CYCLONE STRUCTURAL TESTING STATION

CYCLONE TESTING STATION

TESTING A HIGH SET HOUSE DESIGNED FOR 42 m/s WINDS

Part 1 - Preliminary Results

G.N. Boughton
G.F. Reardon

Technical Report No. 19

© James Cook Cyclone Structural Testing Station 1983

Boughton, G.N. (Geoffrey Neville), 1954- .
Testing a high set house designed for 42 m/s winds.
Part 1. Preliminary results.

ISBN 0 86443 112 0.

ISSN 0158-8338

1. Building, Stormproof. 2. Buildings - Aerodynamics -

TESTING A HIGH-SET HOUSE

DESIGNED FOR 42 m/s WINDS

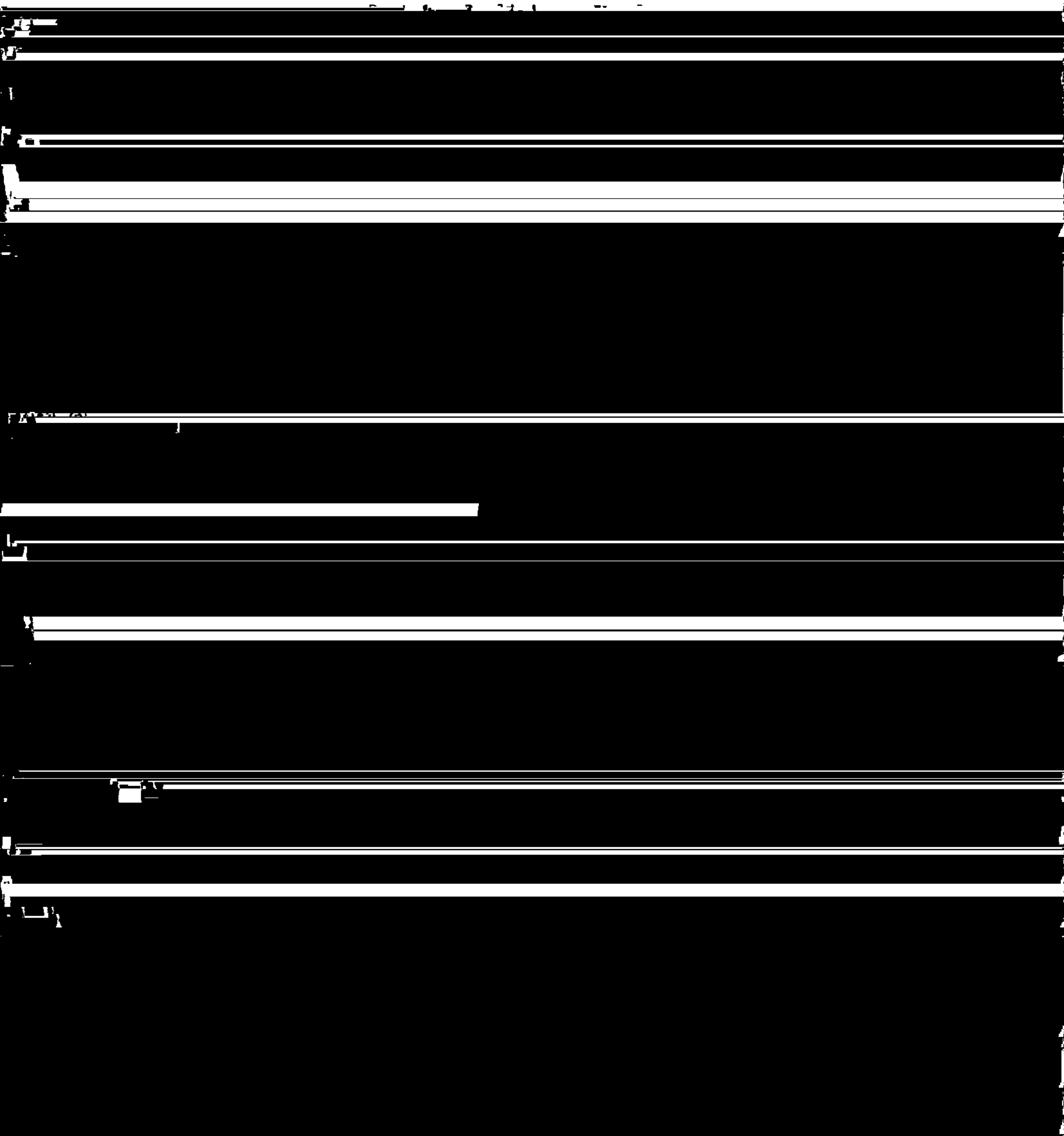


TABLE OF CONTENTS

Page

1. INTRODUCTION

The building regulations that ensure the safety of housing have evolved from building practices over many years. However widespread damage following cyclones 'Althea' in Townsville 1971 and 'Tracy' in Darwin 1974 showed current building standards and presents some preliminary findings. A complete set of recommendations will not be available until the detailed analysis of all of the collected data has been finalised. It will be presented in a later publication.

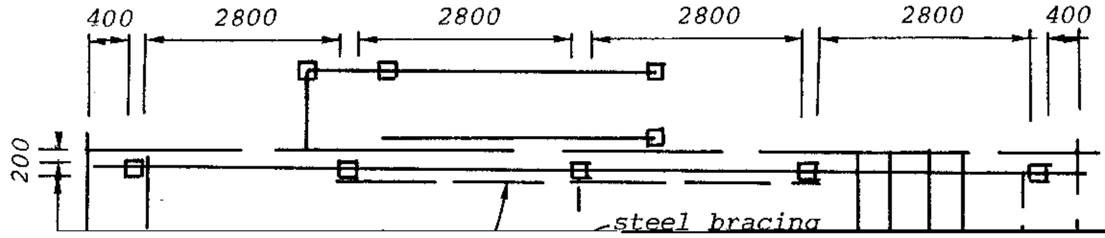
2. DESCRIPTION OF THE HOUSE

2.1 Design

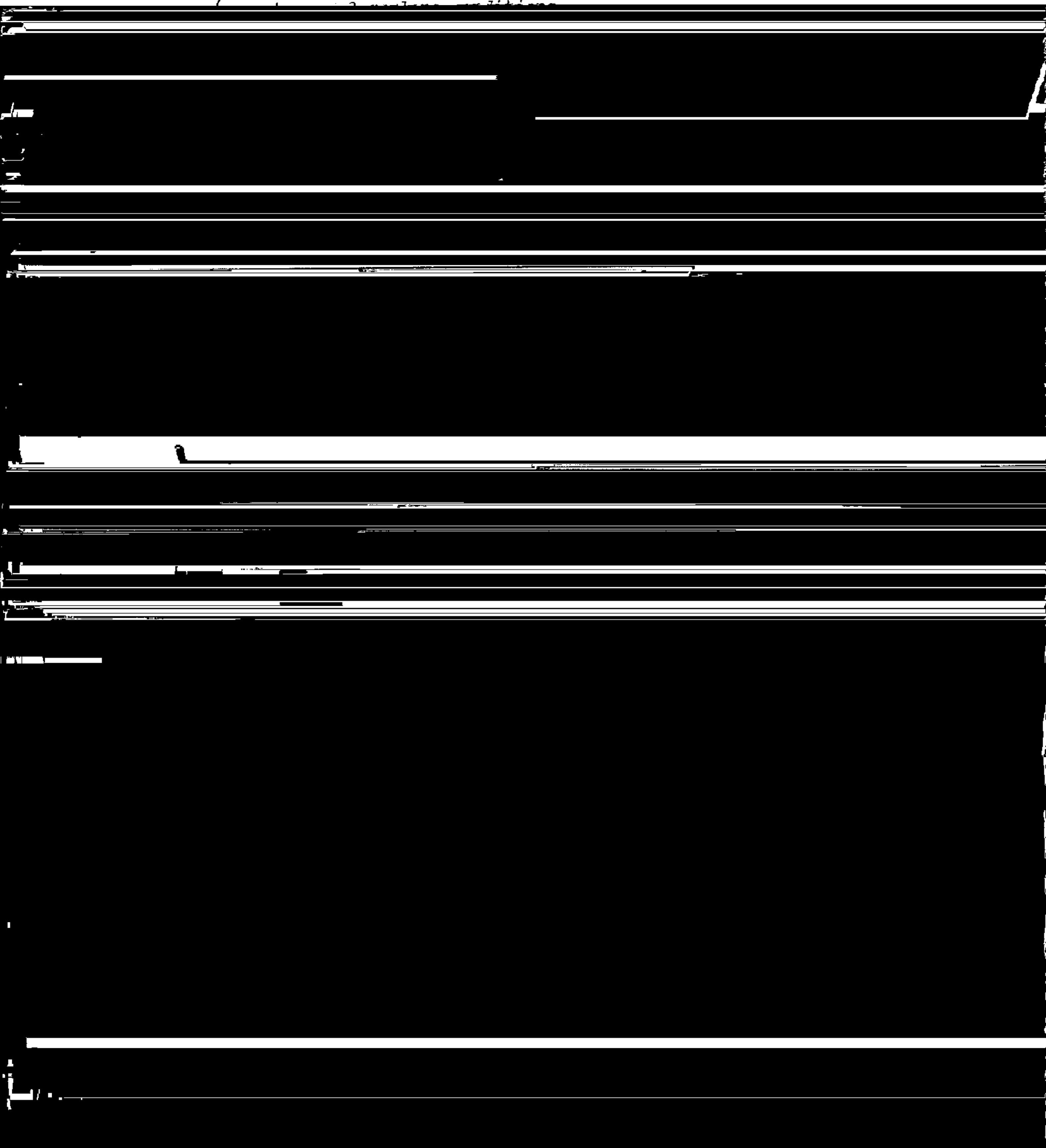
The tests reported in this work were performed on a timber framed, high

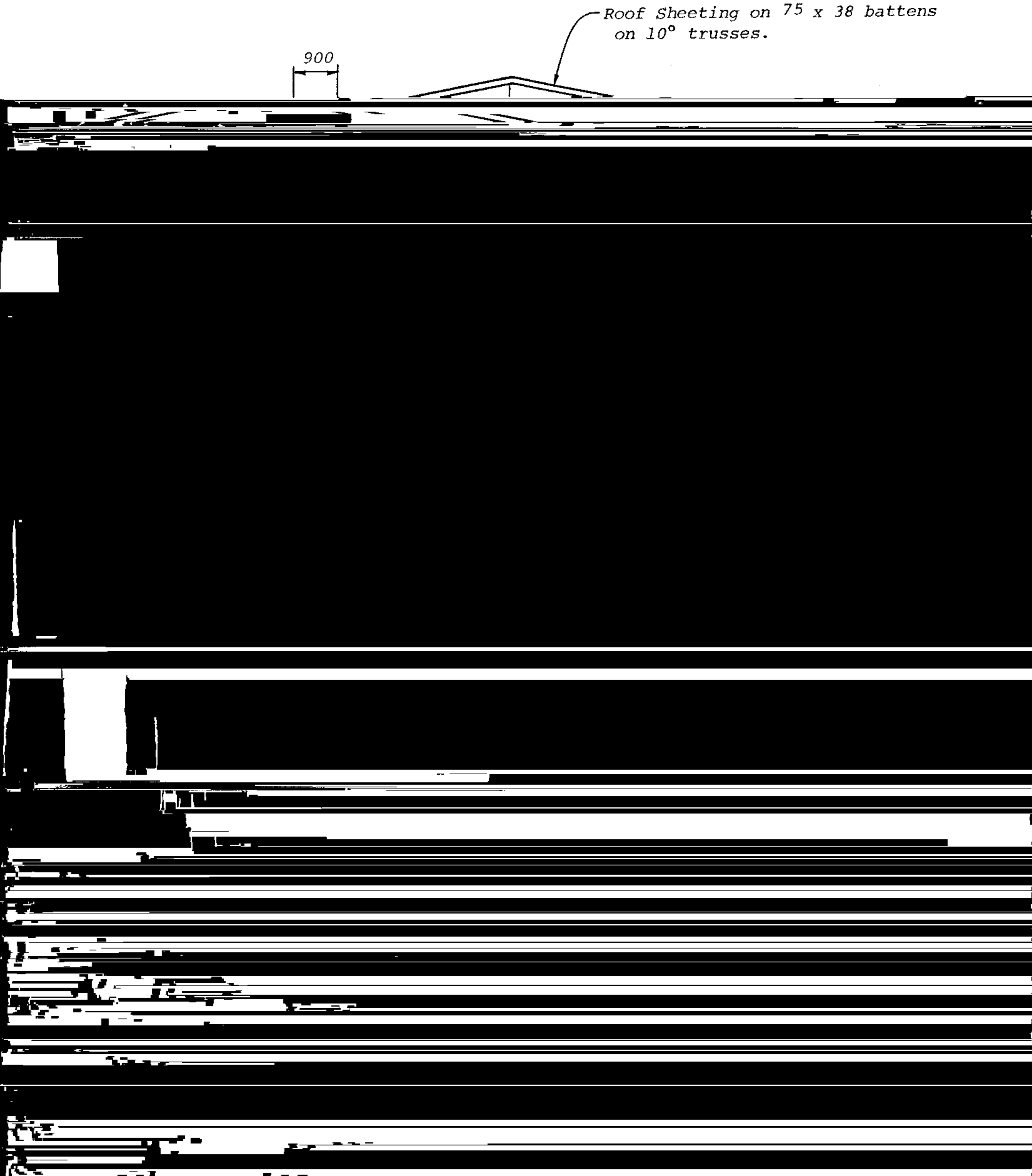
[redacted]

rods. The bearers were tied into the top of the concrete columns with 6 mm steel flat plates, or bolted to the top of steel columns, with 10 mm bolts passing right through the depth of the bearers. Concrete columns


400
2800
2800
2800
2800
400
200
steel bracing

'Custom Orb' roof sheeting fixed in accordance with terrain




Roof Sheeting on 75 x 38 battens
on 10° trusses.
900

2.2. Construction Details

The 200 x 200 mm concrete columns were cast on site and the steel columns set into foundations. All subfloor bracing was completed prior to installation of the floor. The prefabricated hardwood exterior wall frames and softwood interior wall frames were nailed to the floor and supported considered a major concern for the following reasons. The stude [redacted]

	at each end and centre with a 20 mm expanding masonry anchor.
Flooring	19 x 60 mm hardwood strip flooring fixed with one nail per board per joist.
Joist to bearer connection	2 skew nails but also with two framing anchors connections adjacent to tie-down rods.
Bearer to column connections	(i) concrete columns - fish tailed plate 50 x 6 mm with one MI6 bolt. (ii) steel columns - two M12 bolts through full depth of bearer.

Top plate to floor tie-down	12 mm anchor rods from top plate to an under-batten under floor joists at each corner, adjacent to openings and at max. 1800 mm centres.
External wall cladding	Hardie's 4.5 mm external fibre cement sheeting.
Internal wall cladding	10 mm thick plasterboard sheeting with recessed edges.
Ceiling cladding	10 mm thick plasterboard sheeting with recessed edges.
Cornice	100 mm wide curved plasterboard cornice.

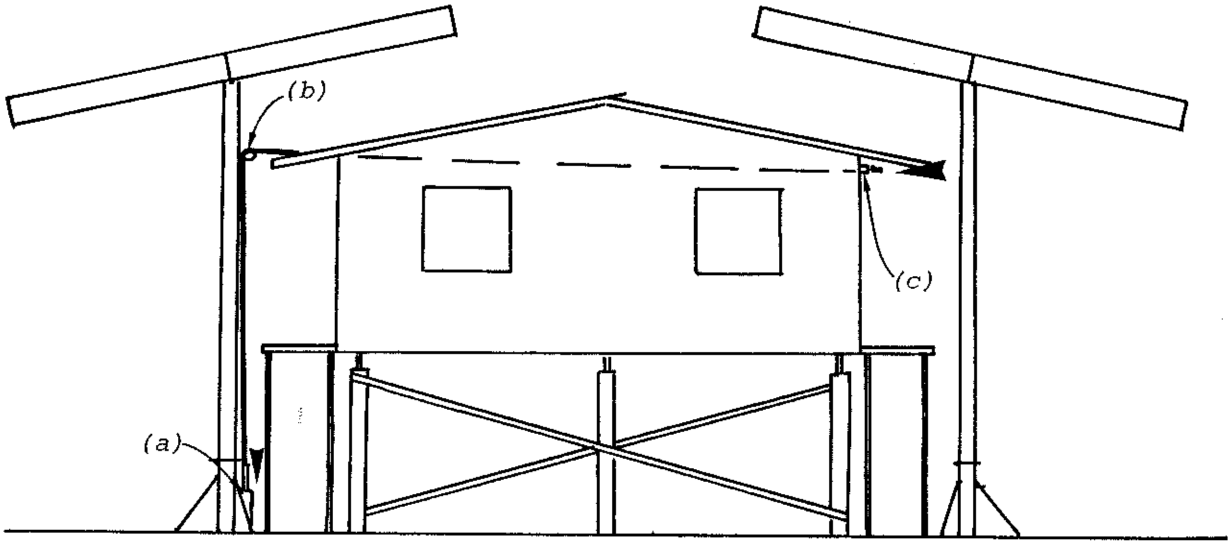
All claddings were fixed in accordance with manufacturers' recommendations.

While the house was structurally complete, it was quite unservicable, as by a digital computer for 18 mean wind directions. Following the analysis of this by Holmes the maximum total loads on the full scale house could and suctions on external surfaces including the underside of the floor. However as the loads were applied to the roof structure the effect of

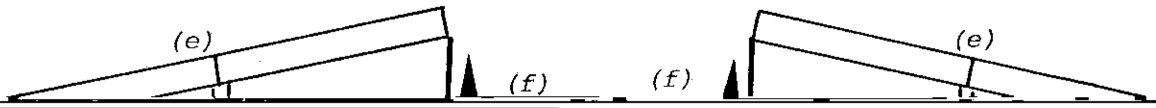
[redacted]

4.1 Loading System

As was seen in the previous section, loads on the house could be divided into lateral loads and uplift loads. The lateral loads acting on the building consisted of pressure loads normal to the wall surface of the windward and leeward walls with the suctions on each side wall cancelling each other out. The action of the wall studs in bending, carries these loads to the wall top plate and the wall bottom plate. The mechanism of load transfer by the studs and the sheeting can be satisfactorily tested in the laboratory, so was omitted from this load simulation. Theoretical analyses, studies of damage following high wind events and tests performed on studs in a house by Boughton and Reardon (1982) indicate that there is ample stiffness and strength in the studs to transfer loads effectively to top and bottom wall plates as a uniformly distributed load with the same total value as the pressure loading on the whole of the house. A [illegible]

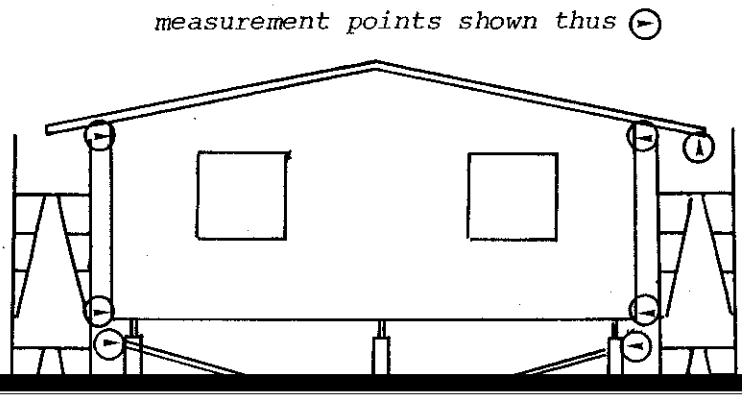


(a) Lateral Loads



The total design uplift forces acting on the house were taken as the highest forces of two alternatives as discussed in Section 3. The highest uplift forces were produced considering full internal pressure, and suction on the outside of the roof sheeting. Thus the appropriate place to apply the uplift loads was in the roof structure. It is generally accepted that with lined eaves, it is possible for the ceiling manhole to blow in and allow the full internal pressure to act on the underside of the roof sheeting. Therefore the total maximum uplift force can be applied directly to the roof sheeting. Again laboratory tests have been extensively used in the past to evaluate the performance of the roof sheeting, and the roof fastening systems.

were measured at up to 52 locations on the structure. A section of scaffolding on the front and back of the house that was independent of both the house and the loading system, provided the datum. Deflection measuring transducers were fixed to this datum with magnetic bases, and relayed information to a micro computer for processing and storage when required. The system is depicted in Figure 6 and described in detail by Boughton (1983).



During the lateral load tests, the transducers were positioned at approximately 1 m intervals along the loaded plate, at the top plate level and bottom plate level,at each wall that ran parallel to the loading cables, level, at and also at the top of each perimeter pile. All of these transducers recorded deflections relative to the ground as datum.

pump controller. At a signal from the computer the pump was started, and the loading cycle commenced. As the load was being applied, the computer there would be little interaction between the walls and the true bracing walls, and stiffnesses could be found. If the stiffness of one wall was for example 10 kN/mm displacement, and in a later test that same wall acting as a diaphragm.

(v) The roof sheeting was then removed, and after installation of the ceiling cladding, the horizontal loads at top plate level were to high wind or other large loads [redacted]

6.1 Uplift on Roof

Uplift loads were generated and applied as indicated in Section 4. The cyclic loading sequence of 10200 cycles as detailed in Section 4.3 was [illegible] truss experienced this load, the uplift load on each truss and the tie-down system as a whole was only 2.2 times the design load. The tie-down system was not showing any signs of permanent damage, but the trusses on each side of the one that had lost the batten screws each showed some splitting of the rafter evident. This supports the failure load obtained in the house tests.

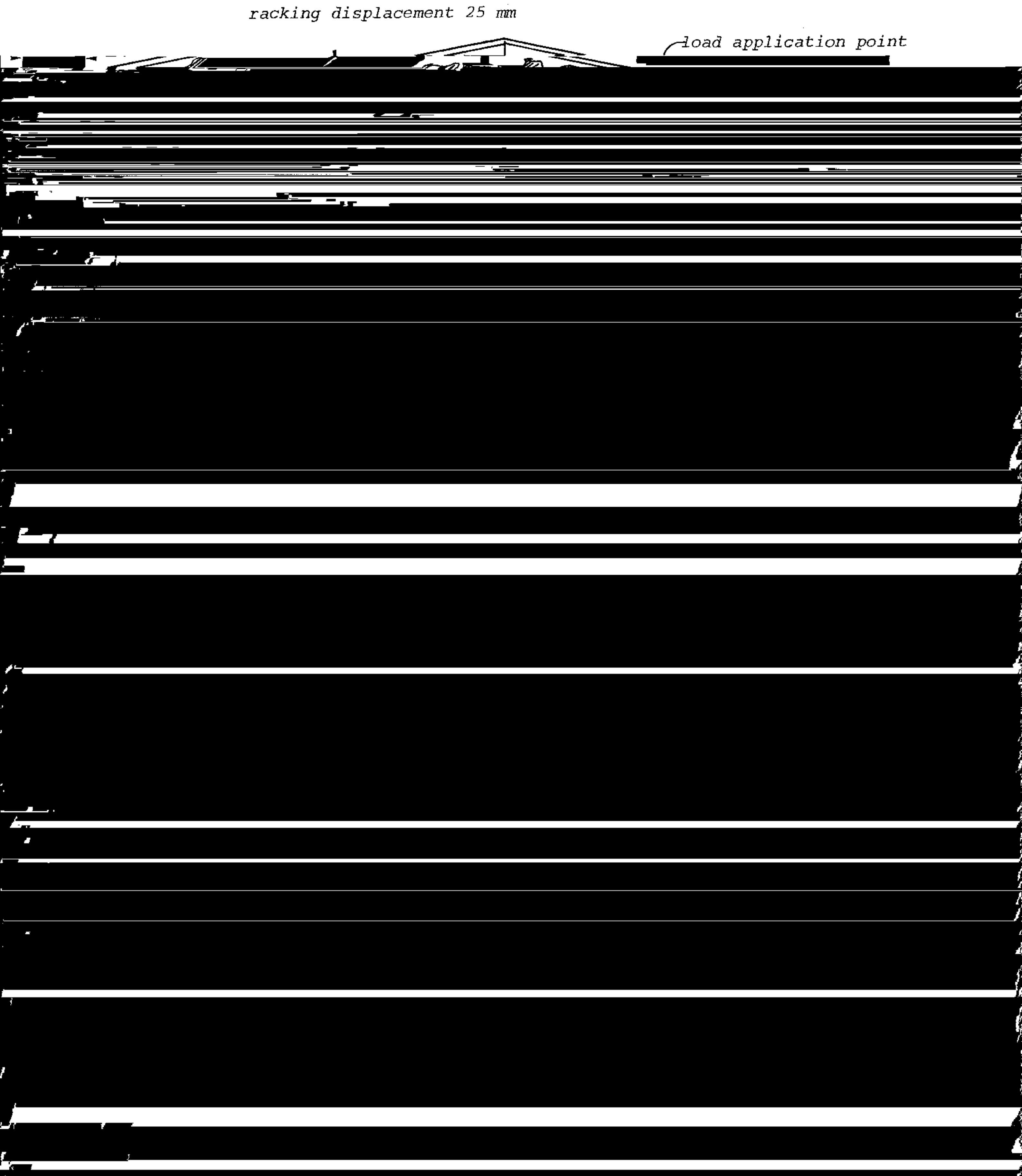
Thus minimum factors of safety obtained in the test were as follows:

Batten screws	3.3
Truss	>2.2
Tie-down system	>2.2

As previously mentioned, the roof sheeting and fastening system employed on the Hyne House was one that has been found to have factors of safety of more than 2.0 in equivalent laboratory tests. It therefore appears that all elements in the uplift forces chain of resistance have minimum factors of safety as built of at least 2, and should therefore perform satisfactorily under design wind conditions.

strengthened four times throughout the course of these tests, but even so the total lateral load was limited to 97 kN, equivalent to 4.75 times design load at top plate level. This limit was placed to prevent failure of sub-floor structural details which could have led to undesired severe damage to the house and testing equipment. The actual sub-floor bracing problems will be discussed in Section 6.3, and all comments in the remainder of Section 6.2 refer only to the house above floor level.

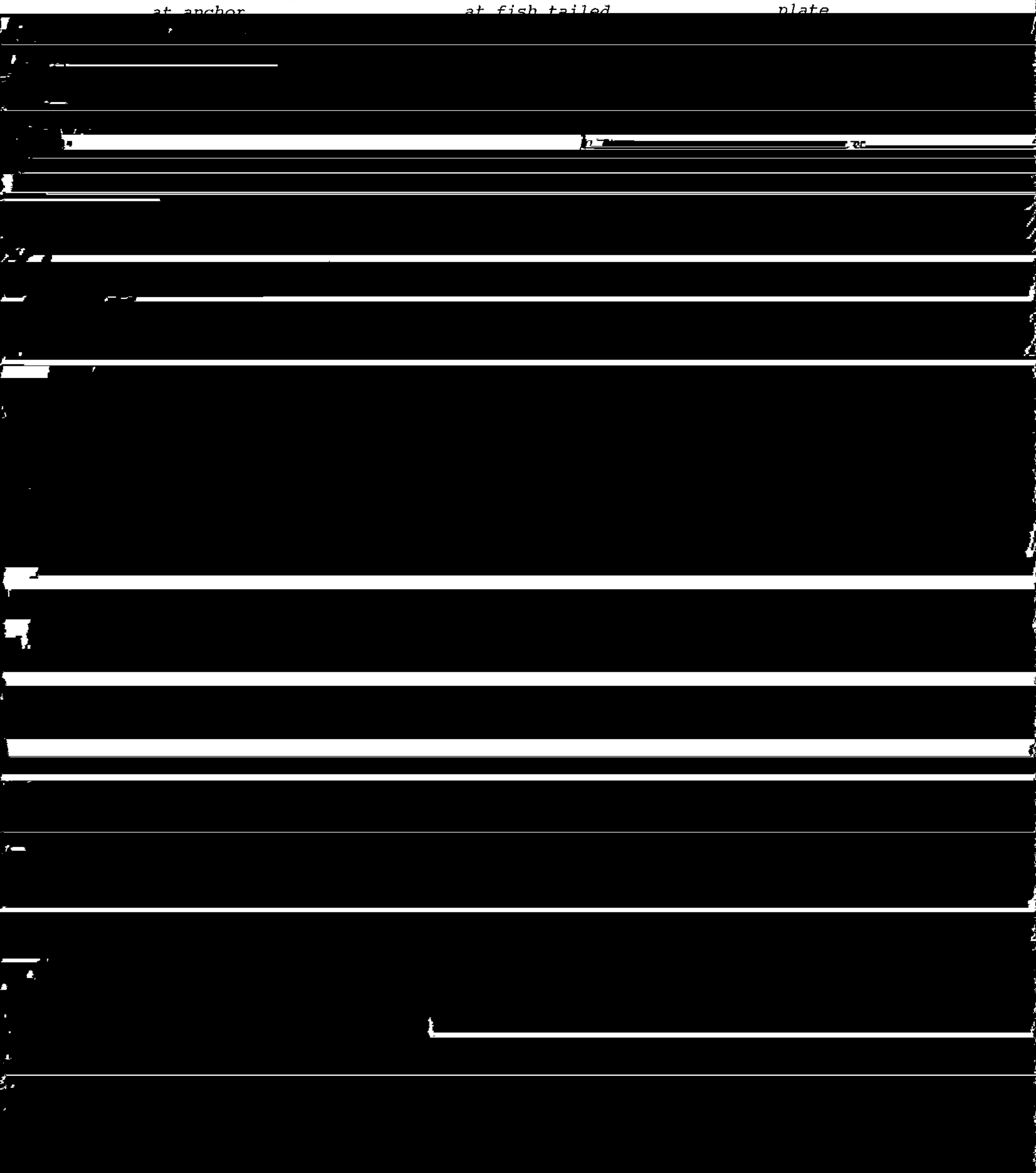
walls. By directly connecting the ceiling cladding to the wall sheeting, shear forces could travel from one diaphragm to another bypassing fasteners in both the ceiling and the walls, timber framework and special bracing wall connections. The cornice was completely removed from the house. This was equivalent to a small timber strip cornice nailed only to the wall frame, and also confirmed that the cornice had carried most of the shear forces into the walls, as the top row of fasteners in the wall plasterboard which had previously been concealed behind the cornice were showing no sign of having carried load. The fasteners near the bottom of most plasterboard walls, however, were showing signs of having carried very significant shear forces out of the walls to the floor. Again 4.75 times the terrain category 3 design load places on each end and the plasterboard had been pushed over the heads of some fasteners by the continual pounding. Again 4.75 times design load was applied to the house but this time some


racking displacement 25 mm
load application point

broken masonry at anchor

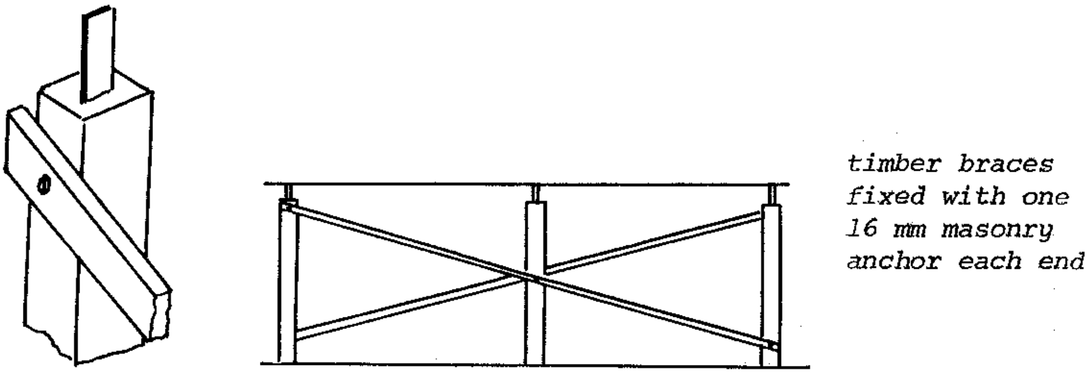
broken masonry at fish tailed

bent fish tailed plate



(i) During the application of a uniformly distributed load at top plate level, failures occurred at column K1, and K3 when the total load on the house was 59 kN or 1.4 times the design load for the sub-floor bracing system. It could be deduced from the load-deflection curves that the fish-tailed plate that secured the bearer to column K3 failed in bending first which removed load from the tension diagonal of the timber bracing set on columns K1, K2 and K3. This transferred extra load to the compression diagonal and caused the concrete failure at the top of column K1.

(ii) To prevent a recurrence of that type of damage, temporary steel



(a) Originally installed

chemical anchors and the bracing system performed well for the remainder of the above floor tests.

At the completion of the tests on the house above floor level, all of the abovementioned temporary bracing was removed. Where concrete had been broken, it was replaced with high strength concrete grout, and the timber braces on columns K1, K2 and K3 changed to the other face of the column where the concrete was undamaged. This also enabled the masonry anchors

Hyne House. A load factor of 2 is generally recommended for design of

[redacted]

(i) The roof, ceiling and floor all functioned as highly effective diaphragms to transmit lateral forces to the top of vertical bracing elements.

(ii) All walls within the house functioned well within their elastic range at working loads, to carry lateral loads from top plate level to floor level.

(iii) The roof structure and tie-down system functioned adequately to

Lysaght Brownbuilt Industries	roof sheeting.
Spurways Cooke	screws and nails.
Teco Pty Ltd	framing anchors.

The Cyclone Testing Station is greatly indebted to Mount Isa Mines Limited, for establishing the MIM Fellowship. Without this fellowship, the house testing project would still be in its infancy.

The authors also wish to thank Associate Professor George Walker for his keen interest in the project and his contribution to on-the-spot assessments of failure modes.

Finally the diligent and enthusiastic work of Mr W. Morris, the technician for the project is also gratefully acknowledged. His patience in unscrewing and rescrewing the roof sheeting six times is to be admired.

9. REFERENCES

BOUGHTON, G.N. (1982). The Bracing Behaviour and Strength of Ribbed Metal Roof Cladding, Proceedings of the Eigth Australasian Conference on the Mechanics of Structures and Materials, University of Newcastle N.S.W.

BOUGHTON, G.N. and REARDON, G.F. (1982). Simulated Wind Tests on a House Part 1 Description, Technical Report No. 12, Cyclone Testing Station James Cook University of North Queensland.

BOUGHTON, G.N. (1983). Load and Deflection Instrumentation for Structural Testing, Technical Report 18, Cyclone Testing Station, 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, Experimental Building Station, North Ryde.

HOLMES, J.D. (1978). Wind Pressures on an Isolated High-Set House.

HOME BUILDING CODE QUEENSLAND (1981). Appendix 4 to the Standard Building