION (undated) Specifications

TRADAC (1979) Queensland timber framing manual - W42. Timber Research and Development Advisory Council.

YOUNG, R.W. (1977) Circular letter, John Lysaught (Australia) Limited

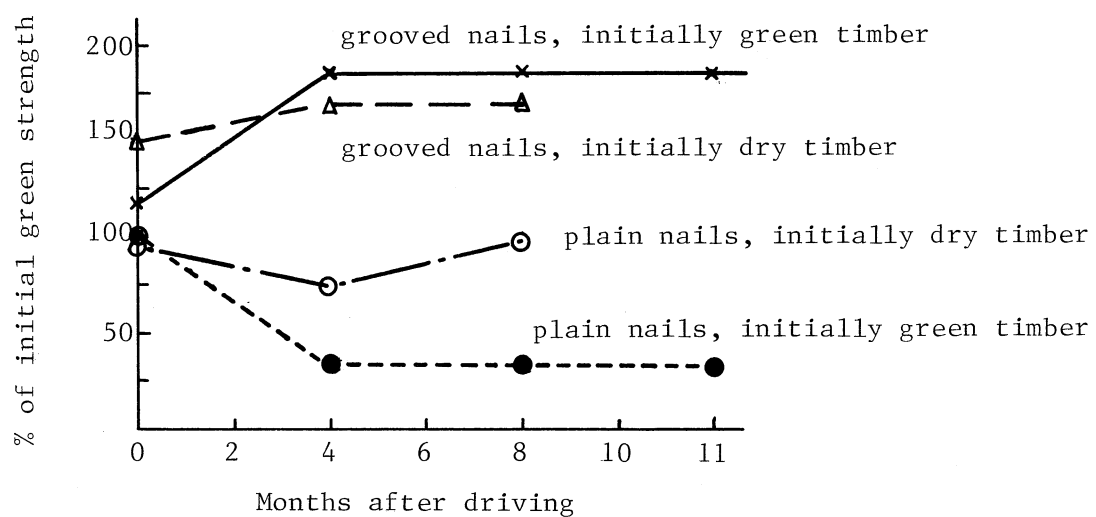


FIGURE 1 Holding Power of Nails

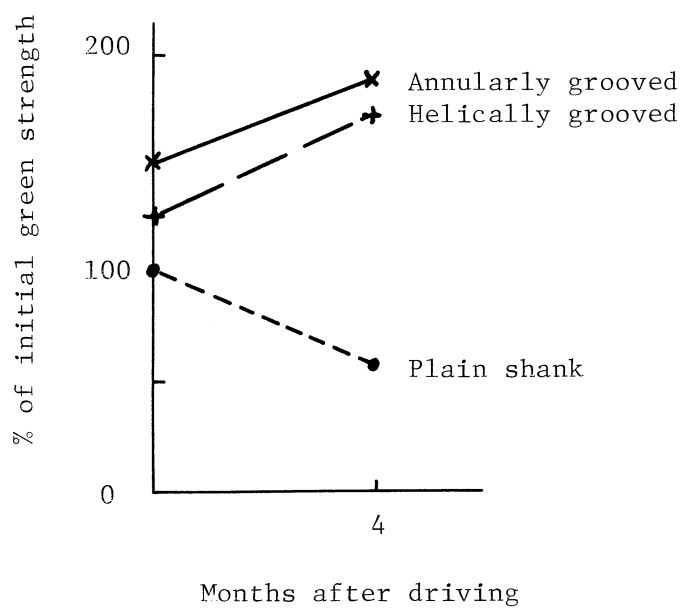


FIGURE 2 (a) Holding power of nails
in Grey Satinash

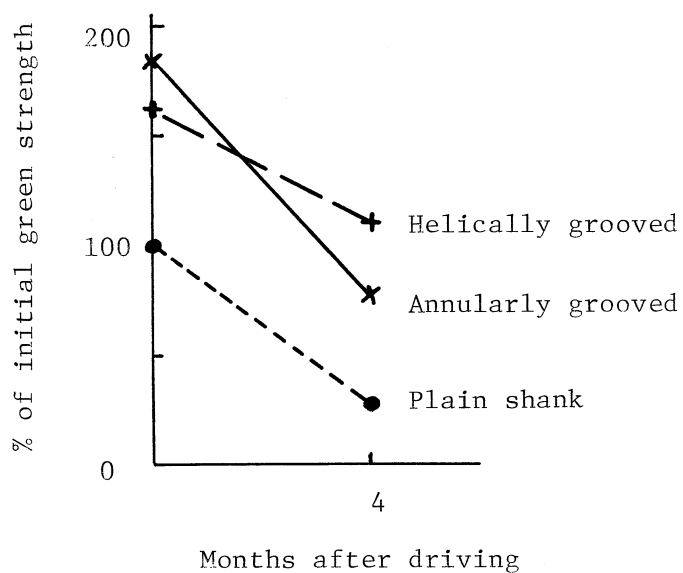


FIGURE 2 (b) Holding power of nails
in Johnstone River hardwood

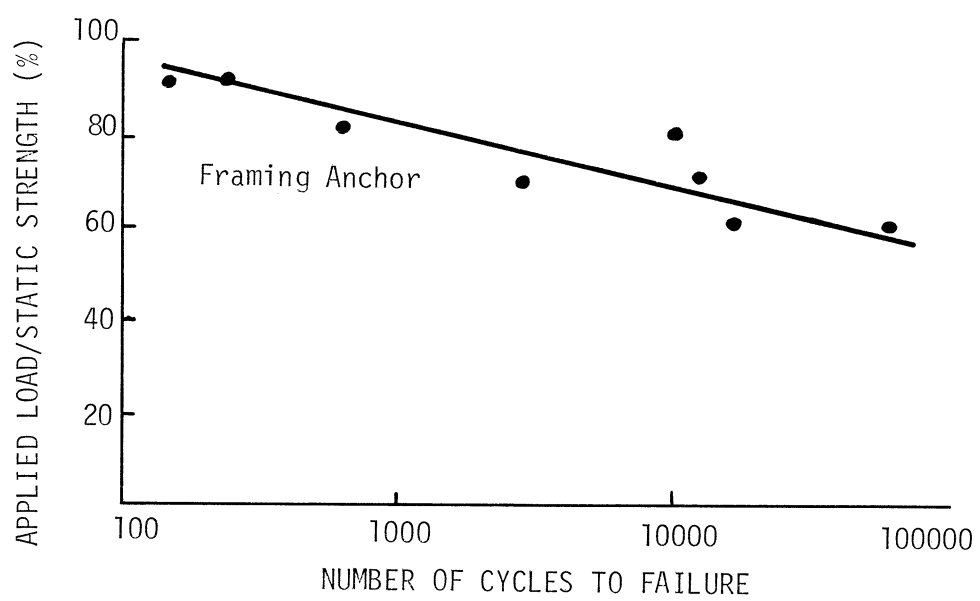


FIGURE 3 Effect of cyclic loading on framing anchors

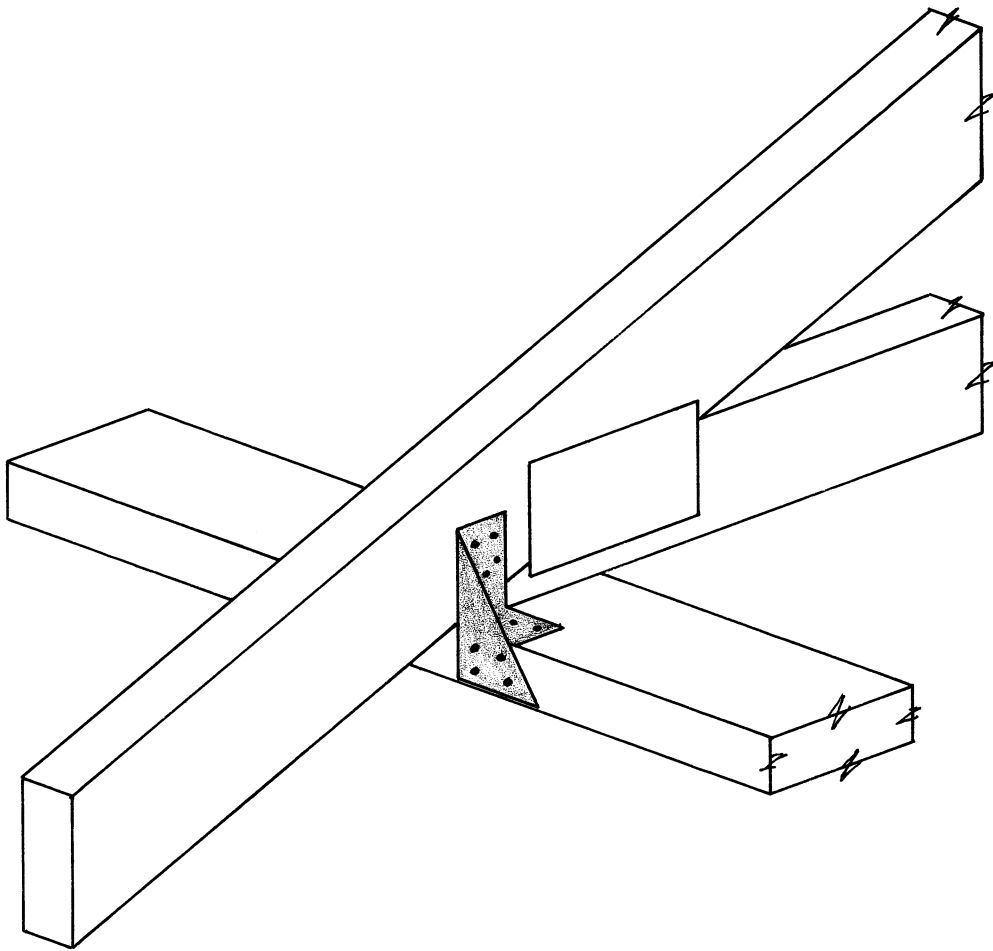


FIGURE 4 (a) Framing Anchor

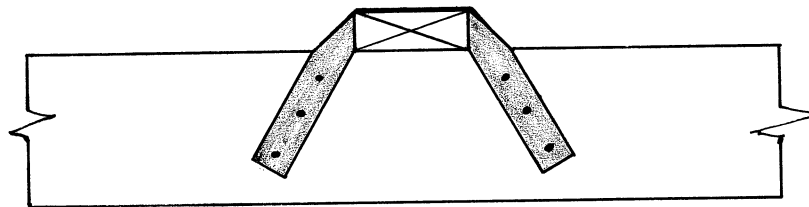


FIGURE 4 (b) Metal Strap

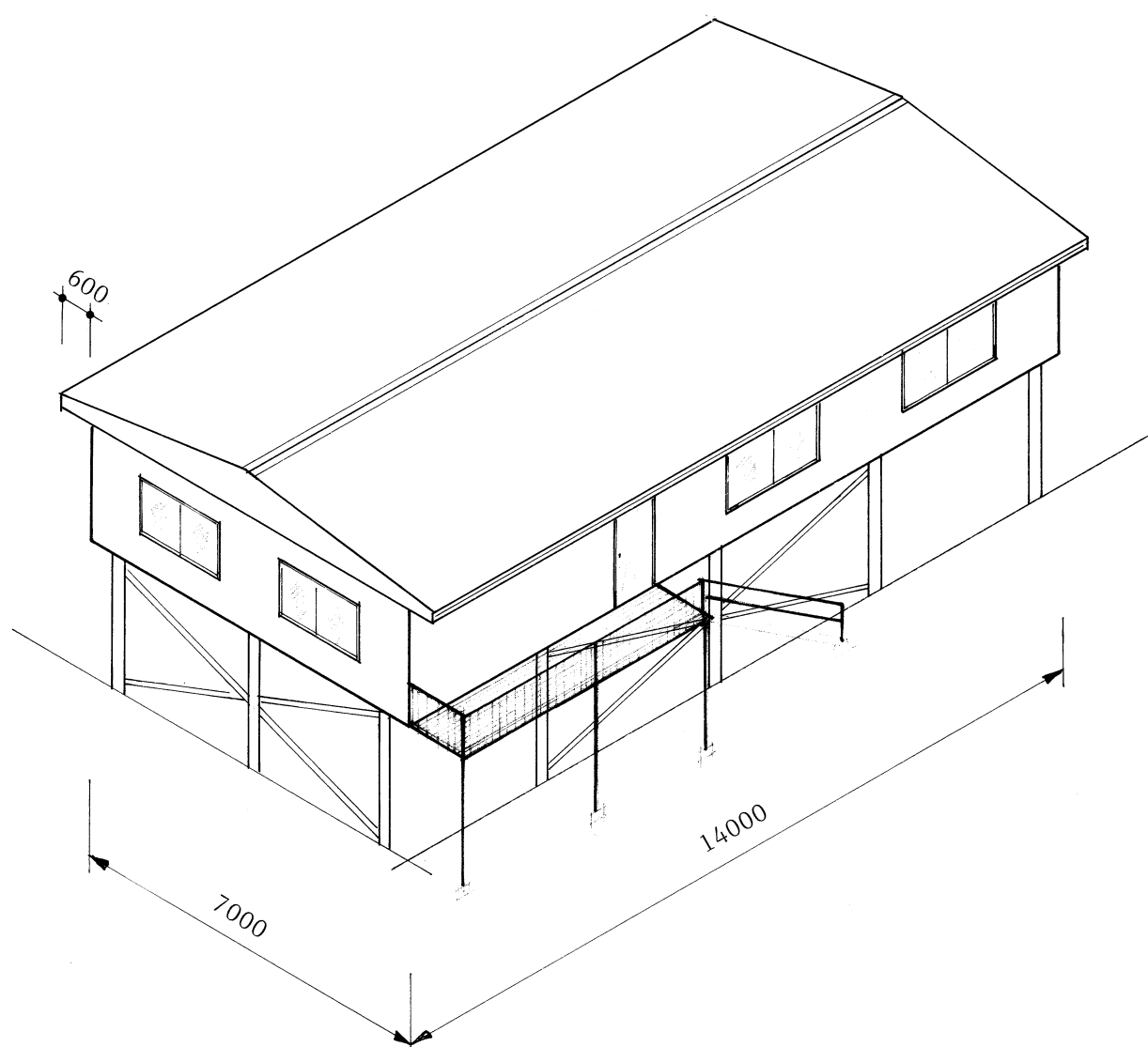
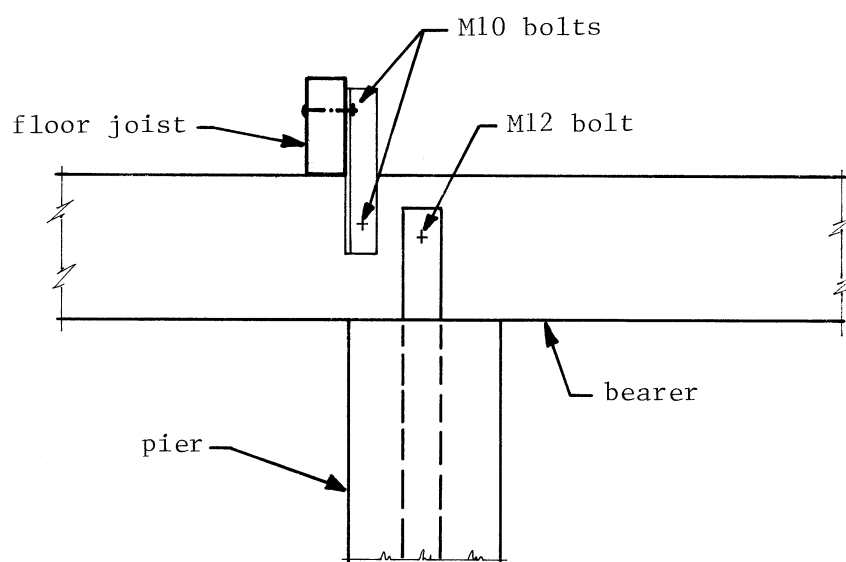


Figure 5 Typical House



(a) subfloor

FIGURE 6 Construction Details

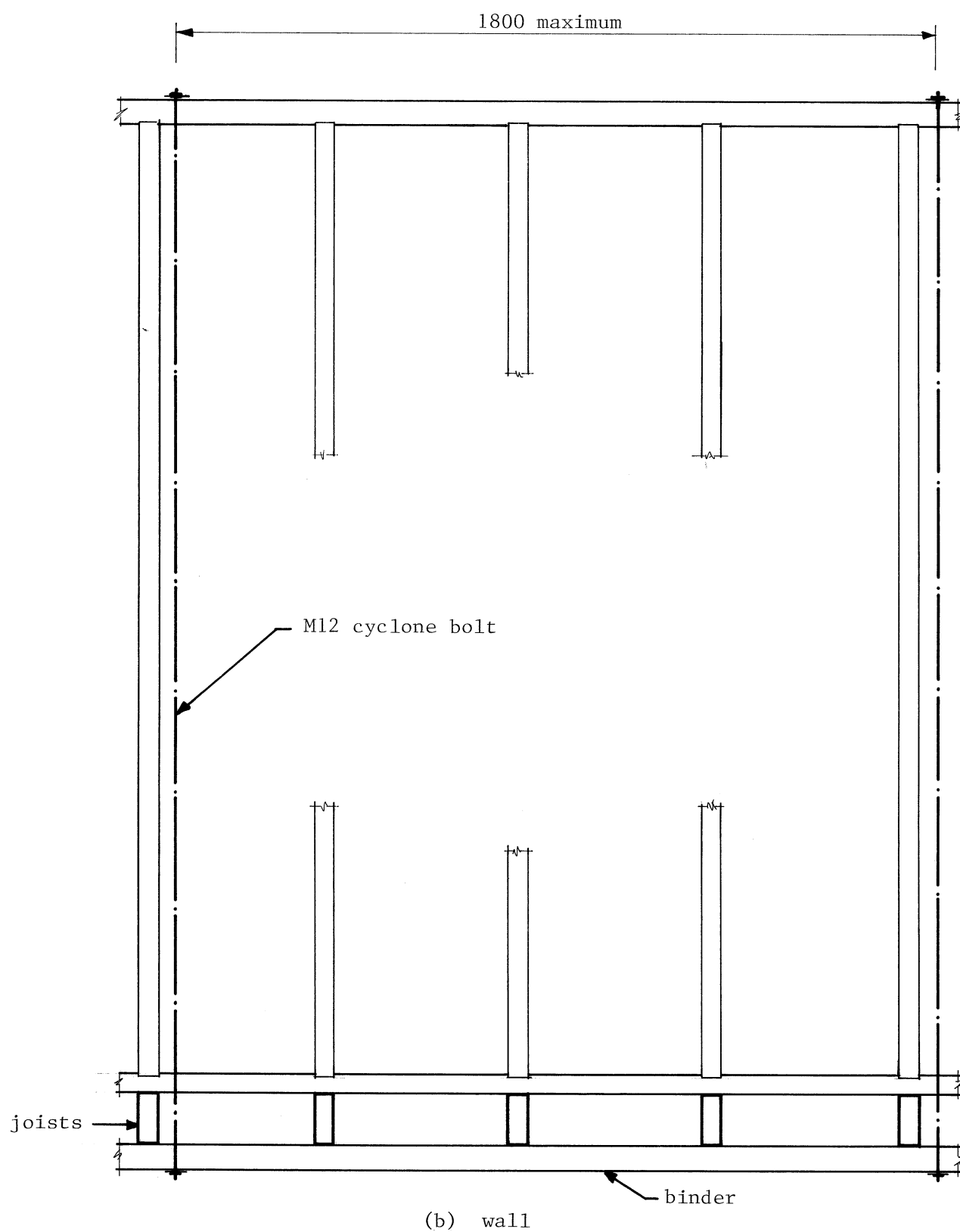
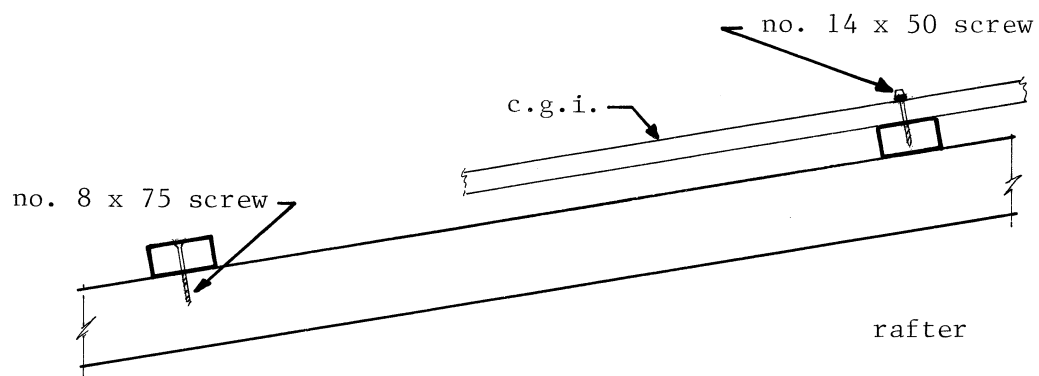
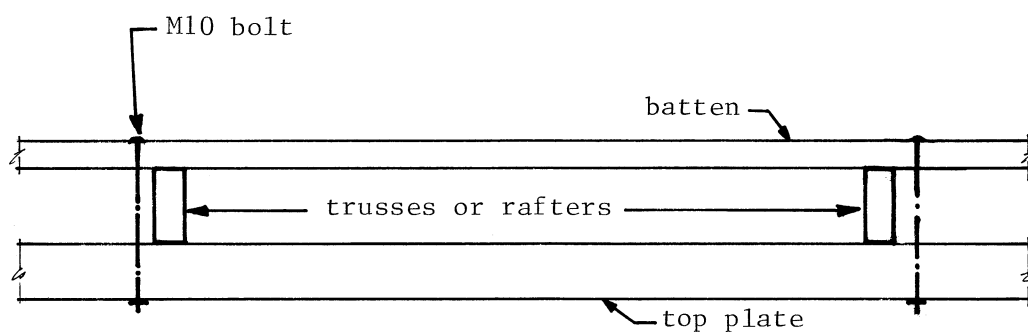


FIGURE 6 Construction Details



(d) roofing



(c) roof structure

FIGURE 6 Construction Details

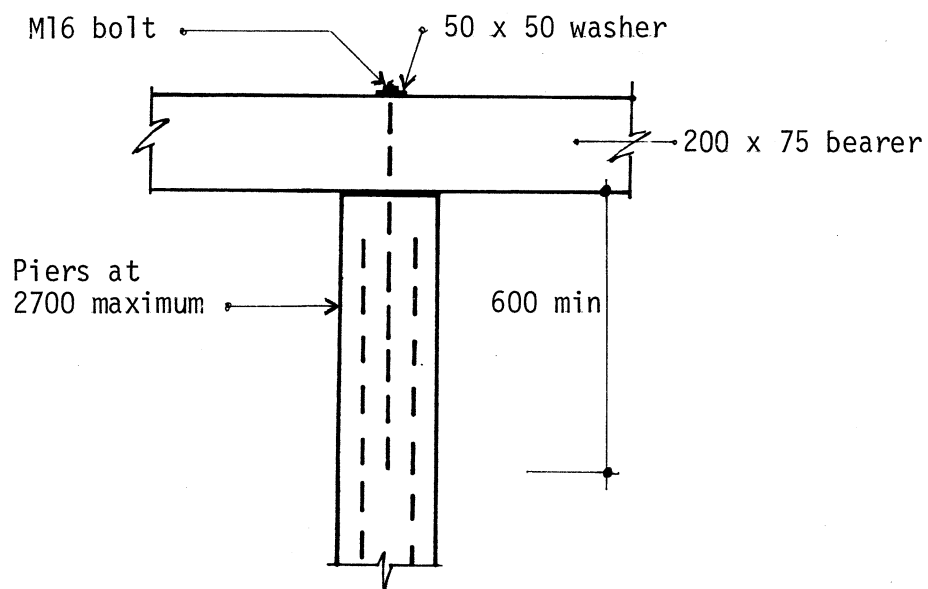


FIGURE 7(a) Bearer/Pier Construction

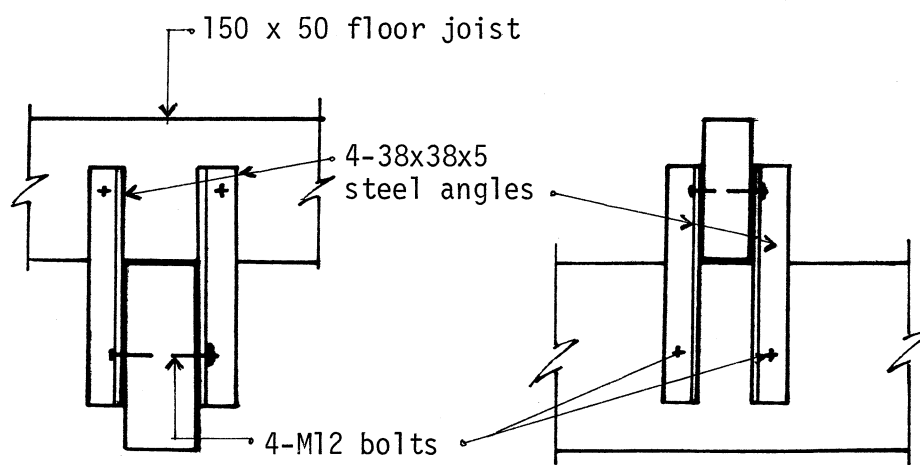


FIGURE 7(b) Joist/Bearer Connection

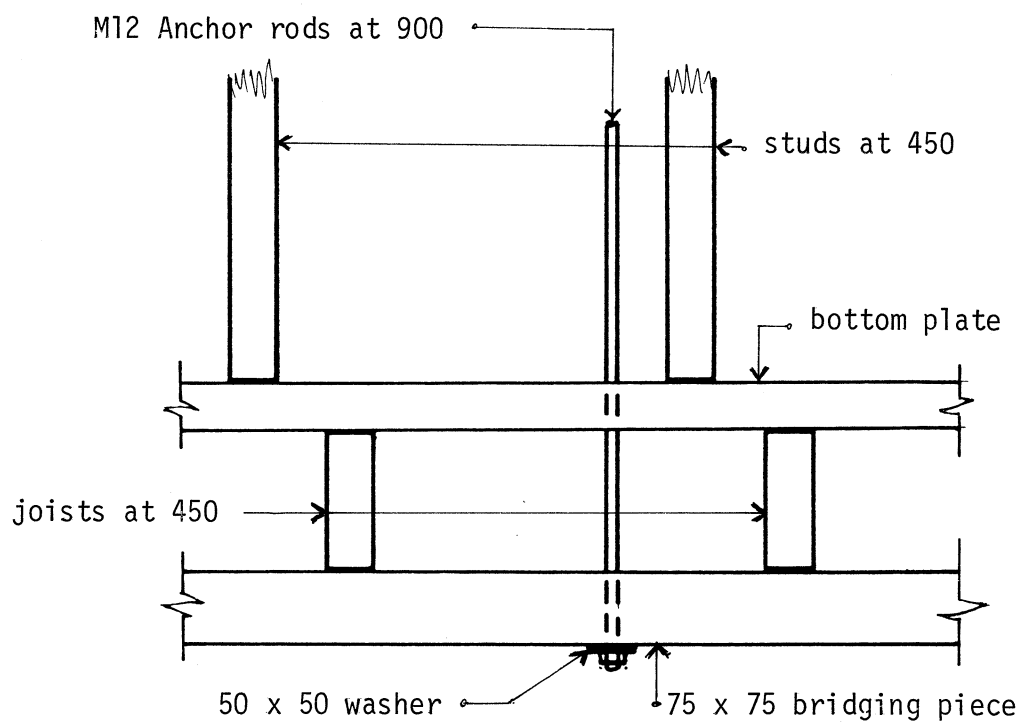


FIGURE 7(c) Sub-floor Anchorage

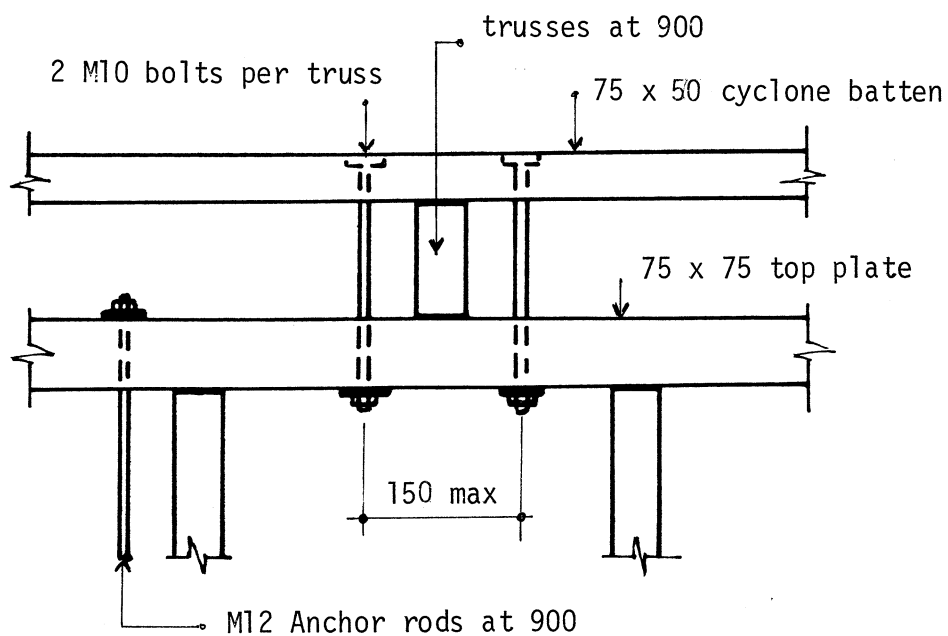


FIGURE 7(d) Roof Truss Anchorage

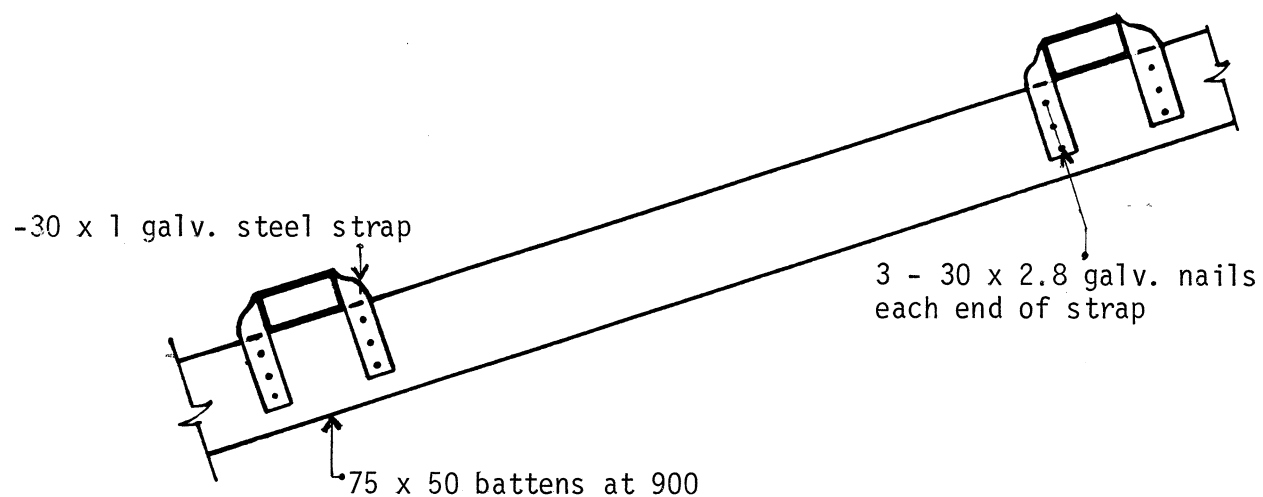


FIGURE 7(e) Batten/Rafter Connection

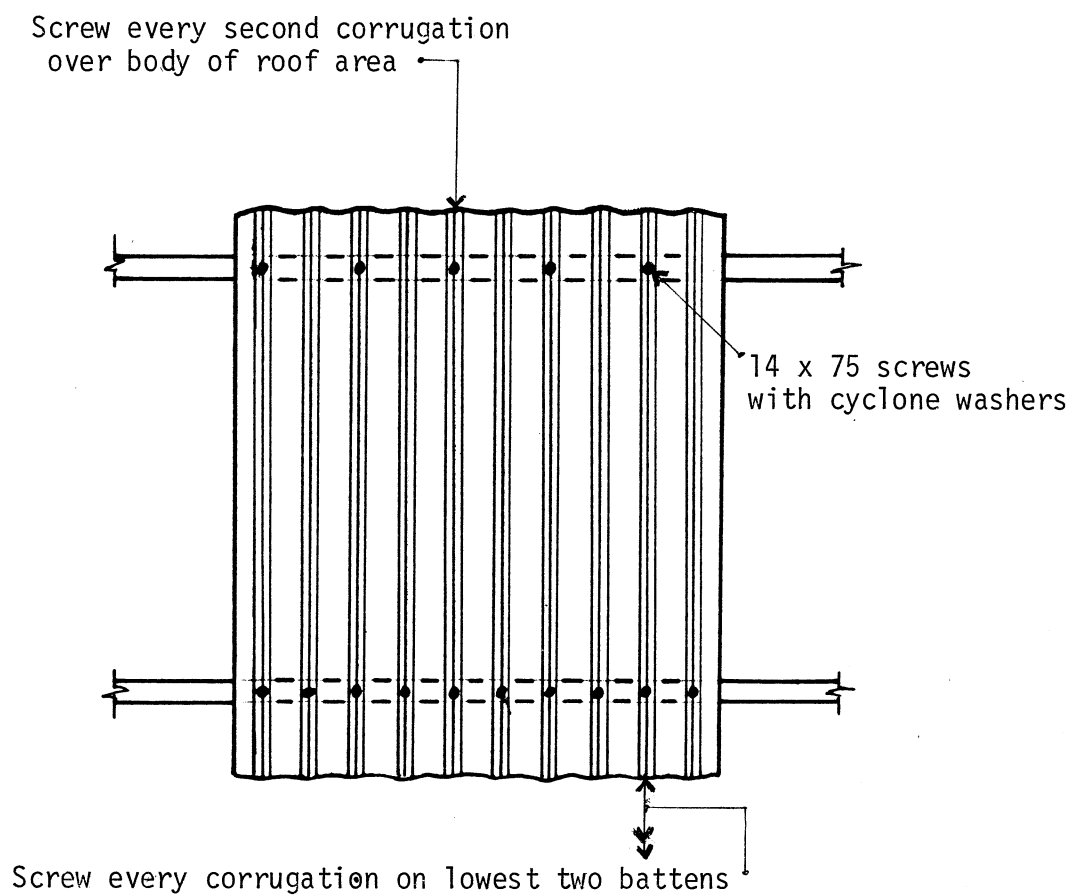


FIGURE 7(f) Fastening Roof Sheetting (Manufacturer's recommendation)