JAMES COOK CYCLONE STRUCTURAL TESTING STATION

CYCLONE TESTING STATION

SIMULATED WIND TESTS ON A HOUSE

Part 1 — Description

TECHNICAL REPORT No.12.

July 1982

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

Boughton, G.N. (Geoffrey N.), 1954-.
Simulated wind tests on a house. Part 1.
Description.

ISBN 0 86443 069 8
ISSN 0158 - 8338

1. Dwellings. 2. Wind-pressure. 3. Building, Stormproof. I. Reardon, G.F. (Gregory Frederick), 1937-. II. James Cook University of North Queensland. Cyclone Testing Station. III. Title. (Series: Technical report (James Cook University of North Queensland. Cyclone Testing Station); no. 12).

690'.8

SIMULATED WIND TESTS ON A HOUSE

Part 1. Description

G.N. Boughton [*]

and

G.F. Reardon [**]

SUMMARY

As part of a continuing research programme into the action of houses in resisting high wind forces, the Cyclone Structural Testing Station has recently undertaken some tests on a full scale house in Townsville. Loads were applied to the house using hydraulic rams and simulated forces generated by strong winds. Measurements of the response of individual components of the house and the house as a whole were made throughout the building. In this way engineers will be able to establish the distribution of forces within a house during high wind loadings, determine the weak links in the chain of structural elements that carry those forces to ground, and make recommendations to the building industry to make more efficient use of structural elements within a house.

Progress on this ambitious project has been encouraging and the success of the first series of tests indicates that the House Testing Project has a real contribution to make to improving the performance of housing subjected to high wind forces.

[*] Research Fellow, Cyclone Structural Testing Station
[**] Technical Director, Cyclone Structural Testing Station

1. INTRODUCTION

Over the past ten years, there has been an increasing awareness of the need to design and to test building products for high wind conditons. This led to the establishment of the Cyclone Structural Testing Station and also increased activity within research and development departments of manufacturing companies. Procedures have been established for testing components of houses and have been reported in publications such as Reardon (1980) and Department of Construction (1978). While every effort has been made to ensure that loads applied in these tests correspond to wind loads applied to houses, the actual distribution of forces within a house still remains unproven.

By conducting tests on complete houses, the distribution of forces within the structures can be investigated, in-situ strength of building elements can be evaluated, and correlation of laboratory tests with in-house performance of building element can be performed. Rather than conduct these tests using jet engines or large fans to create a wind, the loads that high winds would place on a structure were simulated with hydraulic rams.

This publication presents the Cyclone Structural Testing Station's research programme for full scale house testing with particular emphasis on the first series of tests recently performed on a house in the suburb of Garbutt in Townsville. It describes the house on which the tests were conducted, the loading equipment used to simulate the high wind forces, the measurement equipment used to monitor the response of the house, and the tests performed. Some attention is given to describing the damage sustained by the house, but detailed analysis of the results and recommendations arising from the tests will be presented in another publication in this series.

2. THE HOUSE TESTING PROJECT

2.1 The Need for the Project

In the same way that impact resistance of a motor car can only really be determined by staging full scale motor vehicle crashes, the performance of a house under high wind loadings can only really be ascertained when the house is carrying those loads. Unfortunately during times of high winds, it would be very difficult to monitor house performance. Frames erected to carry deflection measurement equipment would interfere with air flow around the house and be subjected to the wind loads themselves. Also, the loading is applied very quickly neccessitating the use of sophisticated equipment to record many hundreds of deflections during a five second gust. The unpredictable nature of high winds means that a house could be instrumented for some years before a loading occurs. This would tie up both the house and the valuable equipment needlessly.

The Cyclone Structural Testing Station has embarked on a research programme to test full scale houses under the action of simulated high wind loads applied with hydraulic rams. This programme will provide a valuable insight into the behaviour of houses in high winds.

2.2 The Long Term House Testing Programme

In the long term it is envisaged that the Station will have a fully portable set of loading frames, measurement frames and equipment, and be capable of moving to a house requiring testing, completing a test programme, analysing the results with a computer and drawing conclusions within a few months. In this way the Station would provide builders, companies or supervisory authorities with valuable information on the performance of a complete house. By testing many different types of contemporary houses, the action of many different materials and sturcutres can be evaluated. The Station would then be in a position to advise builders, building reguatory bodies, engineers and architects on most efficient ways of obtaining composite strength to resist high winds. In the long term it would be advantageous to have one or more houses built by the Cyclone Testing Station in which recommendations can be incorporated and tried under simulated high wind conditions.

Obviously the project described involves a large amount of capital equipment and will take many years to implement. The Station recognises that fact and is therefore staging the development of the project over a number of years.

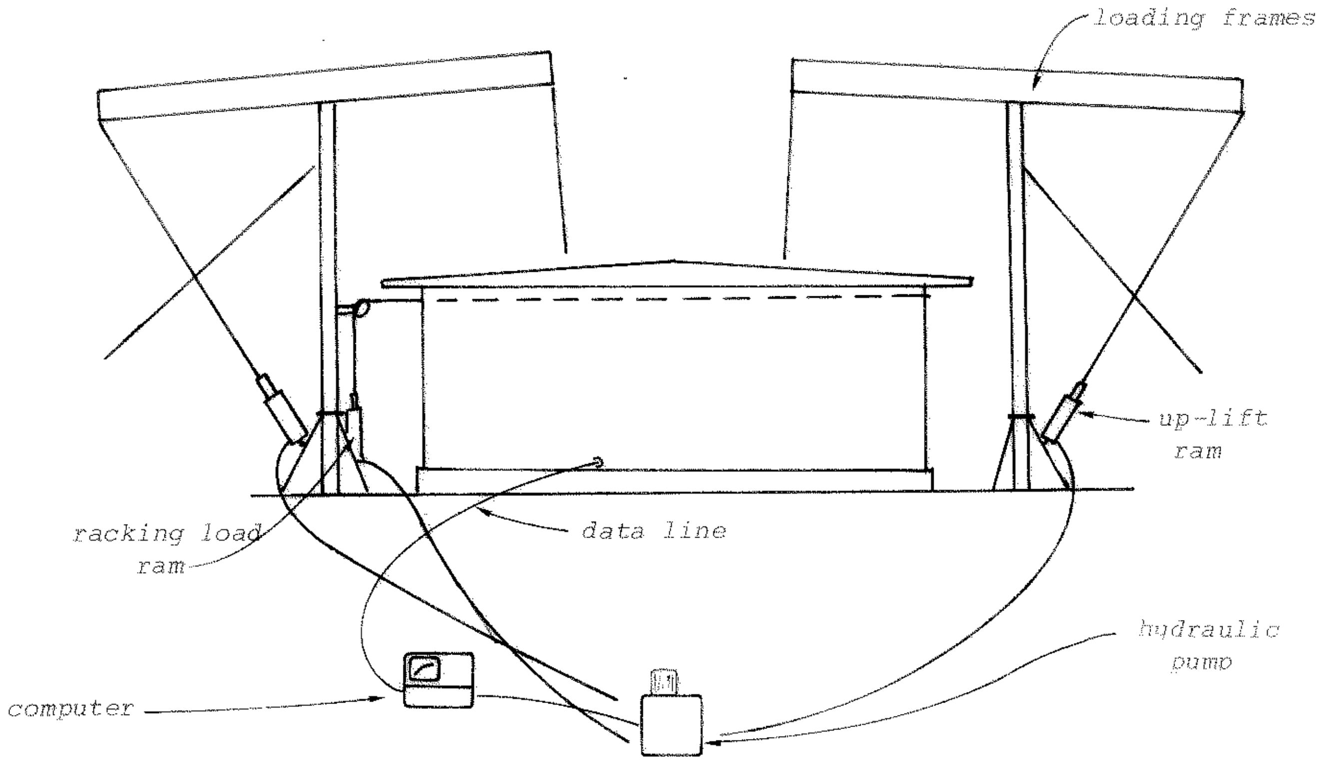


Figure 1. Ultimate development of project

2.3 Staged Development of the Project

The House Testing Project will be developed in three main phases.

(i) demonstration of the usefulness of testing full scale houses using simulated wind loads. This phase incorporates construction of loading frames and testing one house.

(ii) development of software for processing results, purchase of equipment to apply cyclic load to the structure, and to measure deflections using remote monitors. This phase is the most capital intensive and will also incorporate testing at least one house to demonstrate the usefulness of the loading and measurement equipment.

(iii) large scale load testing phase. In this phase many houses would be tested, as energy that had previously been directed into establishing equipment would be directed into testing, and analysis of results.

As of June 1982 the House Testing Project is at the end of the first phase. The Cyclone Structural Testing Station has injected its own funds into the project for the first stage and received considerable support from the Department of Civil and Systems Engineering of James Cook University, and the Queensland Housing Commission. Tests on-site have been completed and all that remains in the first phase is some laboratory testing and processing of the results. The latter is currently being undertaken.

The remainder of this report is primarily centred on the first phase of the Testing Project and in particular the series of tests performed on the first house obtained by the Station.

3. HOUSE USED FOR THE FIRST SERIES OF TESTS

3.1 Supply of the building

The house used in the first series of tests was supplied by the Queensland Housing Commission. The building had been condemned as the floor was below the minimum height above ground required by the Townsville City Council. The basic structure of the house was quite sound with timber still largely free from decay or termite attack. Thus although the building was of no use to the Queensland Housing Commission it was of much use to the House Testing Project.

While the building is referred to as a house in this publication, it was used by the Housing Commission as two adjoining dwelling units. The total floor area was 162 m^2, so consideration of the building as a house was not an unreasonable assumption. A floor plan and elevation of the building as supplied is given in Figure 2. The house when supplied had all glazing, roof and wall sheeting and flooring intact.

3.2 History of the Building

The history of the building is rather sketchy, but has been pieced together with the help of local knowledge and evidence unearthed during the testing and subsequent demolition of the house.

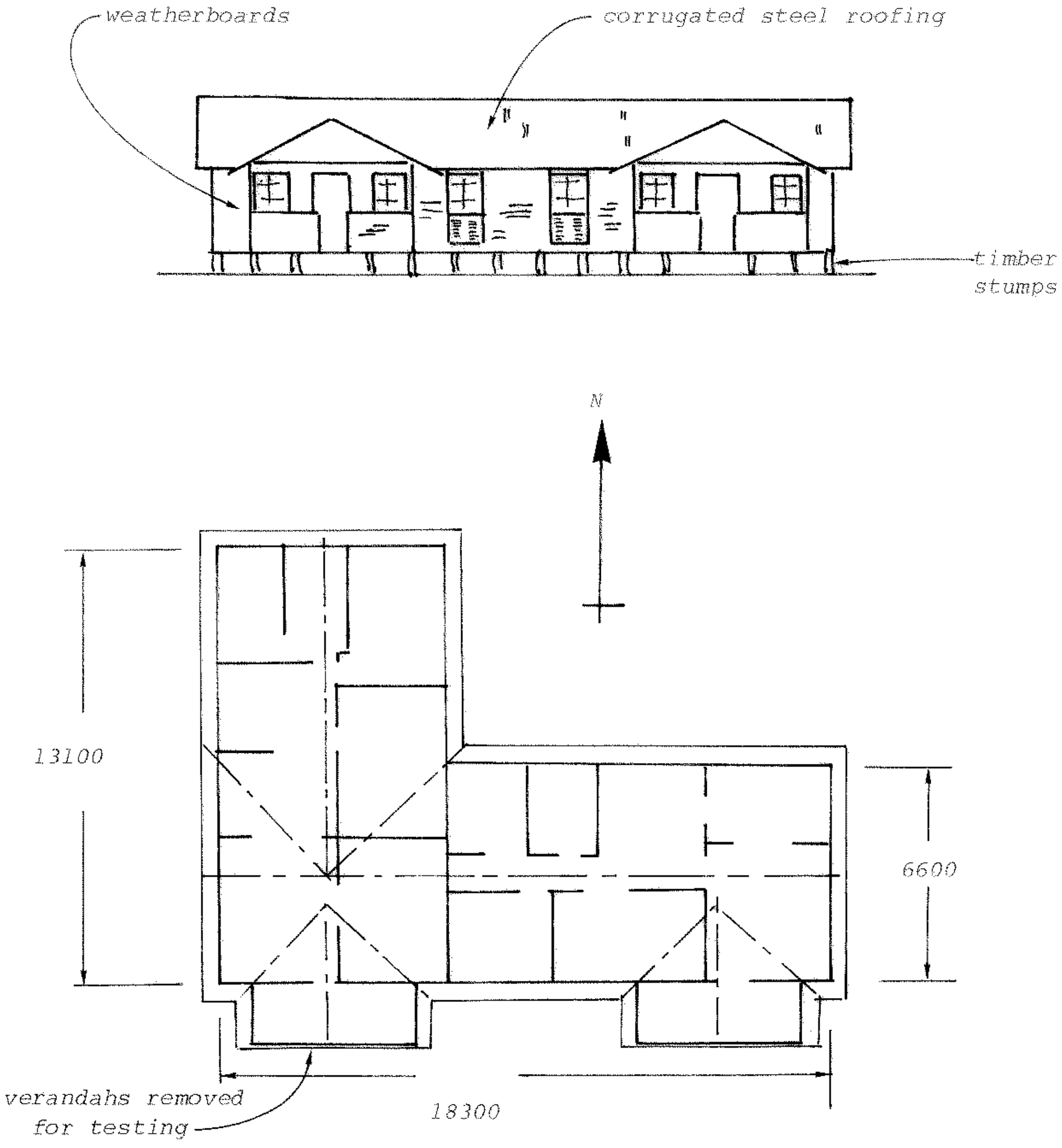


Figure 2. Plan and elevation of building used in first series of tests

The building was constructed by Australian labour and with Australian materials, but under United States Air Force supervision and to USAF specifications in 1942 or 1943. As the under side of the roof sheeting, the roof trusses and the inside of most weatherboards were once painted, it appears that after construction it was used as an unlined building devoid of internal partitions. At a later date the building was converted into the two dwelling units with the addition of kitchen, bathroom and laundry fixtures, internal walls, ceilings and internal linings on external walls. Maintenance has been performed on the building over the years and has included addition of concrete floors in bathroom and laundry areas, replacement of plywood wall linings and "Cane-ite" ceiling linings in the laundry and bathroom with asbestos cement sheeting, and upgrading of pipework.

3.3 Construction of the Building

The building was constructed utilizing a timber frame and bolted timber trusses. The trusses were at approximately 3 m spacing with 75 x 75 mm timber studs under each truss. Between these large timber studs was a centrally placed window and 75 x 50 mm timber studs between the window and the large studs. This gave a stud spacing of approximately 450 mm. The studs were checked into both bottom and top plates and nailed with two 100 mm nails through the top and bottom plates into the end grain of the stud. Diagonal timber braces of 25 x 50 mm hardwood had been checked into the external face of the studs and nailed with two 50 mm nails at every crossing of the brace with a stud. Figure 3 shows the timber frame detail.

Weatherboards that had been cut from 250 x 30 mm timber were nailed to the outside of the frame with one nail per board at every stud. Most internal linings were plywood sheeting, nailed to each stud at 150 mm centres and with cover strips over all joins. In the bathroom and laundry, asbestos cement sheets had been used as wall lining, and these too were nailed at 150 mm centres on every stud.

The roof was supported by timber trusses that had been bolted together. Details are shown in Figure 4.

The corrugated steel profile roof sheeting was nailed directly to 125 x 50 mm timber purlins at 750 mm centres supported on their edge at each truss by

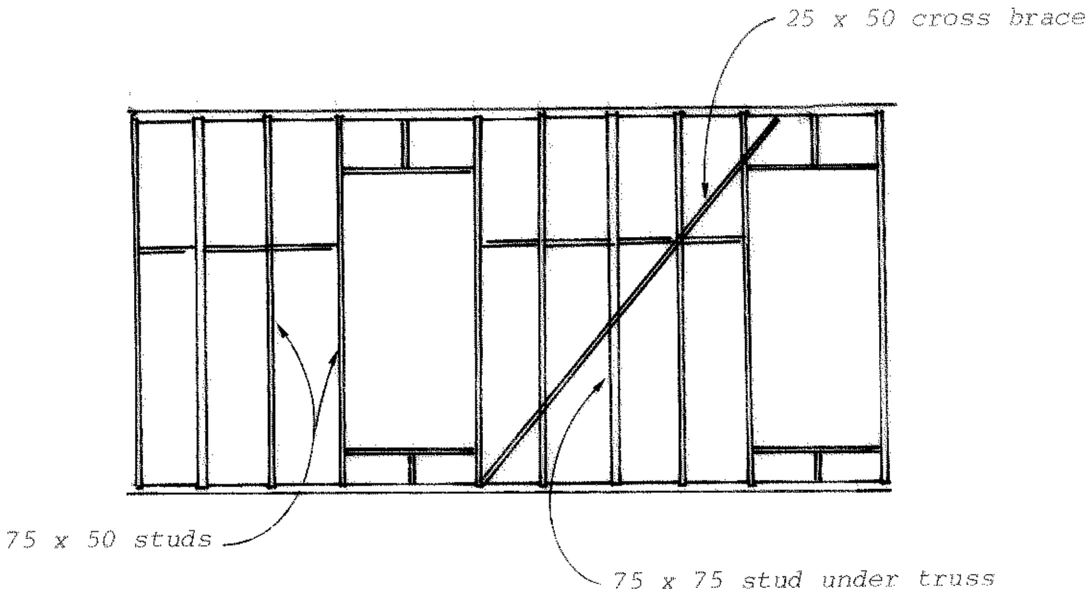


Figure 3. Timber wall frame

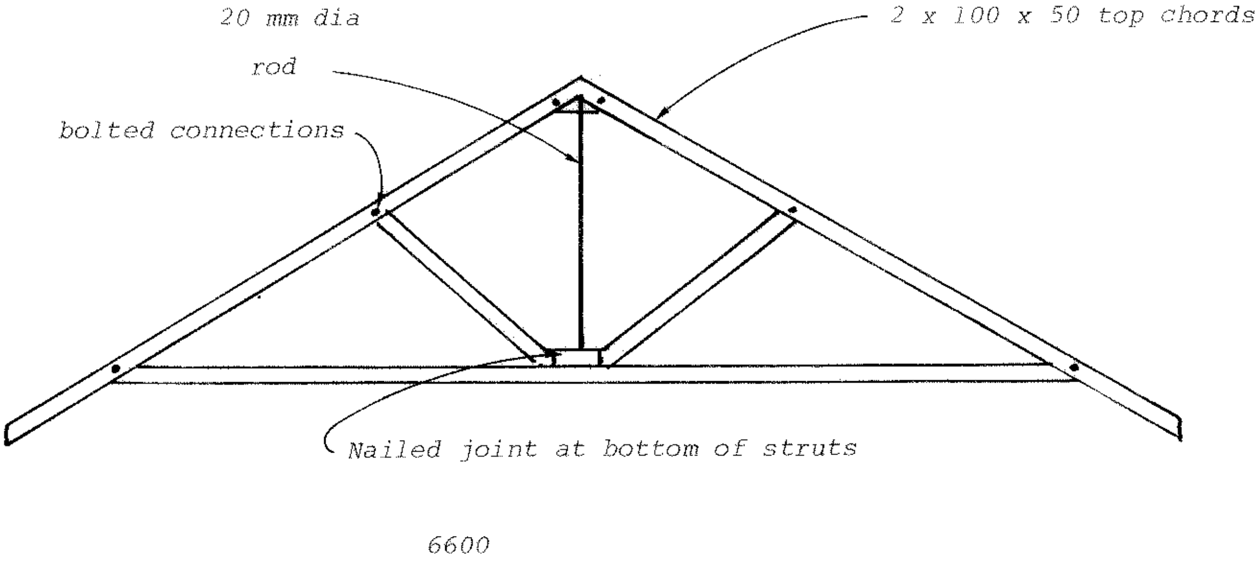


Figure 4. Roof truss construction

nailing blocks as shown in Figure 5.

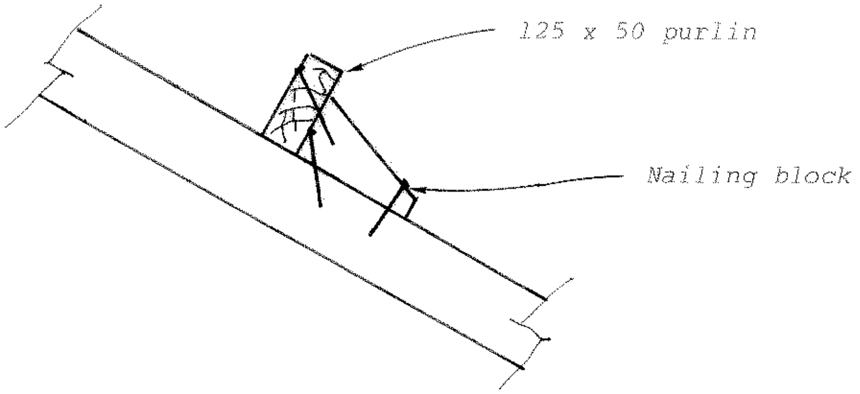


Figure 5. Purlin support system

The purlins were skew nailed to the nailing blocks by one nail per block except at laps in the pulins where two nails per block were used. Each block was held to the truss top chord with two nails as shown in Figure 5. The ceiling material throughout most of the house was 12 mm thick "Cane-ite". It was nailed at 100 mm centres to 25 x 50 mm ceiling battens which were spaced at 450 mm centres. The ceiling battens spanned 750 mm between 100 x 50 mm ceiling joints. These in turn were nailed to the top plates of all internal walls and to the bottom chords of the roof trusses. Figure 6 shows a plan of the ceiling structure.

Over the bathroom, the ceiling had been replaced with asbestos cement sheeting, and the timber framework strengthened with 100 x 50 mm hardwood timber in both directions at 400 mm spacing.

Much of the timber used in the ceiling was second hand and the timber used in the timber framing of the walls varied significantly in density.

4. LOADING SYSTEM

4.1 Loading Requirements

The basic requirement of the hydraulic loading system was that it simulate the action of high winds on a house. It was therefore designed to apply uplift loads to roof panels and lateral loads to walls. As it was envisaged that the project would involve the testing of a number of different houses, the loading frames were designed to be independent of house geometry. The height of the frames was made variable by including a removable section in the column. The point of application of both uplift loads on the roof and the lateral loads on walls was also made variable. As wind loads exert a uniform pressure on the house panels, a number of loading frames would be used on each house and load spreaders incorporated to apply loads to many different points.

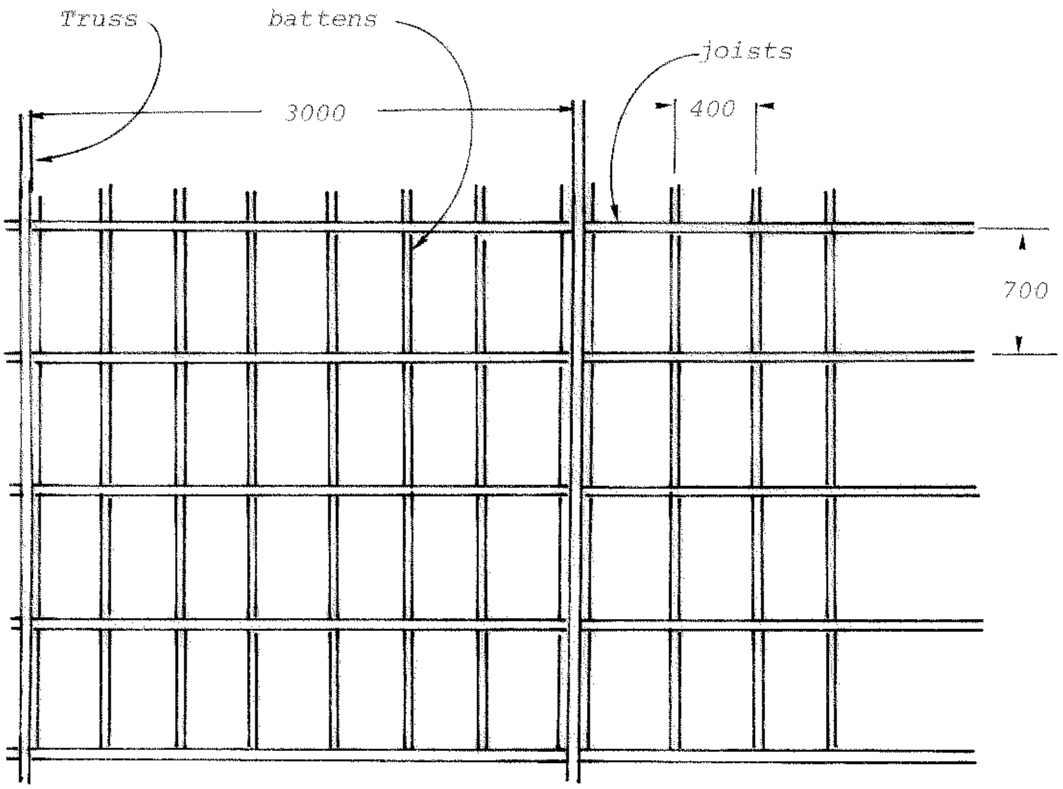


Figure 6. Plan of ceiling structure

4.2 Construction of Loading Frames

Loading frames were designed and built by the Station to satisfy the above requirements. The frames utilized welded steel instruction with bolted connections on 4 main components. This enabled the frames to be transported and erected with minimal on-site equipment. Reactions were taken to the ground through a main tension stay and the steel column of the frame. A 450 mm diameter 2.5 m deep cast-in-place concrete tension pile

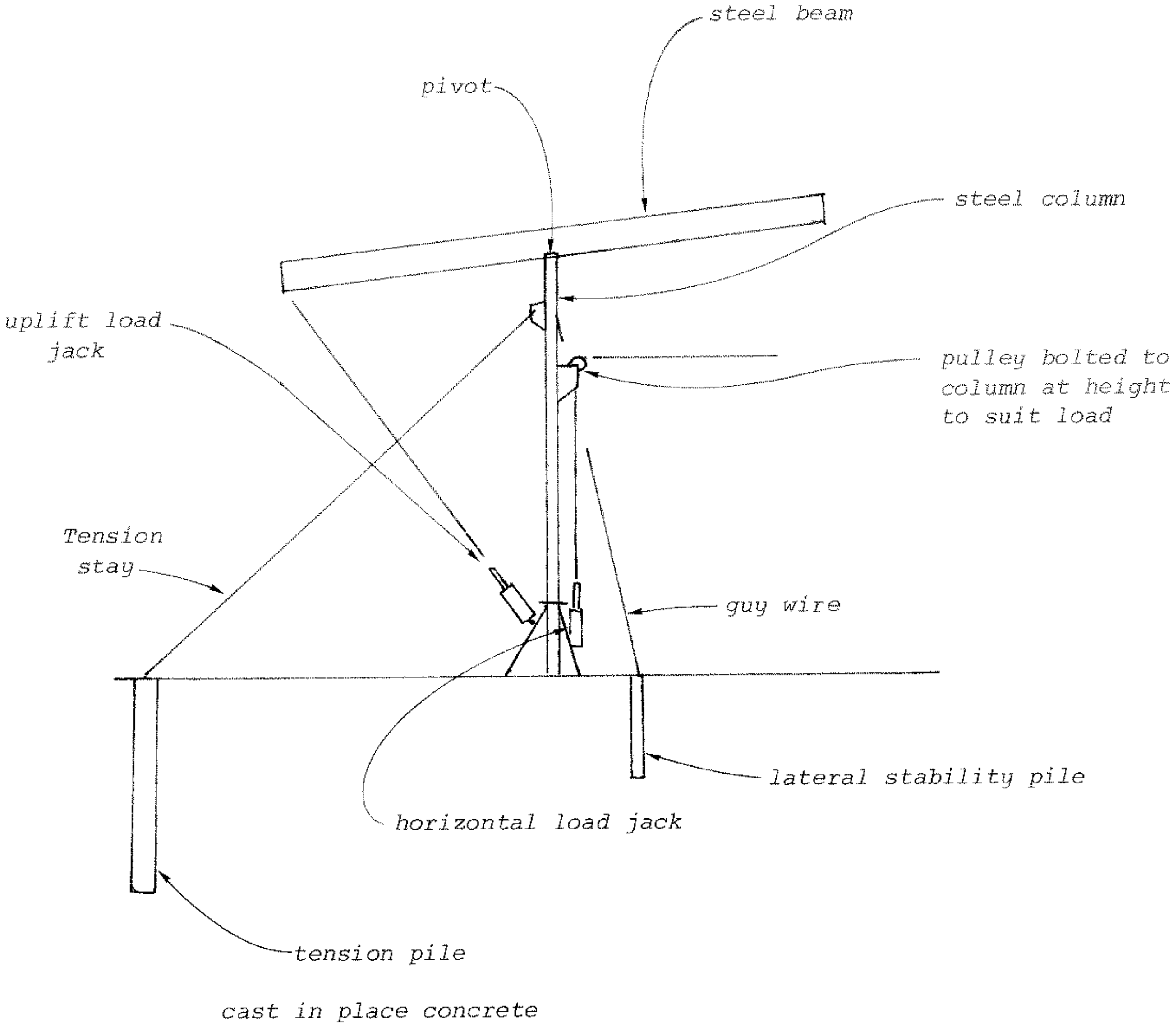
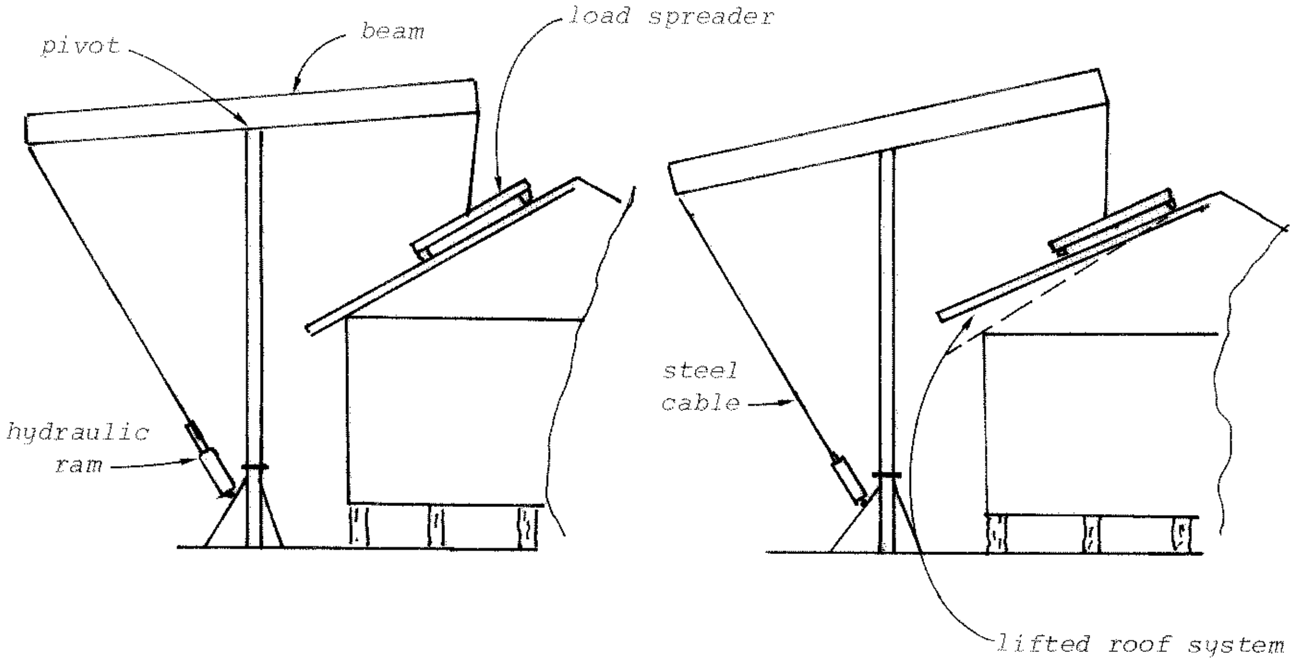


Figure 7. Elevation of loading frame

was used to anchor the main tension stay, and two smaller stays with proportionately smaller piles gave the frames lateral stability. Figure 7 shows an elevation of the loading frames.

4.3 Operation of Loading Frames

(i) Uplift loads: Uplift loads were applied to the roof of the house using a hydraulic tension ram mounted on the column footing. This pulled down on one end of a large steel beam pivoted on the top of the steel column. The other end of the steel beam was connected to the roof using a cable. The load in the cable was transferred to 6 points on the purlins by a steel load spreader. The operation is sketched in Figure 8.

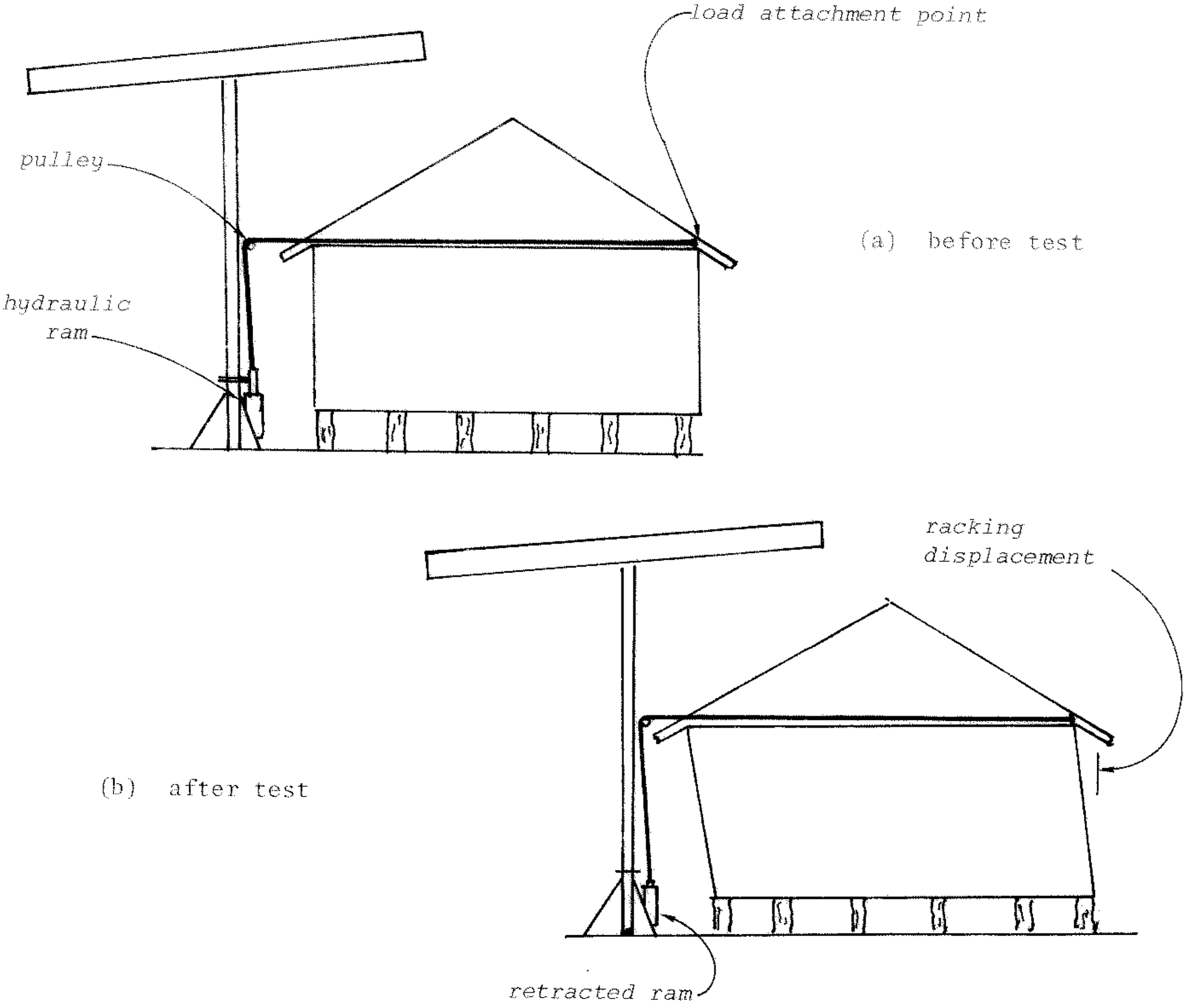


(a) Frames before test

(b) After test

Figure 8. Loading frames during uplift test

(ii) Lateral loads at top plate level: These loads were applied to the house using a hydraulic tension ram again mounted on the column footing. This pulled downwards on a cable that passed over a pulley mounted on the column at top plate level and then horizontally through the roof space to be attached to the house on the other side of the building. The effect therefore was the same as the wind blowing directly onto the opposite side of the building. Figure 9 shows an elevation of the loading frame employed in this manner.

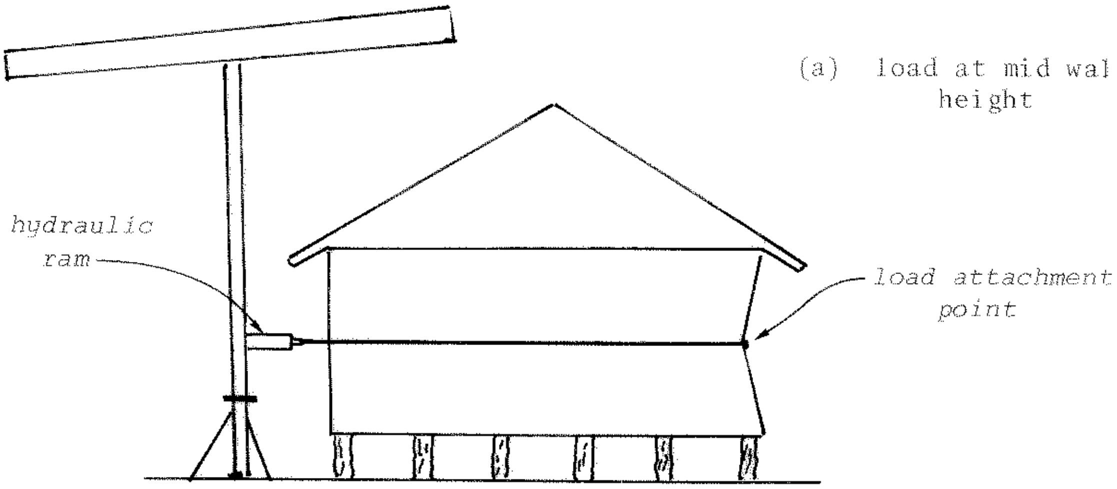


(a) before test

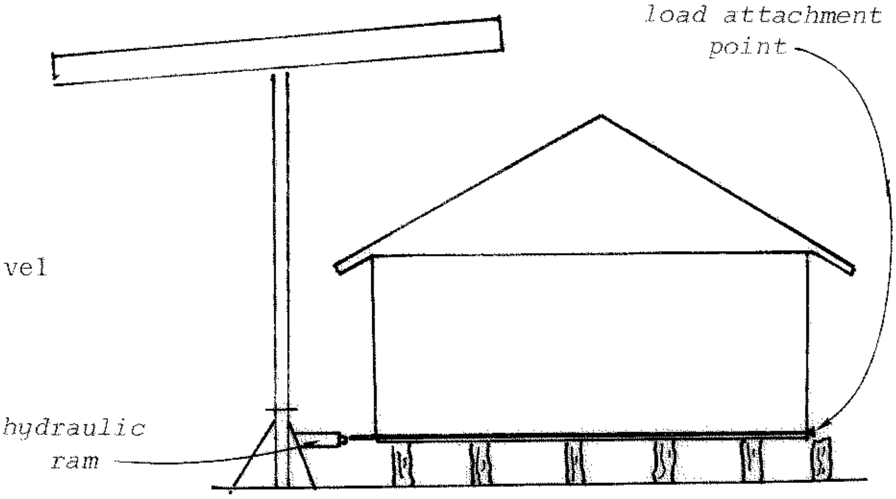
(b) after test

Figure 9. Loading frames during top plate tests

(iii) Lateral loads at mid wall height or floor joist level: These loads were applied to the house using a hydraulic tension ram bolted directly to the column and pulling a horizontal cable at the correct height for the load position. Again the load was applied to the opposite face of the building so that the load simulated wind pressure of the type normally experienced on windward walls. Figure 10 shows the loading frames employed in this manner.



(a) load at mid wall height



(b) load at floor joist level

Figure 10. Loading frames used for lateral loads at mid wall height and floor joist level

4.4 Loading System Implemented for House 1

As indicated in section 3, the geometry of House 1 was that of an "L". The loading condition chosen was that of a high wind blowing from the North. The majority of tests were performed on the leg of the building that ran East-West. In this case as the pitch of the roof was greater than 20°, only the southern side of the East-West ridge line experiences suction for winds from the North. Uplift loading was therefore only required on the Southern side of the building. By positioning four frames on the Southern side of the building, both uplift forces and lateral forces commensurate with a Northerly wind could be simulated. Each frame had a capacity of 50 kN in both uplift and lateral loading capacity. Only the central two frames were equipped with uplift load beams giving a total uplift capacity of 100 kN and a total lateral load capacity of 200 kN. Loads obtained using AS 1170 Part 2 (1981) Wind Forces were 61 kN uplift and 59 kN lateral load.

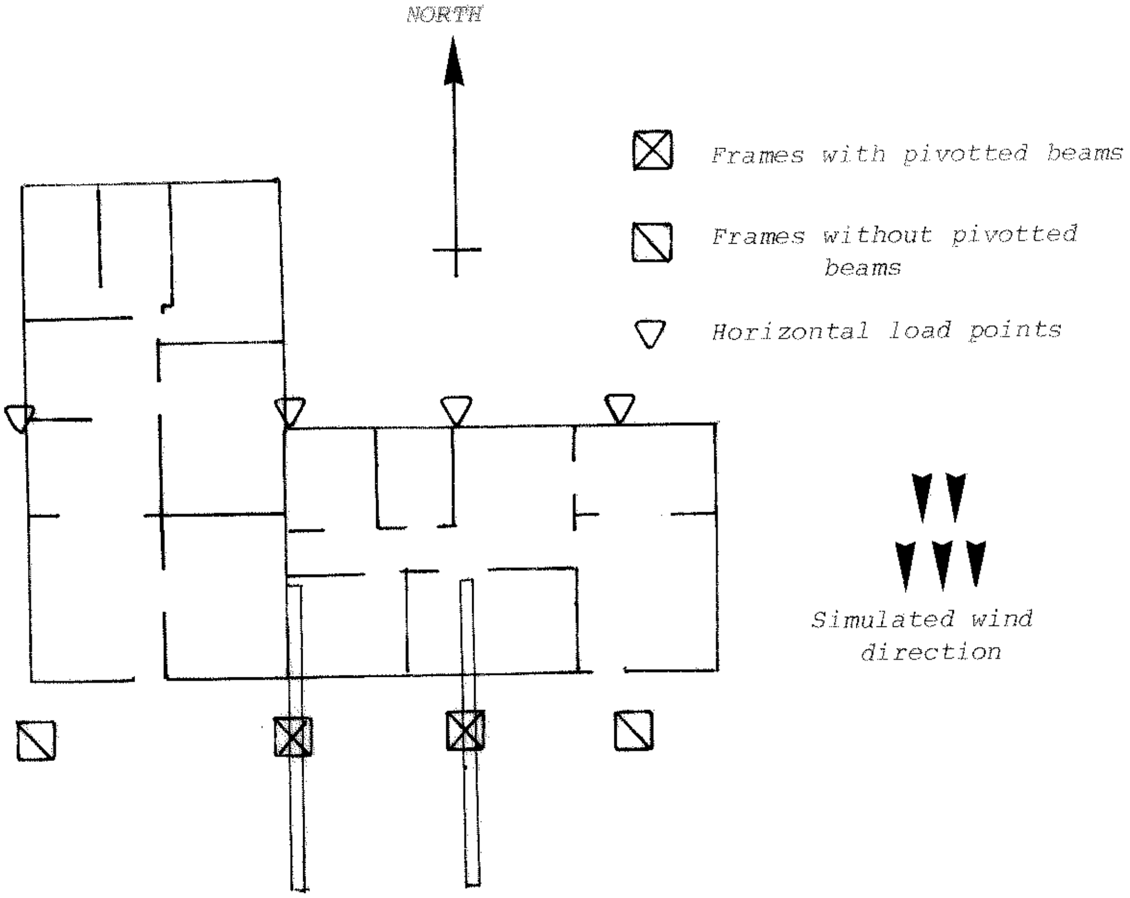


Figure 11. Plan of house showing load frame positions

5. METHOD OF MEASUREMENT

5.1 Measurement Devices

In this instance funds were insufficient to invest in electronic measurement devices.

Forces were measured with a compression load cell that was utilised at the application point for most of the lateral load tests. For the uplift test and tests in which loads were applied from more than one load frame, hydraulic pressure gauges were used to monitor loads. These gauges had previously been calibrated with the rams used so that the pressure reading could be accurately converted to a load.

Deflections were measured with dial deflection gauges. Up to ten such gauges were used in any one test. Between ten and twenty increments in load were used for each test, so each test resulted in up to 200 dial gauge readings to be taken and recorded. The readings were recorded on a desk top computer as the test was being performed, and could be plotted at any stage during the test. This meant that any errors could be quickly found and also that failure conditions could be identified prior to damage occurring.

5.2 Reference for Deflection Measurements

Where possible, the deflection readings were taken relative to the ground. Gauges were fixed to scaffolding on the North and South sides of the house. Movement of the scaffolding was generally less than 0.05 mm which amounted to less than 1% of total deflection of any gauge except in two tests where three gauges showed very small deflections.

5.3 Problems with Method of Measurement

Although the method of measurement is the aspect of the testing most in need of improvement, the measurements obtained on House 1 were consistent and were repeatable. It will therefore be possible to draw conclusions from the results of this series of tests, and attach a high significance to them.

However the small number of measurement points was a severe limitation. The small number of measurement points was neccessary to stay within budget limitations for this stage of the project, to facilitate manual reading of deflections, and to speed the recording of data so that creep was not a major consideration.

It is anticipated that for the next series of tests more load measurement points and deflection measurement points will be available. Electronic deflection measurement will be used so that gauges can be placed in locations where manual reading was impossible and to minimise reading time, and hence the effects of creep.

6. TESTS PERFORMED ON HOUSE 1

6.1 Aims of the Tests

This series of tests had three main aims:

(i) to determine the strength of the house in an assembled state.

(ii) to determine the way in which wind forces are distributed throughout the house.

(iii) to relate the performance of structural elements assembled in the house to the performance of the same elements in laboratory tests.

To achieve these aims a testing programme was devised that would leave some structural elements intact so that they could be tested in the Cyclone Testing Station laboratory.

6.2 Programme of Tests

The testing programme was as follows;

- 3 strength tests on wall studs using the loading system shown in Figure 10 (a).

- 4 stiffness tests from a single loading point, with the load applied at top plate level as shown in Figure 9.
- a roof uplift strength test with two frames simultaneously applying loads as shown in Figure 8.
- a strength test with all four loading points applying loads as shown in Figure 9.
- a strength test with two loading frames applying loads at floor joist level as shown in Figure 10 (b).
- 6 stiffness tests from a single loading frame with the load applied as shown in Figure 9. Prior to each of these six tests a structural element was removed from the house so that its contribution to the stiffness of the building could be measured.
- 2 further strength tests on wall studs after the weatherboards had been removed. These tests used the loading system shown in Figure 10 (a).
- An internal wall which acted as a bracing wall in the assembled structure, and a 2.5 x 2.5 m section of ceiling complete with battens and joists were removed from the structure intact and subjected to laboratory strength tests in the racking frame. (Reardon 1980).

Throughout the programme above, "strength test" refers to a test in which a failure point was sought and attained and "stiffness test" refers to a test in which a failure was deliberately avoided. The loading and measurement methods adopted in both strength and stiffness tests were essentually the same.

6.3 Testing proceedure

The loading and measurement systems have been described in sections 4 and 5 respectively. Loads were applied using manually actuated hydraulic pumps and the load incremented in even steps through the elastic range. At each load increment, all the deflection gauges were read. In cases where significant deviations from elastic behaviour were detected, load increments were reduced to more accurately define the load verus deflection curve. Each test took between 1 and 3 hours depending on the number of increments and the complexity of the gauge reading process.

Strength tests were conducted on the above basis until a failure occurred. In most cases failure was sudden and catastrophic and meant the termination of the test. For the strength test using lateral loads applied from the four loading frames at top plate level, a failure occurred near one loading point only, leaving the other three loading points able to sustain their loads.

Stiffness tests were conducted by incrementing loads until a pre-determined deflection near the upper end of the elastic range was reached. At this point, the load was released slowly and the structure allowed to recover. In this way permanent damage to the structural elements being tested was largely eliminated, and further tests could be performed on the same element.

7. RESULTS OF THE TESTS ON HOUSE 1

7.1 Detailed Analysis of Results

The detailed analysis of the results of the tests on House 1 will be published later in another publication in this series, but at the present time some qualitative comments on the results can be made.

7.2 Results of the Strength Tests

The loads obtained at failure of various elements in the structure were higher than those predicted in most cases. This is not surprising bearing in mind the nature of the construction of the house revealed as demolition of the house proceeded.

(i) Stud Tests - The timber used for the studs varied throughout the house, but never the less it appeared that the weatherboards assisted in transferring loads from the tested stud to adjacent studs. This effect may even have been evident near windows as lateral deflection was observed on both sides of window frames near the tested studs. The loads carried by the timber studs at failure were well in excess of those required in AS 1170 Part 2 (1981) - Wind Loads. Failure was initiated at flaws in the timber such as knots, or a check out.

After testing studs with the weatherboards in place, a significant reduction in ultimate load was obtained by removing the weatherboards. This confirmed the effectiveness of the weatherboards in distributing loads laterally away from a loaded stud.

(ii) Roof Test - As discussed in Section 3, the roof structure was not typical of a house. The weak link in the uplift chain from purlins to footings, in this instance was the purlin to rafter connection. This detail failed quite suddenly by pull out of the nails driven through the purlin into the nailing block as shown in Figure 12. However, the trusses themselves did suffer some minor damage during the test.

The roof appeared to have suffered little damage during cyclones that have occurred in the life of the building, as there were no readily identifiable new sheets of roofing and there were no noticeable repairs to trusses or purlins. In fact nearly all sheets of roofing material could be positively identified as original sheeting. This indicates that the roof has stood the test of time quite well.

The static load at failure as applied in the test was again in excess of that required by AS 1170- 2 (1981) but caution should be used in attaching too much importance to that statement as cyclic loading of the type experienced during high winds may have considerably reduced the failure load.

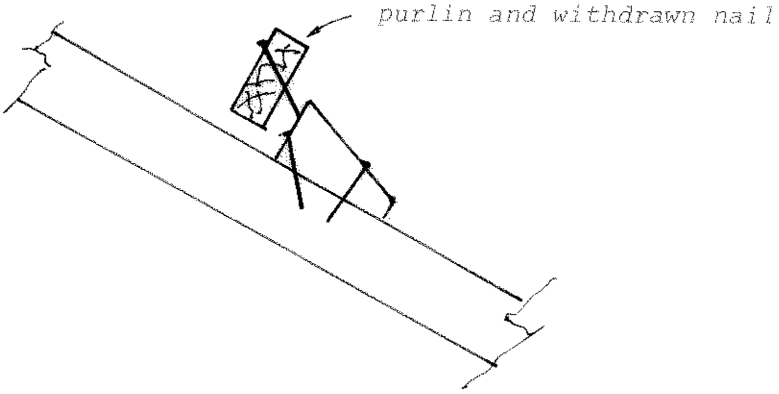


Figure 12. Failure of purlin to rafter detail

(iii) Top Plate Tests - Loads were applied to the top plate at four locations. One was between an end wall and an internal wall with a large opening. Another was adjacent to a 3 m long internal wall. A third was adjacent to a 6.6 m long internal wall and the fourth was adajcent to an 11 m long external wall. Figure 13 illustrates the locations of the loads.

With the house intact, the capacity of the hydraulic rams used not sufficient to cause failure at loading points 4, 3 or 2 in Figure 13. At point 1, however, the top plate failed in bending causing damage to the ceiling within 1.5 m of the failure point. Evidence of movement of the ceiling could be seen near load points 3, 2 and 1, and movement within the roof sheeting could be heard but not seen. Very little movement was observed near the long transverse walls at load points 3 and 4. The test showed that the action of a house in resisting lateral loads is quite complex. Further comments are made on this action in Section 7.3.

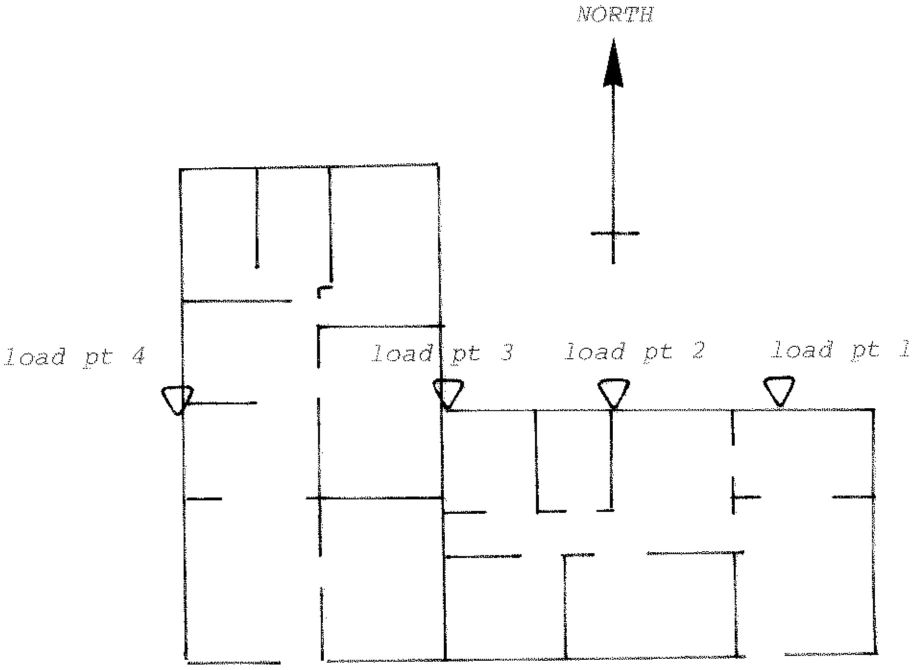
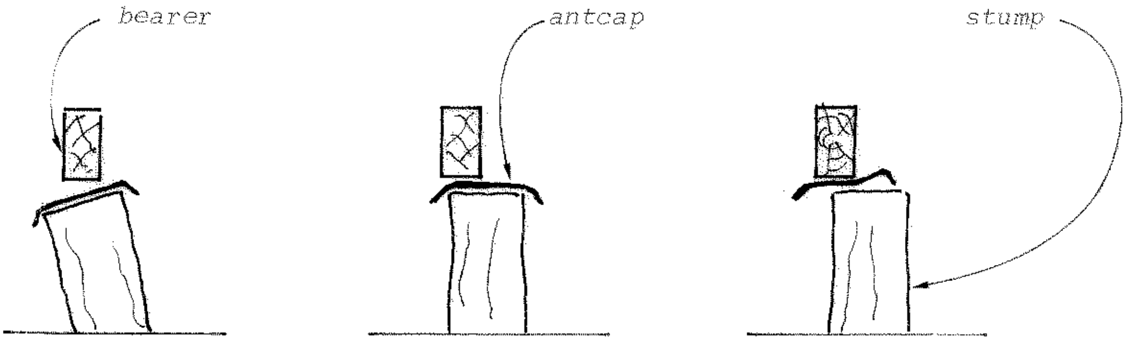


Figure 13. Location of top plate loads

(iv) Floor Test - The tie down of the floor system to stumps was by ten 12 mm diameter bolts for the entire house. The bolts from the floor bearers to the stumps proved totally ineffective in resisting any lateral load. This was due to the very badly corroded screws into the stumps. Those that had not corroded through, broke in the course of the test. The floor system showed a classic friction behaviour in sliding across the stumps. Only one stump was observed to rotate significantly, with the bulk of the movement taking place either as sliding of the bearers on the antcaps or as sliding of the antcaps on the top of the stumps, as shown in Figure 14.



(a) rotation of stump
(b) sliding of bearer on antcap
(c) sliding of antcap on stumps

Figure 14. Modes of failure - floor test

7.3 Results of Stiffness Tests

Most of the on-site tests performed were stiffness tests and all were designed to isolate the structural members in the house that distributed lateral loads sideways to bracing walls. The analysis of these results is quite complicated and so will not be treated here. However, the tests showed that substantial loads are carried through bracing action of ceiling sheeting and roof sheeting to the bracing walls. Very little load is carried in actual bending of wall claddings and wall timber, although the ceiling joists and battens may also have helped in load distribution independent of the ceiling cladding. It is to be noted again that excessively heavy ceiling support timber was used in parts of the house. After examining the deflections in detail it will be possible to obtain an accurate distribution of force between the bracing members within the house.

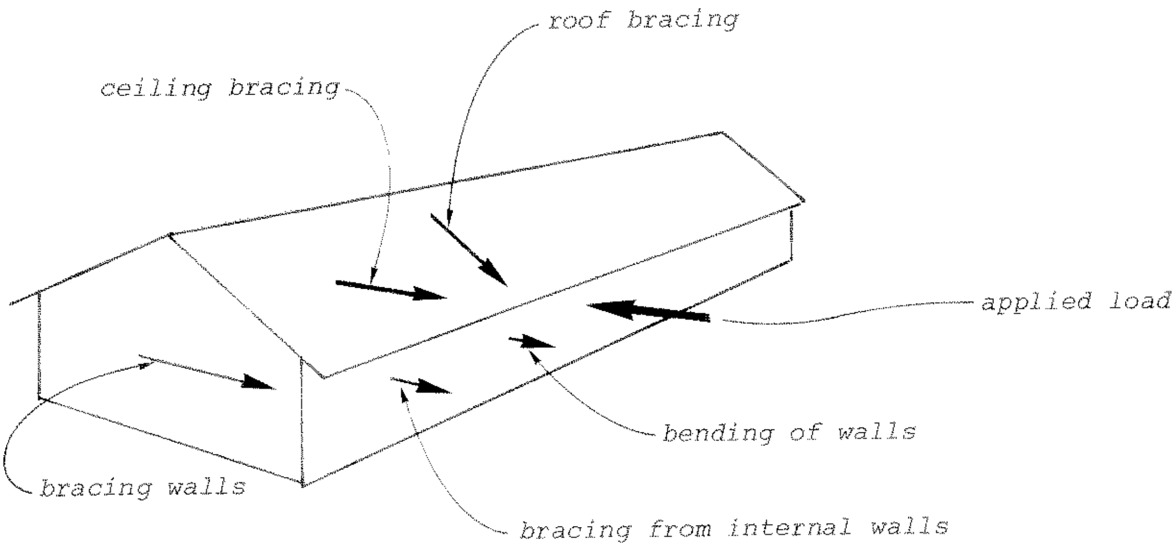


Figure 15. Distribution of horizontal forces within the house

7.4 Results of Laboratory Tests

At the time of writing, the laboratory tests had not been performed. They will be presented in detail with a detailed analysis of all other test results on House 1 in a later publication.

8. THE IMPORTANCE OF THE TESTS

8.1 Potential Benefits of the House Testing Performance

The principal benefit of the programme is the greater understanding of the way forces are transmitted throughout a house. By fully understanding force paths within the structure, building codes and regulations can be formulated with a rational basis for such items as spacing of bracing walls or fixing of ceiling materials. The greater rationalisation of building methods will in turn allow more flexibility in house design for high wind areas, and more efficient use of structural systems to provide safety in the event of high winds.

Other potential benefits to be accrued from the programme of tests include a reference for laboratory tests, so that laboratory behaviour of materials related more accurately to field performance. This is particularly useful in that work performed by the Cyclone Structural Testing Station on roof sheeting as a bracing membrane [Nash and Boughton (1981)] and work performed by researchers at James Cook University on ceiling diaphragms [Walker and Gonano (1981)] can be directly related to stiffness tests performed on the house at Garbutt. On-site stiffness of these and other bracing members can be compared with estimates and laboratory experimental work and hence steer research work to maximise the benefits from the findings.

The knowledge of the strength of components of a house while they are installed can help to identify weak links in the chain of structural strength from the point of application of the loads to the foundations of the structure. Thus further effort can be directed to increasing the strength of parts most effective in resisting high wind forces. By applying the wind forces slowly with hydraulic rams, it was possible to locate the elements which initiated failure.

The ultimate benefit to be sought in this and other investigatory work on the action of high winds on houses, is safer housing that still allows design flexibility and is built at a minimum extra cost.

8.2 Benefits of the Series of Tests Conducted on House 1

While it is recognised that the benefits outlined above are long term goals, the results of the series of tests conducted on House 1 at Garbutt have shown that the programme is capable of achieving those goals. At present the importance of roof sheeting and ceiling structure as bracing elements is recognised, but in the tests outlined in this report data has been gathered to quantify their contribution to the stiffness of a real house. Recommendations to builders and planners can be made as a result of the first series of tests and will be published in a later booklet in this series.

The first series of tests were important as a prelude to the remainder of the house testing programme. They have demonstrated that it is possible to test a house in the way outlined, and to obtain meaningful results. Expertise in operating the loading frames and working in a house structure has been built up in a team of engineers and technicians. This expertise is important to the efficiency and success of the remainder of the House Testing Project.

9. THE FUTURE OF THE HOUSE TESTING PROJECT

9.1 Further Houses for Testing

The first series of tests were performed on a house that was approximately 40 years old. This had some advantages in that as the house was no longer required it could be systematically demolished in the course of the tests. The house was also known to have withstood some severe winds within its lifetime with minimal damage. In that respect we were testing a proven structure to determine why it worked, and there was certainly value in that.

However it is necessary to test current building practice to ensure that it is capable of withstanding high wind forces. Certainly Cyclones Althea, Ada and Tracy provided a very expensive test for building construction of that time. Using hydraulically applied loads of similar magnitude to high wind loads, on selected houses only is a much more preferable method of evaluating current building practice and recommendations.

Within the next six months the Cyclone Structural Testing Station will be looking for a more recent house to test.

9.2 Loads to be Applied in Further Tests

Static loads are quite suitable for evaluation of stiffness of structural elements, however high wind events of the last ten years in Australia have indicated that strength of structural elements may be considerably reduced under cyclic loading of the type produced during a cyclone. In order to more accurately simulate this action on a structure, a loading system capable of applying repetetive loads must be used.

A cyclic loading system has been devised in which the computer currently used for data aquisition will control an electrically driven hydraulic pump and some automatic valves to continually apply and then release a given load. Loads will be monitored by load cells and signals fed to the computer as required.

9.3 Monitoring of Deflections in Further Tests

As already noted in section 5.3, the small number of deflection measurements, the time taken to read dial gauges and the limitations in placing gauges where they can be read with safety were severe limitations in the first series of tests. It is proposed that for the next series of tests, electronic deflection measurement devices should be used. This will enable very rapid readings to be obtained, with approximate reading rates of more than 10 gauges per second. It will also enable gauges to be placed in locations within the structure where only remote reading is possible. The faster reading times will minimise the effects of creep, enable more deflections to be monitored and allow cycling of the loads within a small period.

10. CONCLUSIONS

There are a number of important conclusions that can be gained from this series of tests. The first and possibly the most important is that techniques have been developed to enable such tests on houses to be conducted. A suitable testing rig has been designed that not only has sufficient strength, but can be dismantled and moved to other test sites. Thus the concept of proof testing houses can be made a reality.

Secondly, sufficient data has been gathered to enable the analysis of force distribution within the house and individual element strengths. The results of these analyses, currently in progress, will be related to other houses of similar construction and even to houses in general.

Finally the work has enthused the authors so much that they are planning a future test programme based on the application of cyclic loading to a house, hopefully much younger than the one described herein. These plans are outlined in Section 8. However although some preparation has already been made for cyclic testing, the Station does not have the electronic equipment to control the loading regime or to simultaneously monitor the response of the entire building.

Whilst the Station supported the cost of the project on the first house, it does not have the reserve funds to purchase the equipment needed for the cyclic loadings project. Further funding is therefore needed from industry or government to continue this important research.

ACKNOWLEDG EMENTS

This series of tests was made possible by the donation of a house to the Station by the Queensland Housing Commission. The authors thank the Commissioner Mr N.J. Hitchins for his assistance and generosity in that regard.

The authors gratefully acknowledge the assistance given by the technicians who have given of their expertise and their own time in seeing deadlines met. Thanks Keith, Ron, Wayne and Charlie.

The authors would also like to thank many persons, organisations, companies and authorities in Townsville for their assistance during erection of the test frames and performance of the tests. In particular we would thank

Dunlop IBC for providing ablution facilities for all our men while on site,

The Townsville City Council for assistance in excavating foundations,

Cyclone Scaffolding for the scaffolding,

Mrs Buchan for keeping an eye on the house and equipment after hours,

Ken Corporation for labourers used to demolish verandahs,

Tomi Australia Ltd for supply of a builder's pole for electric power.

REFERENCES

AUSTRALIAN STANDARD. AS 1170, Part 2 - 1981. Wind Forces. Standards Association of Australia.

DEPARTMENT OF CONSTRUCTION (1978). Guidelines for the Testing and Evaluation of Products for Cyclone-Prone Areas. Technical Record 440. Experimental Building Station, North Ryde, N.S.W.

NASH, L.N. and BOUGHTON, G.N. (1981). Bracing Strength of Corrugated Steel Roofing. Technical Report No. 8. Cyclone Structural Testing Station, James Cook University of North Queensland.

REARDON, G.F. (1980). Recommendations for the Testing of Roofs and Walls to Resist High Wind Forces. Technical Report No. 5. Cyclone Structural Testing Station, James Cook University of North Queensland.

WALKER, G.R. and GONANO, D. (1981). Investigation of Diaphragm Action of Ceilings. Technical Report No. 10. Cyclone Structural Testing Station, James Cook University of North Queensland.