
DARWIN RECONSTRUCTED:
A DOMESTIC ARCHITECTURE FOR KEEPS...

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This document is presented to the Department
of Architecture and Planning, Western Aus-
tralian Institute of Technology, in accord-
ance with the requirements set for the term-
inal unit; Architecture 502.

ANNE BALL
NOVEMBER, 1978.

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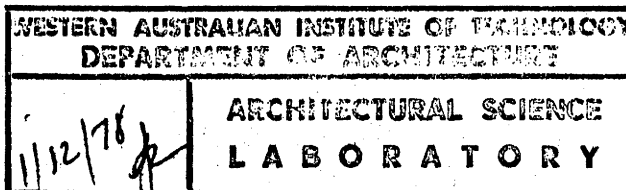
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ABSTRACT

IN THIS REPORT, THE ENVIRONMENTAL DESIGN DETERMINANTS OF DARWIN, AND THE ARCHITECTURAL FORMS WHICH HAVE EVOLVED WITHIN THESE DETERMINANTS, HAVE BEEN OUTLINED.

THE STRUCTURAL AND SOCIAL DETERMINANTS WHICH EMERGED AS A DIRECT RESULT OF THE DEVASTATION INCURRED BY CYCLONE TRACY, ARE SUMMARIZED.

THESE DETERMINANTS ARE THEN ANALYSED COLLECTIVELY TO REVEAL THEIR CONTRIBUTION TO AN UNPRECEDENTED DOMESTIC ARCHITECTURE, DISTINCTIVE IN THE DARWIN CONTEXT.

THE RESULTANT HOUSING FABRIC IS ANALYSED IN TERMS OF ITS MEANING TO THE OCCUPANT, ITS STRUCTURAL SUCCESS AND ITS IMPACT UPON THE RESIDENTIAL SETTING NOW AND IN THE FUTURE.

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SECTION 1 INTRODUCTION

".....if houses are made more and more alike and yet not identical, are not the ambiguities created by slight differences far more disorienting than sharp visual breaks with the past, where a very new arrangement has to be a matter of conscious decision." M. MEAD; EKISTICS, 186: 329-330.

1.0. INTRODUCTION

The production of standardized housing has become a necessity as:

- (i) Sophisticated technology has enabled regions of climatic severity and isolation to become habitable.
- (ii) The displacement of large sectors of the community, due to the technological rearrangement of the social order, creates a demand for low cost housing.
- (iii) This very technology, renders the craftsman non-competitive in many areas of the housing market.

Technological advancement satisfies the demand for mass produced housing that it intrinsically creates. The process is regenerative. The end product has elicited strong criticism, justifiably, from the environmental psychologist.

In the last decade, many studies have been undertaken to determine the behavioural response to these environments which are characterised by anonymity. Questions which arise include:

"Will homes built of new materials be as satisfactory to family usage, as ones built of more conventional materials?"

"Will the new materials dampen or increase noise levels?"

"Are the new materials suited to the specific climatic conditions of a region?"

"Will the houses looking virtually identical to every other house in the complex have any behavioural effects?"^I

"Will the lack of flexibility in these homes render them inadequate as family needs change?"

^I HEIMSTRA, 1974: 44.

"Does the house support the individual group roles of these people who will be forced to live in them?"

"How will interhouse distance and the orientation of doors affect social interaction?"

"Will the house form and location expose the inhabitants to unnecessary social prejudice?"

The findings of these studies, often reveal areas of conflict and alienation in housing environments. These implications may be acknowledged by the authorities, who are forced under economic pressure to produce a standard item. Unfortunately however, these studies do not offer a set of well prepared documents for an alternative scheme which can be effected within the same economic framework. Thus the standardized item continues to be produced with only minor modifications to accommodate a new production technique or available material.

In the Australian context, mass produced housing has had a limited impact in the major centres. Traditionally, these have been characterized by strongly defined nuclear family territories containing detached dwellings, relatively rich with display and personalization. The Australian home is, in fact, elongated across the front of the suburban allotment to increase its potential for display.

In Australia, mass produced housing has had most impact in mining towns, where it is provided as an incentive to stabilize a population without which the mining operation is not viable.

Darwin is a city sharing characteristics of isolation and climatic severity similar to most Australian mining towns, although unique in its raison d'etre. Housing in Darwin has been erected to entice the population needed to support its frontier administrative role. The bulk of housing in Darwin was designed and constructed by the Commonwealth Department of Housing and Construction for use by Commonwealth Public Service employees. More recently, as Darwin has emerged as a city in its own right, the Housing Commission have become responsible for the construction of low cost housing for the private sector. In addition, privately constructed dwellings have begun to make some impact upon the Darwin housing scene.

The Public Service housing, constructed under bulk contracts, was to determine the basic flavour of domestic architecture.

The Tropical Savanna climate, associated with Darwin's geographical location, creates a set of conditions quite unique when compared with those for which mass housing is constructed in other parts of Australia. It is clearly the primary determinant of the house form which has evolved.

This report will deal with the nature of these conditions and the principles which must be implemented in the built form to ameliorate the severity and achieve standards acceptable to Europeans.

An even more unique circumstance of Darwin, and the reason it is the subject of this study, is the occurrence in December 1974, of Tracy, an intense tropical cyclone, which effectively destroyed the bulk of newly constructed houses.

While Tracy is remembered with bitterness by many of the victims and as an economic liability for the nation, she was to become an unrequested salvation, for those who had experienced, through occupancy, the shortcomings of mass produced housing.

The special value of the disaster in the architectural sense is the opportunity it created for reconstruction, and more significantly, the opportunity for individuals to build their own homes, under the same conditions of isolation, limited resources and maximum economy, as the authorities who are engaged in housing construction under bulk contracts.

The owner-builder, either by resorting to his own devices, or with the assistance of private contractors and specialists, has produced homes quite different in the Darwin context. The cumulative impact of these individual contributions has significantly shaped the appearance of Darwin, post cyclone. Each home clearly demonstrates that a house is more than the provision of shelter, and is inextricably entwined with symbols, which are often subconsciously expressed without realization in the act of building.

Clearly, the meaning of "home" is very different for each individual, depending on his environmental background, to which the emerging built environment in Darwin bears testimony.

It is this fact that I found most evident after several days of observation in Darwin. The architecture truly expresses the psychological and functional reaction against monotony and lack of identity which previously characterised Darwin's residential developments.

Thus the first objective of this study is to:

ASSESS THE MANNER IN WHICH INDIVIDUAL HOME OWNER BUILDERS HAVE
ACHIEVED THE EXPRESSION OF SELF THROUGH THEIR BUILDING ACTIVITY.

This assessment can only be of value where there exists the triad
at geographical isolation, cyclonic vulnerability and climatic
stress, which is characteristic of Darwin. These factors interplay
to influence the individual choice of house.

The very specific need for hazard mitigation and disaster relief,
created by Tracy, clearly distorts individual perceptions of "home",
to varying degrees, which presumably mellows over time. For this
reason the initial objective encompasses:

THE ASSESSMENT OF REACTIONS TO A MAJOR NATURAL DISASTER AS EXPRESSED
BY THE RESULTING BUILT FORM.

A natural disaster is only recognized as such because of the losses
in human or material terms, which are incurred. The most basic
function of any structure is protection of its inhabitants from ex-
posure to predicted hazards. Because "Tracy" so clearly demonstrated
the need for a structure to mitigate the effects of cyclonic damage,
if loss is to be avoided, the second objective of this study is to:

ASSESS THE BUILT ENVIRONMENT, THE CONSTRUCTION METHODS, MATERIALS
AND SYSTEMS USED, AS A FUNCTIONAL DEVICE AGAINST EXTREME WIND LOADING.

Also included in the report is an analysis of the structural requirements, at the domestic level of construction, for adequate structural integrity to resist loadings equivalent to those generated by Tracy.

It was written by Olivier Marc that:

To build a house is to create an area of peace, calm and security, a replica of our own mother's womb, where we can leave the world and listen to our rhythm; it is to create a place of our very own, safe from danger. For once we have crossed the threshold and shut the door behind us, we can be at one with ourselves.

Olivier Marc describes an intimacy with home that few of us have the physical or psychological freedom to achieve. The ingredients of this architectural recipe, are restricted in Darwin by a monopolized and limited system of supply and the products of small scale technology. The method is restricted to time honoured building practice, building regulations, the system's intolerance to change and well defined natural determinants.

The ideal of free architectural expression is further diminished by the limits of each individual's frame of reference and the urgency created by post disaster havoc.

It is intended in this report to discuss and summarize the social, political and economic setting within which reconstruction was staged.

Many of the housing solutions were naturally the direct result of the post cyclone conditions which no longer exist. These houses, together, however, form a vital link in the architectural record of Darwin's history.

They form the precedent to architectural events which follow. It is therefore of interest, to predict, how these homes will perform, practically and aesthetically, for their anticipated life span. Will these homes as individual units and as arrangements of units, juxtaposed in a variety of ways, enhance or intrude upon the landscape? - Thus the third objective of this study is:

TO ASSESS THE HABITABILITY AND THE AESTHETIC IMPACT OF THIS CLASS OF RECONSTRUCTION OVER TIME, FOR ITS ANTICIPATED LIFE PERIOD.

The more practical value, however, of the privately constructed homes is their potential influence upon future developments in the public sector, should the present demand for housing persist.

To assess the suitability of the house forms, as prototypes determining the shape of future mass produced housing, it is necessary to take a closer look at those components which have rendered successful some of the designs. Are they successful when measured by the public sector yardstick?

Can these results only be achieved through greater monetary expenditure?

Is it merely through the act of creation that satisfaction is achieved, rather than through the creation itself?

Could economies of scale be realized with the adaptation of successful principles to mass production?

While this area of investigation was not an initial objective of this study, it became strongly evident that much can be learned from the private sector.

If the principles are adopted, then the reconstruction of Darwin has truly been a worthwhile exercise in revitalizing the quality of the home environment. Certainly, constant reference is made in reports compiled by the Department of Housing and Construction that house types require constant re-assessment and that new materials and methods of construction need to be researched and prototypes developed which stimulate thought about design and encourage new ideas.

To quote from a report prepared in 1973 for the Australian Government Department of Works, Northern Territory Region:

..... materials and methods of construction need to be critically re-examined in the light of advancing technology and the wide range of products available in southern capitals. Perhaps the initiatives in this field must, of necessity, be with private enterprise and the design of individual houses can only proceed within the established criteria that exists along traditional lines, until acceptable alternative solutions are offered.

This subject is really beyond the scope of this research programme, although some personal recommendations are made in conclusion, in the light of findings which have revealed some very exciting possibilities for low cost housing in the future.

The comments which constitute this report are based upon three months of contact with home owners, builders, building industry dictators, professionals in the design fields and other persons qualified, by their direct experience with the reconstruction of Darwin, to offer worthwhile comments.

SECTION 2 ENVIRONMENTAL DETERMINANTS

Physiological evidence would seem to indicate that man, with his relative hairlessness and a sweating mechanism which provides a heat regulating mechanism superior to that of any other animal, had his origin in the tropics. With increasing ability to control the effects of an unfavourable environment some members of the human race succeeded in establishing themselves in climates far removed from that of their original home. Very recently, some of these people have returned to the tropics, but have brought with them a manner of living unsuited to their new environment.

McPHERSON, 1962: 73

2.0 ENVIRONMENTAL DETERMINANTS

2.1. CHARACTERISTICS OF GEOGRAPHICAL LOCATION

Located at latitude 12°40' south, Darwin experiences a climate known as Tropical Savanna, which is characterized by a hot wet summer, with day temperatures ranging between 29-35°C, and high night temperatures between 25-30°C. By comparison the winter is dry, although generally warm, with day temperatures ranging between 25-30°C and night temperatures ranging from 16-21°C.^I

Because of its latitude, Darwin is subject to direct solar radiation from both the north and the south - a problem not encountered in the temperate regions of Australia. Sunshine tables, do allow accurate calculation of sun penetration into a building at any time. See Figure 3 for this data.

A greater source of discomfort than the high dry bulb temperature however, is the consistently high humidity which ranges from between 70-80% in the wet season (summer), to between 50-70% in the dry season (winter).

The wet season which occurs between November and March is considered less comfortable because the small daily temperature range (between 5.5-8°C), which means little relief is obtainable during sleeping hours. This is aggravated by the high humidity levels which limits the efficiency of the evaporative process.

Thunderstorms, associated with high rainfall intensities, are frequent during the early weeks of the WET, during which time 90% of the annual rainfall of 1400 mm precipitates.

^I DRYSDALE; 1975: 3

The wind directions during the WET are mostly weak south easterlies through to north - north westerlies. It is during this period that air movement is most essential for relief from high wet bulb temperatures. Refer Figure 1.

Monsoonal driving rains also prevail from this direction.

Cloudy skies are especially frequent during the wet season and during the weeks immediately preceeding the WET, known as the "build up". Large clouds often reflect bright sunshine, causing an increase in radiation intensity by up to 10%.¹ On occasions when the sky is completely over-cast, clouds shielding the sun, disperse the solar radiation making the whole sky a source of heat and glare. This is particularly uncomfortable when the cloud depth is thin.

The dry season, which occurs between May and September is less intense and consequently less stressful. Stronger winds from the east through to the south, do however, create a dust nuisance which originates in the hot dry dusty hinterland to the south east.

Refer to Figure 1.

The conditions which prevail, promote the growth of luxuriant tropical vegetation. In the regions where tropical rainforest formed the natural landscape of which only small pockets still remain, gardens and parklands can be established with relative ease and speed. This assists in alleviating, localized dust problems and reflected radiation. This is a greater problem in the adjacent arid regions.

Except for the rainforest which is virtually non-existent today, Darwin has few natural resources, suitable for shelter as the European man has come to expect.

¹SAINI; 1970: 23

There are some regions abundant in clay loamy soil within suburban sub-divisions suitable for pise construction, although a component of portland cement is required to upgrade its stability to meet today's building standards.

2.2 PRINCIPLES OF ENVIRONMENTAL AMELIORATION

2.2.1 BASIC PRECEDENTS

Figure 2 illustrates the basic shelter forms evolved under similar climatic conditions in Florida and Colombia. In other parts of the world where hot humid conditions prevail, where visual privacy is socially important, open work screens are integrated into similar basic structures.¹

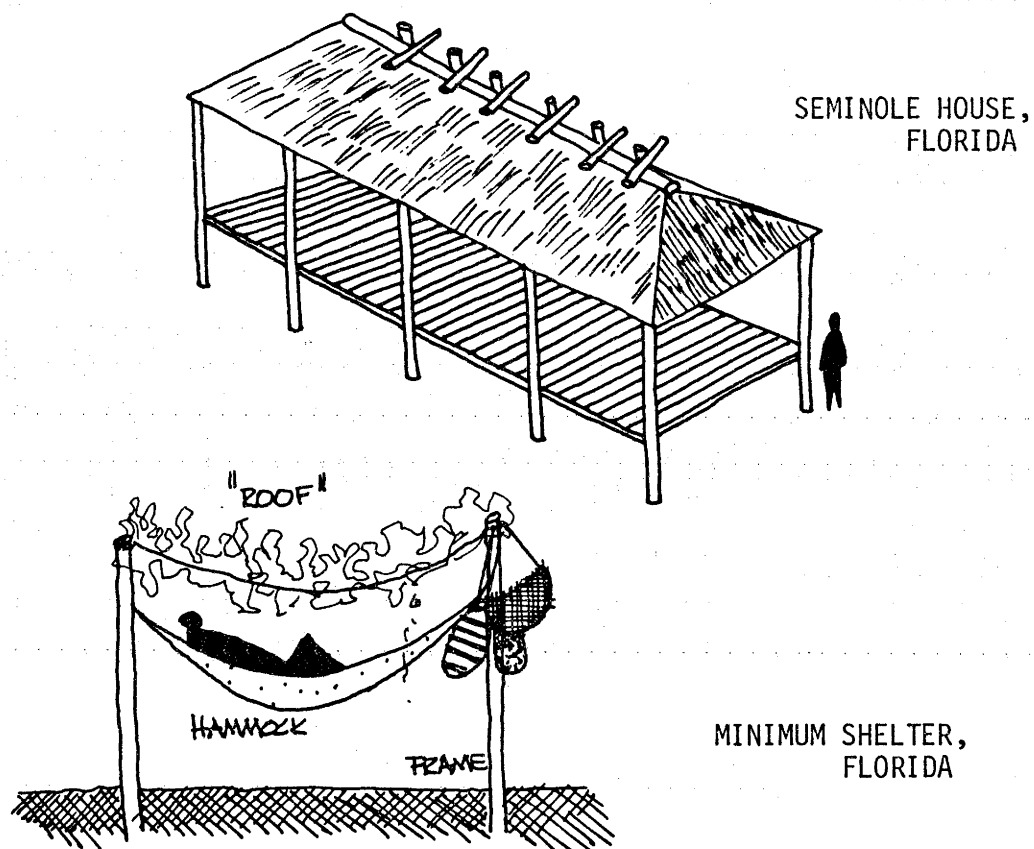


FIGURE 2 - BASIC SHELTER FORMS IN HOT HUMID REGIONS

¹ RAPOPORT; 1969: 95

2.2.2 SUN CONTROL - SHADING

Solar radiation, whether diffuse or direct is the most significant source of heat gain in a building, and thus the primary cause of discomfort. The increase in temperature of exposed external surfaces which can be as much as 17-36°C has an accelerating effect on heat flow into the material, which in turn alters the internal temperature via radiation, conduction and convection of heat.¹

The basic solution to this problem is the provision of shade to the structure and to the adjacent area to minimize reflective heat.

The effect of shading which is desired, is maintenance of the external surface temperature at or near the shaded air temperature.

This can be achieved in a variety of ways.

(i) Orientation

If a building is rectangular, then orientation along the east-west axis, (ie long sides facing north & south) ensures that one long side is completely shaded at all times of the year, and the opposite long wall can easily be protected with 900 mm eaves, at most times when radiation is intense. Early mornings and evenings pose a sun penetration problem of greater complexity. East and west walls should be constructed as a barrier against heat transmission into the interior.

(ii) Shading Devices

The roof, because of its orientation, requires the most careful attention in the design stage as a shading device. This assists in minimizing heat transmission through to the substructure and protects materials, highly susceptible to deterioration in a climate of this severity.

¹ SAINI, 1970: 24

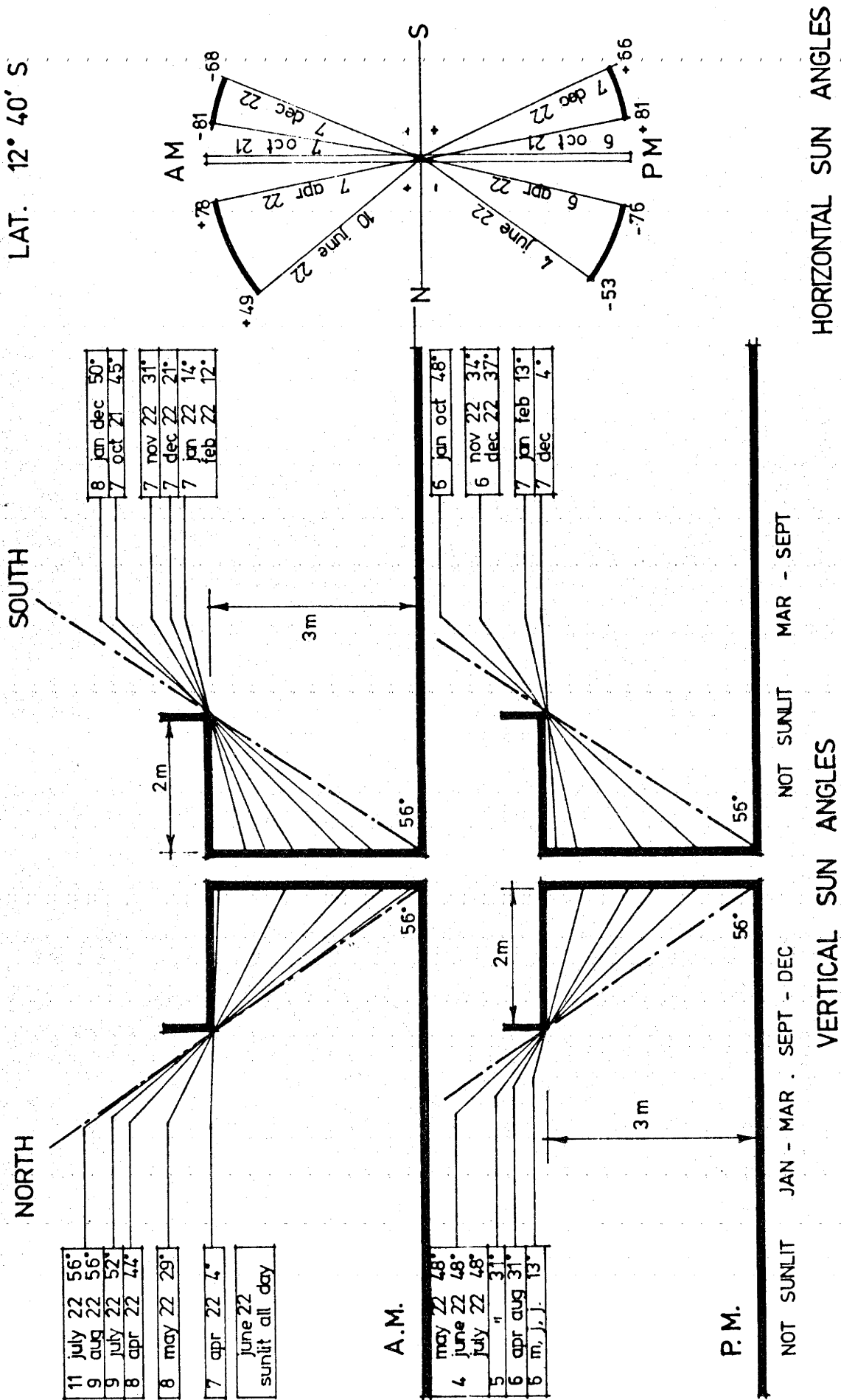


FIGURE 3 NORTH & SOUTH SUN ANGLES FOR DARWIN

EAST

WEST

LAT. 12°40' S

10	jan-aug	43°-48°
9		27°-40°
8		12°-25°
7	j. f. m. a. j. - 5°	
	s. o. n. d. 6°-11°	

A. M.

P. M.

NOT SUNLIT IN P. M.

VERTICAL SUN ANGLES

NOT SUNLIT IN A. M.

HORIZONTAL SUN ANGLES

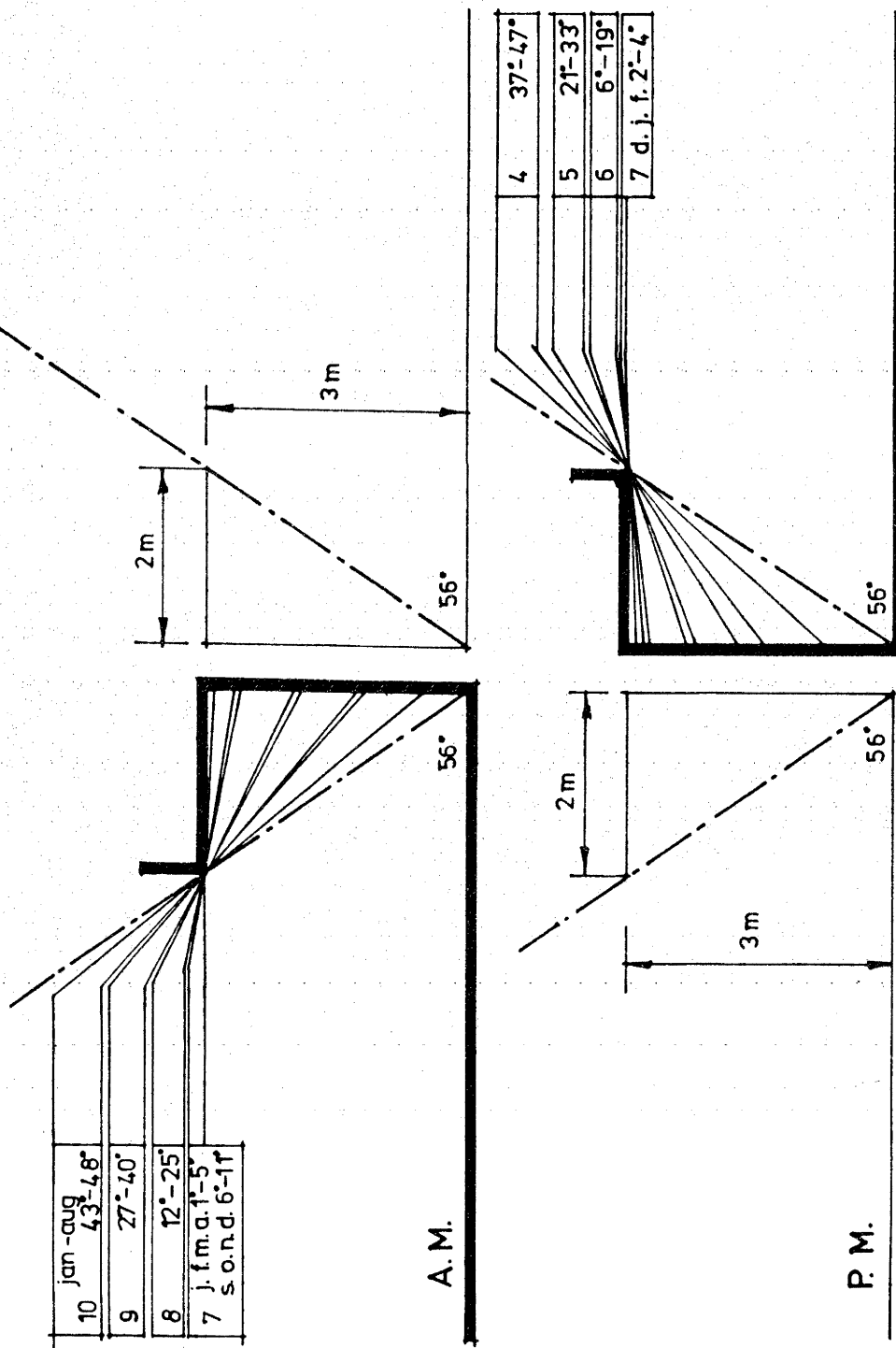


FIGURE 3 (CONTINUED) EAST & WEST SUN ANGLES FOR DARWIN

Alternatively, louvres and wall projections can shade external surfaces. The effectiveness of such devices can be diminished if they become heat stores. Vegetation, provided it does not restrict air-flow or shade a roof mounted solar absorber, if installed, is a most aesthetic and effective means of shading a building. Heavy planting adjacent to east and west walls, which are not usually open to breeze access, can reduce the need to insulate, hopefully inducing a cost reduction.

2.2.3 AIR MOVEMENT

The high vapour content in the atmosphere especially during the wet months inhibits the evaporation process on the skin surface creating an abnormally high body temperature. This cooling process must therefore be stimulated by activating fresh air across the body. This causes a sensation of coolness, particularly desirable in the afternoon and late evening.

(i) Passive Control

To promote this effect, air-flow should be unrestricted across the home, normal to the wind direction.

The "one-room deep" house minimizes the obstruction of air-flow through the building.

As is evident from Figure 1, the most relieving breezes - those during the wet season - come from the north-west.

To optimize the benefits of shading, and cross ventilation due to orientation, the ideal house orientation is calculated to be 15° west of north, east of south.

The nature of air movement in the home is also vital. Openings and wind deflectors must be installed to ensure air-flow across the body in all normal positions of domestic activity. An upward breeze tends to achieve a more satisfactory result. Ideally, lower openings of horizontally adjustable louvres allow the breeze to be projected upwards. This also forms a more effective barrier against driving rains. Mid-wall and upper opening louvres are more effective if vertically adjustable, allowing breeze, parallel to the building surfaces to be deflected into the building.

(ii) Mechanical Aide

A constant flow of air across the internal spaces of a building cannot always be maintained using natural means. Very still conditions are frequent, often coinciding with periods of high humidity. Light breezes do not eddy around corners and cannot therefore penetrate living areas if they are incident, normal to the end blank walls. Insect screens also inhibit penetration, if they are dirty and the angle of incidence of the breeze is low.

The simplest and most economic system suitable in assisting air movement is the air circulating fan. If mounted on the ceiling, a vertical air-flow is created beneath the fan, and a horizontal air-flow across the room with fans of diameter greater than 1000 mm. See Figure 4 overleaf.

The cooling effect of air movement corresponds to air-flow to an optimum of about 200 feet per minute. In rooms of greater than normal volume - the vertical air-flow, achieved by the ceiling fan can be directed across the space by installing wall mounted fans of up to 24 inches in diameter. The ceiling fan does however offer advantages of energy, economy, quietness and safety.¹

¹ SAINI; 1970: 35

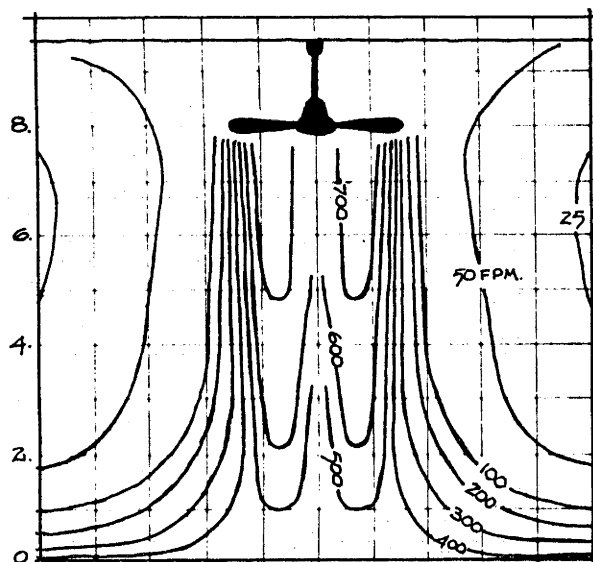


FIGURE 4: Air velocity distribution contours for a ceiling mounted air circulating fan.

2.2.4 VENTILATION

Ventilation, by comparison to air movement is the expulsion of "used" air, be it hot, stale or smelly air from internal spaces. The dissemination of hot air prevents heat build up in an enclosed space and effects cooler air-flow into the space from outdoors. This action allows the internal air temperature to approximate the external air temperature simulating the environment beneath a thick shady tree. Ventilating roof space is particularly beneficial by removing a major heat source which can raise the surface ceiling temperature. Experimental work indicates a reduction of 30°C in roof space can be effected with ventilation.¹

Enclosed roof spaces also tend to maintain high humidity levels, which increases condensation prompting fungus and mildew growth with a corresponding deterioration in roof and ceiling fabric.

Exhaust fans are commonly used to expel cooking, laundry and washing odours and excess heat.

¹ BONNER ATKINSON & SHAND, 1973(a): 8

2.2.5 INSULATION

The need for insulation in a structure is of course considerably reduced if the principles of shading, and air movement are satisfactorily achieved. However the materials selected for a building, the treatment of these surfaces and the manner in which they are constructed together determine how much, and at what time, heat is radiated, conducted and convected into an enclosed space. Thus in climatic amelioration, methods of construction and materials are important.

(i) Conduction

Heat gains into a building by conduction from the surroundings can be reduced by increasing the insulation qualities of the structure - as measured by heat transmission coefficients. The effect of insulation in the tropics, where the diurnal temperature range is low, is limited, as heat, accumulated within the building cannot be released through the structure when temperatures do drop marginally in the evenings.

For this reason light weight framed construction is more suitable for the Darwin environment. Because sensitivity to temperature change is high in a light weight structure, conditions within the home can become intolerable during the day when solar radiation is at peak intensity.

A combination of light and heavy weight construction, determined by the nature and time of room use, room relationships and orientation, can eliminate most heat gains, through conduction, with considered planning.

Massive flat roofs of high thermal capacity, are an alternative, for the benefits of structural stability, economy and sound insulation which they afford. However a penalty of delayed heat transmission is incurred. This can be minimized with the addition of earth, vegetation or water into the roof slab. The time lag between the upper and lower surface in a 150 mm concrete slab is 5 hours - a 200 mm slab is 6 hours.¹ Vegetation has a cooling effect upon the air above the roof, preserves moisture in the soil, maintaining the temperature at a reduced constant. By stabilizing moisture content and temperature, the concrete slab is preserved. It has been found that if 1 inch of water is maintained over a roof, the heat flow is only 35% of the amount which would flow through a dry roof of similar construction.² This insulation principle is normally associated with arid regions where increased time lag is desirable to counteract the cold evening temperatures. Darwin, however, does have, as a legacy of the cyclone a number of heavily reinforced concrete slab roofs of thicknesses capable of supporting insulation weight of the magnitude that would be incurred by earth coverage.

(ii) Radiation

The control of heat transfer through radiation is a more complex problem. As the vertical surfaces of a building can be easily shaded, the roof becomes the chief medium for radiated heat transfer. The downward penetration of heat is especially oppressive to the occupants.

The main control of radiation is reflection, achieved by increasing the reflective quality of the surface or increasing the angle of the incident ray upon a surface.

¹ & ²
SAINI; 1970: 30

Thus the most effective way of reducing heat gain through radiation is to increase the reflective quality of the roof. Reflective insulation is effective, while the surface remains free of dust. However in regions where dust accumulates on ceilings, the efficiency of such materials, has been shown to depreciate by half in twelve months. Corrugated iron and asbestos sheets, also tend to be inefficient as reflectors unless coated by lime or reflective paint.¹

Increasing the angle of incidence of the sun's rays intersecting a building surface, has the effect of increasing the reflected component of solar radiation, with a corresponding reduction in heat gain. The sphere, preferably painted white, is the most efficient geometric form in this regard, as the area subject to rays incident at 90° at any time, is minimized. Alternatively increased roof slope and profiled roofing materials can assist in reflection. The flat roof at theoretical midday is the most inefficient solar reflector. As discussed earlier, the flat roof requires special attention if comfortable conditions are to be created internally, or mechanical aides allowed to operate efficiently.

(iii) The Parasol Roof

This parasol roof form combines the principles of insulation and reflectivity. The parasol allows the ceiling to be treated as a shaded wall, allowing the insulation value of the ceiling to be considerably reduced. Heat transferred into the air (optimum depth .6 mm of air space) by conduction and convection can substantially reduce heat load on a building if this heated air is expelled at a rate in the vicinity of .9 cu m/sec.²

¹ SAINI; 1970: 30

² BONNER ATKINSON & SHAND; 1973(b): 6

Insulation of the underside of the parasol can arrest the radiated heat flow across the air space during the day. Because the parasol allows ceiling insulation to be reduced, the rate of heat dissipation from the building in the evening is increased.

2.2.6 WEATHER SEAL

Water penetration in buildings is a problem created by the intense rainfall, in conjunction with the high speed gusts. This means window protection in the forms of eaves or verandahs, need to be of a considerable depth to be effective. High levels of humidity and weak breezes coincide to create critical levels of discomfort prior to precipitation. If protection to openings is not adequate, these must be closed to protect internal finishes from water damage, making internal conditions unbearable. The use of the hopper window and louvre bank are less restrictive in this regard. Atmospheric moisture is a problem of sufficient magnitude to necessitate the ventilation of all cupboards, and floors (usually timber) to prevent mildew and fungus growth.

2.2.7 INSECT & VERMIN PROTECTION

White ants are a real threat to timber and earth structures in the tropics. For this reason tropical houses are elevated to allow sub-structure inspection and increase illumination in locations susceptible to attack. The problem of biting insects subject to fluctuation corresponding to seasonal and tidal change, necessitate the installation of screens over most openings. Screens have the undesirable effect of restricting air-flow especially as the incident angle of the breeze upon the screens decreases.

Dust collection on screens also contributes to restriction in breeze penetration. Cockroaches are an additional problem, requiring all cavities, where cockroaches may breed to be sealed. It is common practice to suspend cupboards off the floor, eliminating this most likely breeding ground.

2.2.8. DUST CONTROL

High levels of atmospheric dust, creates a household nuisance in the dry season. This problem is not easily overcome without reducing the efficiency of other climatic controls. Vegetation, surrounding an elevated home is the domestic situation of least vulnerability. Sealing of roof spaces to prevent dust collection is unfortunately in total conflict with the ideal of the parasol roof arrangement.

2.3. ARTIFICIAL CONTROL

The principles of climatic amelioration previously outlined can only create an environment as comfortable as those which could be experienced in a shaded outdoor position. As accommodation standards are raised, people's comfort expectations have increased to a level whereby air conditioning is considered a necessity by many.

It is not intended that technical aspects of air conditioning systems be analysed in this report, but the resultant design changes effected by the installation of air conditioning is significant. Naturally if the heat loads on a building can be minimized by adopting the architectural principles of shading, and radiation reflection, the resultant efficiency in maintaining the artificial environment can effect a reduction in running cost and installation cost of the system.

2.3.1 ESSENTIAL DESIGN CHANGES TO OPTIMIZE EFFICIENCY

(i) In contrast to the non air conditioned space, where air-flow is unrestricted and the thermal capacity of structure is low, the air conditioned home must be effectively sealed, to prevent the escape of conditioned air, and insulated to prevent the transfer of the negative heat load, thus created through the building.

(ii) The design must be compact to reduce the external surface area (thus potential inefficiency) and minimize the volume of ducting space.

(iii) The energy load on any system is directly related to the room volume and thus to offset the extremely high operating cost, room volume is reduced.

These are the principle three ways in which designs are affected by controlling the internal environment artificially. In many respects these requirements are in complete contrast to the architectural principles of passive control.

2.3.2 DESIGN ADVANTAGES

(i) The principles of effective air-flow are often achieved at the expense of an adequate weather seal and more significantly at the expense of structural integrity. By reducing opening size to improve the house seal, the former problem is resolved and by compacting the design much greater structural stability is achieved. The use of materials with a high insulating quality, usually increase the debris resistance of the structure.

- (ii) Because the climatic determinants are clearly understood and relatively strict, design features tend to become repetitive, creating monotonous and ugly streetscapes. Air conditioned houses are not subject to the same restrictive determinants.
- (iii) Many of the nuisances associated with tropical living such as mildew, insects, dust and glare, can be more easily controlled in an air conditioned environment.

2.3.3 DESIGN DISADVANTAGES

- (i) The most obvious penalty for all the additional comforts is cost, created by system operating and plant installation.
- (ii) Space penalties are incurred to accommodate the operating plant and ducting network.
- (iii) A structure designed to assist in the efficient operation of an artificial system, is uncomfortable - even intolerable - if the system is to suffer a failure either mechanically or at the energy source. Power failures are a regular occurrence during the wet season in Darwin.

2.3.4 FUTURE PROSPECTS

Solar air conditioning systems have the potential of overcoming many of the disadvantages presently associated with artificial environmental control, when a system can be simplified and perfected to make the cost of plant components realistic. This will become a particularly advantageous technological advance to Darwin, where radiation intensities are constantly high. - Generating on average 2 kw hours per square metre of roof area.¹

¹ BONNER ATKINSON & SHAND; 1973(b): 10

2.4 THE EVOLUTION OF THE DARWIN HOME

2.4.1 THE FIRST HOMES

The early homes constructed in Darwin were Australian adaptations of the nineteenth century British colonial bungalow homes, modified to suit the tropics.

The basic home was a large - tending to square core, encircled with a deep verandah and capped with a deep elegant, but simple roof.

Housed beneath this all embracing roof were spacious bedrooms and living areas all opening onto the deep verandah. The kitchen, pantry and dining room were integrated into the core of Australian homes when domestic labour could not be employed.

The ceilings were high and ventilated into the large roof space which was also ventilated either along the ridge or at the gable ends.

The structure was light weight and usually clad in asbestos or weatherboard with corrugated iron to the roof.

The deep verandah provided shade to all walls, insulating them against the intense solar radiation. The washing areas were usually situated in an enclosed section of the verandah.

2.4.2 ADAPTATIONS FOR THE TROPICS

In tropical regions these homes were elevated to subject the structure to prevailing breeze and protect it from white ant attack.

However, the compact, square layout did not allow breezes to flow through the bedrooms. Consequently the verandahs were enclosed by fly wire, sometimes latticed to reduce glare and became the main sleeping and living area.

The lattice work was not however effective against driving rains, and thus canvas blinds were installed which had the undesirable effect of blocking the breeze at critical times of high humidity. These old homes were of sound geometric form and aesthetically beneficial to the streetscape, despite their simplicity and repetition.

2.4.3 THE ONE ROOM DEEP HOUSE

The inadequacies of the early homes inspired a reviewal of housing principles in the fifties, when Darwin was on the brink of an enormous acceleration in population increase.

The result was the one room deep, elongated plan. - An architectural form which was to have the most significant impact on the suburban character over the years which preceded cyclone Tracy. This house form was the architectural manifestation of a desire to optimize air movement across the body and the resultant cooling effect. The one room deep house orientated north-south composed almost entirely of louver banks on the long sides, with internal walls terminating 600-900 mm below the ceiling, encouraged cross ventilation at all times.

Refer Figure 5 overleaf.

It was in itself an ideal solution in a hot humid climate. Its development however coincided with other factors which cumulatively were to render it inadequate. A rapidly expanding Public Service created a demand for housing unprecedented in Darwin. Monotonous rows of this house form were constructed in the central residential areas until these were fully developed compelling new residential areas to the north of the city to be opened up, where the monotonous sprawl was to continue.

The need to reduce costs, which coincided with this period of rapid development meant verandahs dwindled in size, exposing large openings to driving rains, sun penetration and neighbours. Allotment sizes were reduced which, aggravated the problem of aural and visual privacy, interrupted the air-flow and increased noise pollution. This proximity to neighbours was in complete conflict with the accepted ideal of the encapsulated nuclear family.

The louvres were a cleaning burden to the householder, and did little to prevent dust penetration even when closed.



FIGURE 5. Typical "one room deep" house.

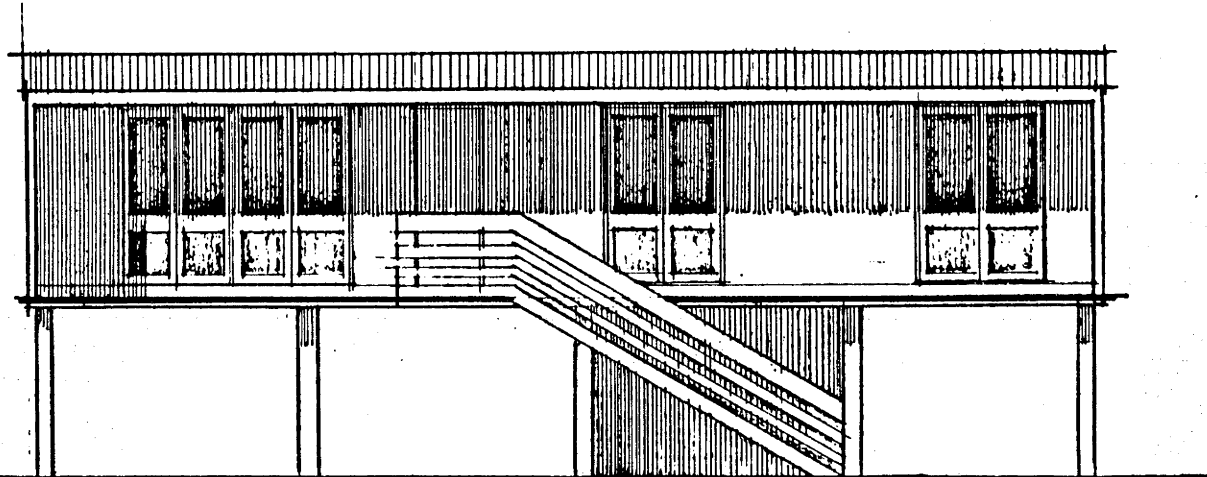
Note the similitude of this house form with the basic precedents illustrated in Figure 2.

2.4.4 THE "M" & "T" SERIES HOMES

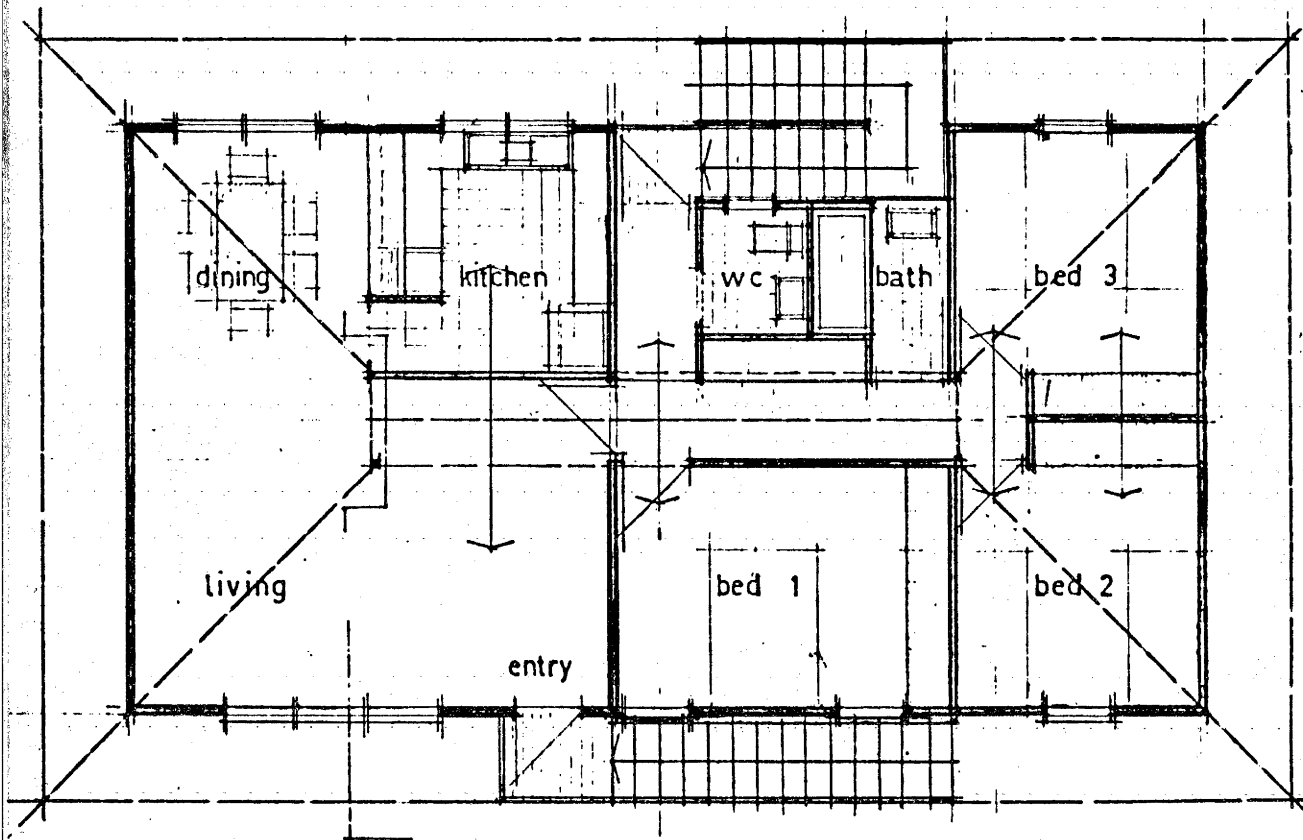
Alternative housing types were developed and constructed in an attempt to overcome some of the shortcomings of the one room deep house and to allow system components to be incorporated in the construction. The two major alternative forms were the "M" & "T" series. Refer Figure 6 & 7.

The "M" type house was more suitable to the smaller sites and more economical to build by virtue of its more compact proportion. The penalty incurred however was less effective cross ventilation, making the ceiling fan a necessity. Further modifications to design were made in an attempt to promote air-flow. Louvred doors were used internally and a trunk above the central passage opening into a ventilated roof ridge, dissipated hot air from bedrooms, setting up convection currents to draw cooler air in through the openings. The additional cost was again offset by reducing ceiling height and verandah area.

An adaptation of the basic plan to suit ground level construction was developed as an alternative to reduce privacy problems. Many occupants disliked the elevated position as it restricted access to the garden, complicated the supervision of children and was generally more tiresome. The additional covered space afforded by the elevated home was appreciated however for drying clothes, parking car, entertaining and storing junk.



ELEVATION



UPPER FLOOR PLAN

'M' TYPE HOUSE

FIGURE 6.

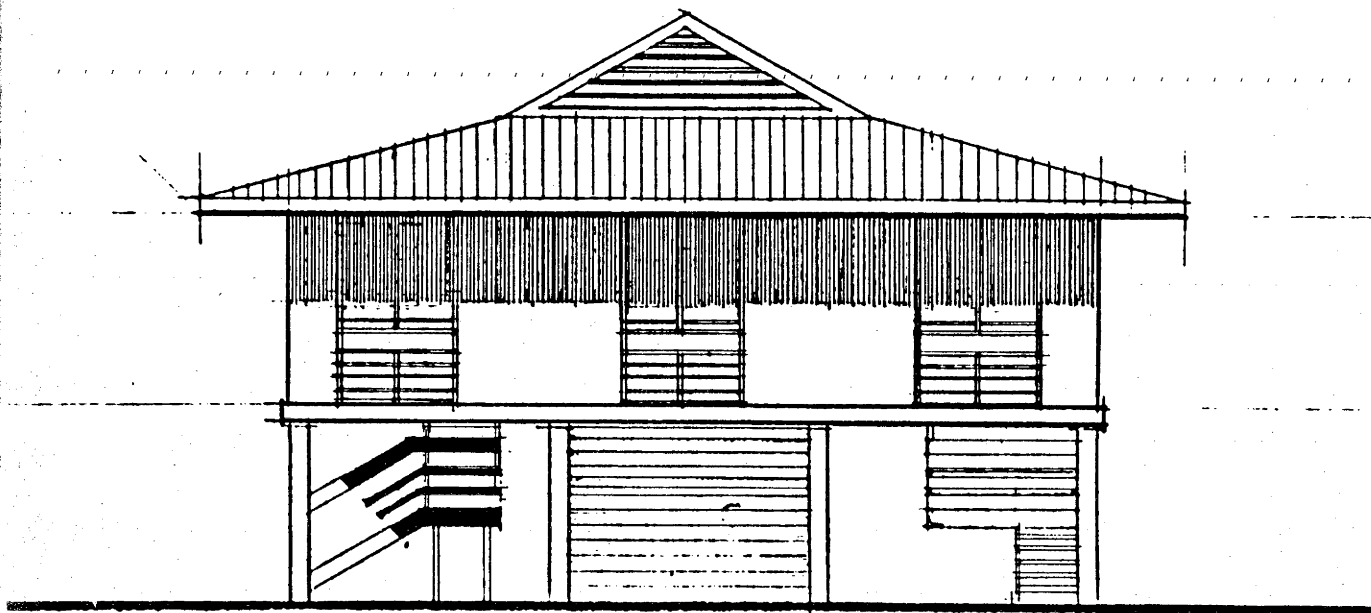
The "T" type house or "H" plan, allowed cross ventilation through all living and sleeping areas, regardless of orientation. The opening could be placed on opposite walls in either direction. The two half courts created a more introverted and private arrangement and captured breezes which could be directed internally as desired. The roof treatment - incorporating the ventilating trunk - and the "H" plan form, considerably improved the interest in elevation. These homes were in the main, constructed of Karlson Ucon precast concrete panels in an exposed reinforced concrete frame. This plan, while less economical than the "M" type was a good solution and was also adaptable to ground level construction.

Other modifications such as winged gabled walls and V angled plans were built. The basic problems of monotony, exposure, both climatic and social still however existed.

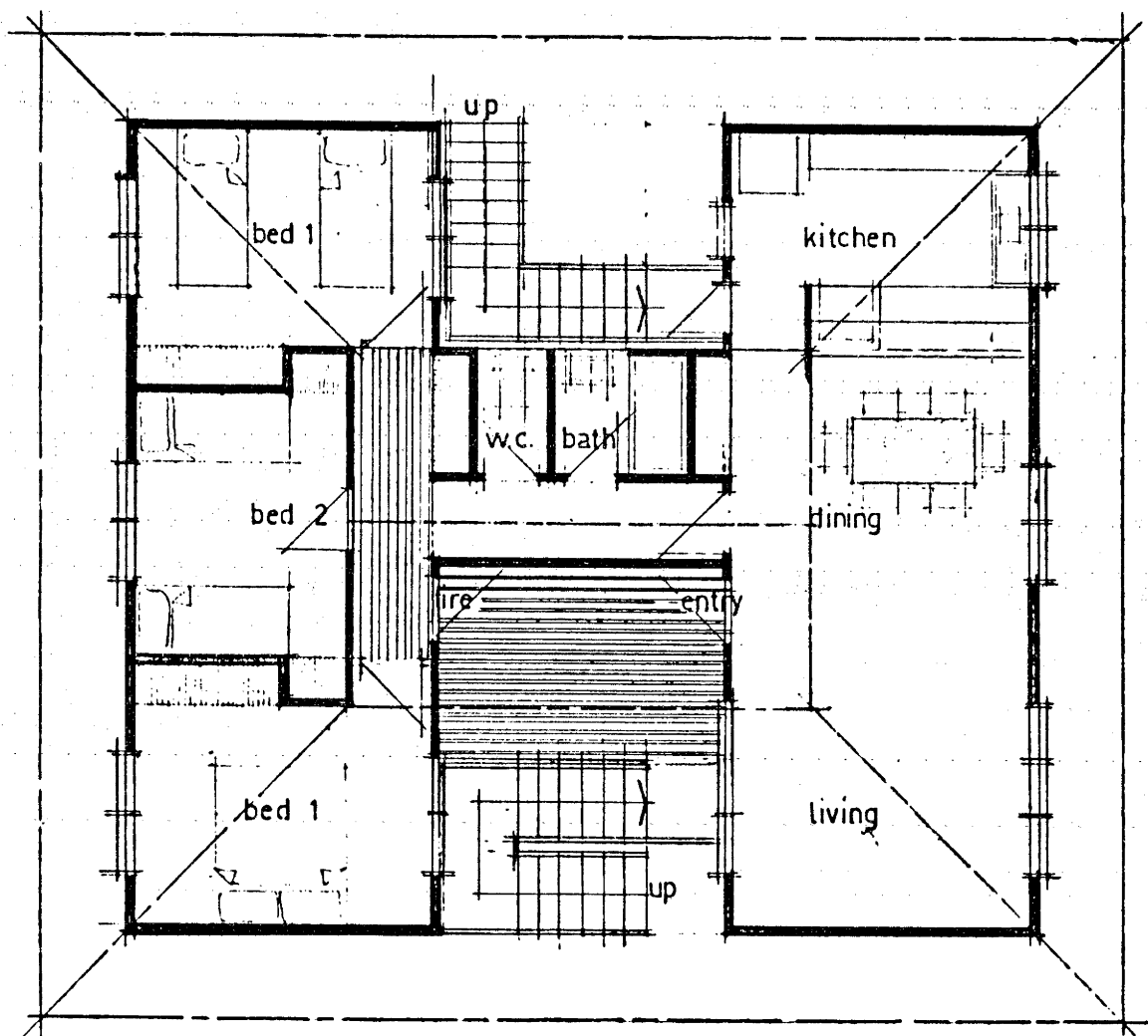
By the early seventies, despite the modifications already implemented, the housing authorities were still aware of the stress being created by the shortcomings in the houses as a whole.

The basic plans have been illustrated Figures 5 & 6, as they form the basic material which a large proportion of private individuals were to upgrade and dramatically modify, when the opportunity arose in 1974. Refer SECTION 7.0.

By 1974 many of the Public Service homes were owned privately, as public servants, after a nominal period of service to the Government were able to purchase their rented homes.



ELEVATION



UPPER FLOOR PLAN

'T' TYPE HOUSE

FIGURE 7

2.4.5 THE EFFECT OF AIR CONDITIONING UPON DESIGN

Air conditioning, had received some attention in Public Service housing reports prior to the seventies, but it was not until 1973 that any real effort was made to design homes economically with artificial control. Naturally the air conditioner had the potential of eliminating all the problems previously encountered, although many could not afford this luxury or preferred to live without it.

Thus designs were prepared in 1973 by architects in private practice, under commission to the Department of Housing and Construction.

As was previously indicated in the introduction to this report, the Department, by the early seventies had recognized the vital role that private enterprise could play in resolving housing problems.

This confidence was very largely founded on the relative success of the "T" type Karlson Ucon precast concrete homes, which were a privately initiated design which met department housing requirements.

These new housing types were a vast improvement. They were larger in area, improved in appearance utilizing much wider range of materials, diversified in form, being elevated, ground level and split level. Siting criteria was established to improve privacy with additional improvement in finishes, equipment and detailing.

Although none of these designs was ever constructed because of Tracy's unexpected arrival, an event which was to dramatically alter the structural requirements in all building, they evolved as a result of careful investigation into housing needs, by architects with specialized expertise in the field of tropical housing.

As such, they represent the most ideal solutions to the problems of housing in Darwin suburbs under pre cyclone conditions. For this reason the three designs are illustrated, so that they may form a standard by which, the privately constructed or upgraded homes might be compared, at least in terms of comfort and function.

Each house type illustrated is 111.48 sq metres in area excluding verandahs, car shelters and access stairs where included, and meet the standard requirement set down for a three bedroom Public Service home at that time. The designs are of course adaptable to other family requirements. Each design incorporates solar collector panels for water heating and a parasol roof.

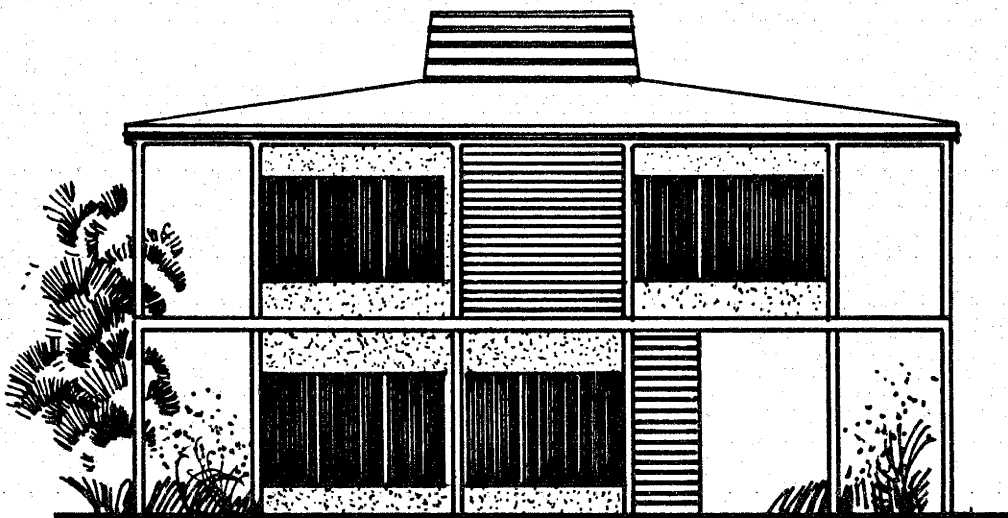
The illustrations, in Figures 8 to 10 inclusive on the proceeding pages, and corresponding design descriptions are extracted directly from the study team report "Housing For Hot Humid Areas" prepared in 1973. The study team consisted of Howard Bonner, Atkinson and Shand - Architects and W.E. Basset and partners - Mechanical Engineers. More operational details are of course described in the above mentioned document. It is only the intention of this report to illustrate the design principles.

2.4.6 THE LATEST DESIGN ALTERNATIVES

HOUSE A - SPLIT LEVEL PARTIAL AIR CONDITIONING - FIGURE 8.

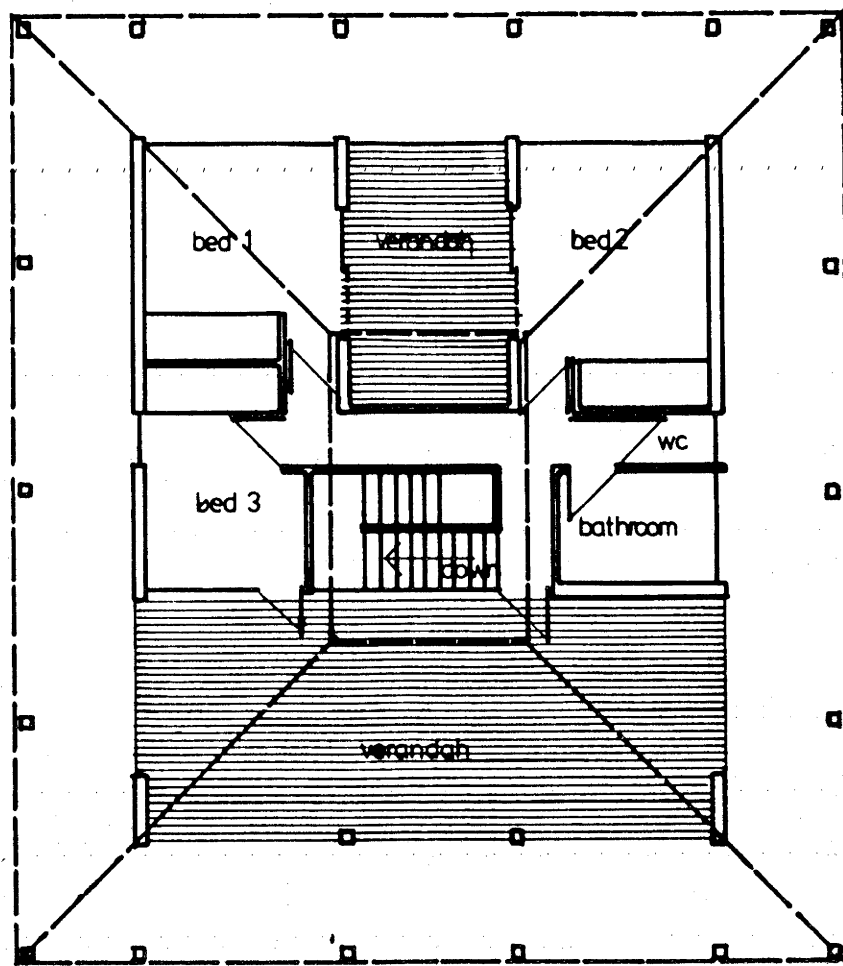
Split level home designed primarily for the upper floor to be air conditioned, and the lower area to remain un-air conditioned.

Large open living areas are provided allowing infant supervision from the kitchen and laundry, or alternatively separate recreational activities to accommodate the more diverse needs of an older family. The east wall is blank to block hot and dusty breezes from this direction. Bedrooms positioned to take advantage of the cool north and west prevailing breezes. Access to covered outdoor areas is provided from all bedrooms and living areas - the revival of a feature considered mandatory for Public Service housing in the thirties. Car parking facilities are available under cover.

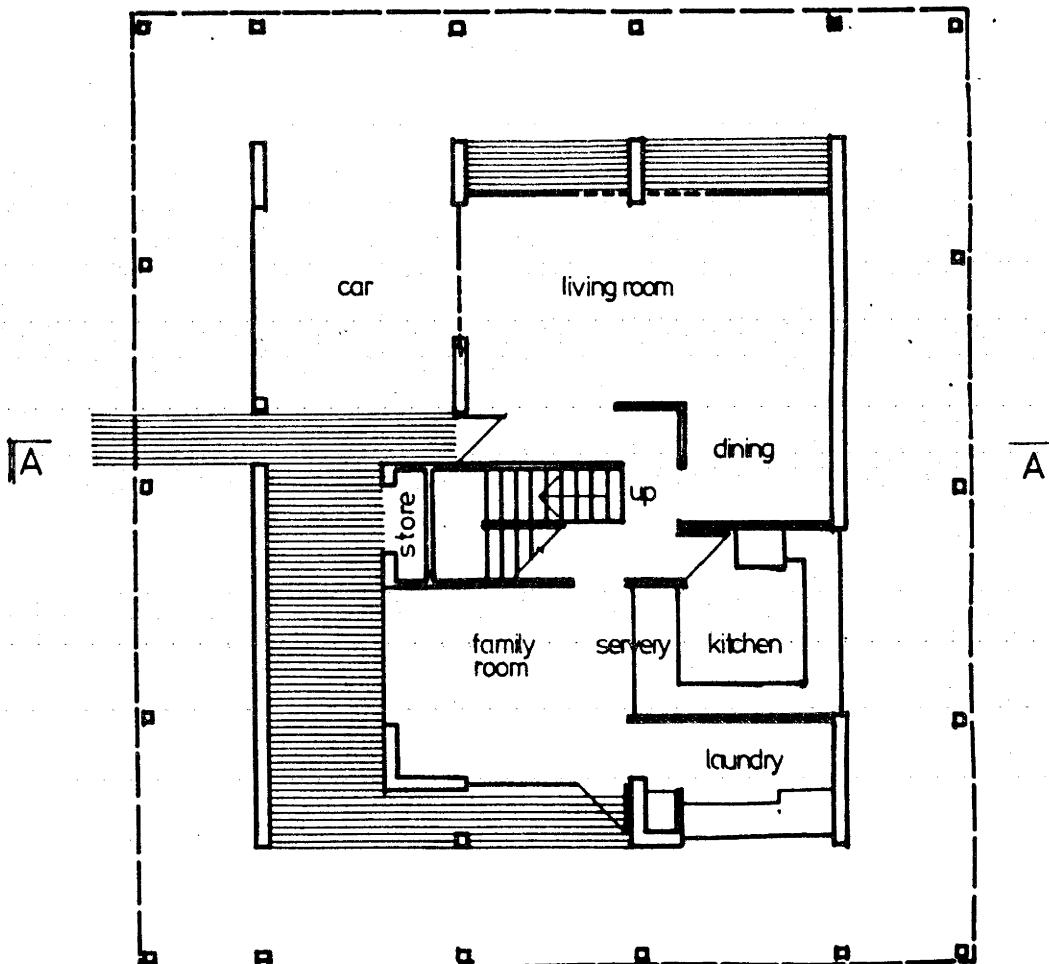


FRONT ELEVATION

FIGURE 8 House Type A - partly air conditioned



UPPER FLOOR PLAN



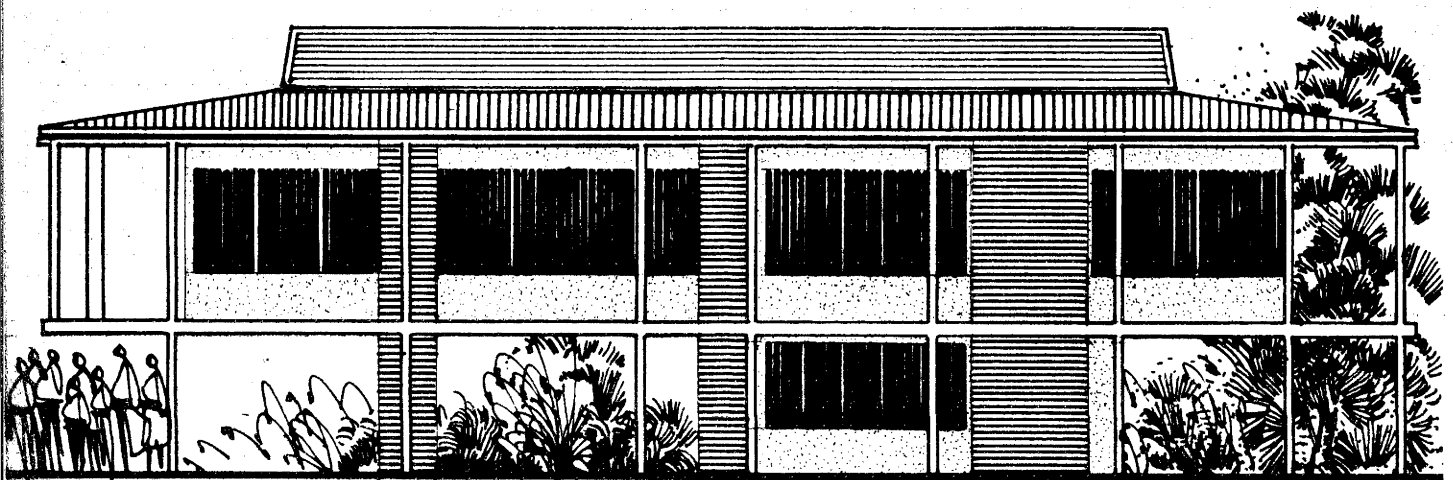
GROUND FLOOR PLAN

FIGURE 8 (b)

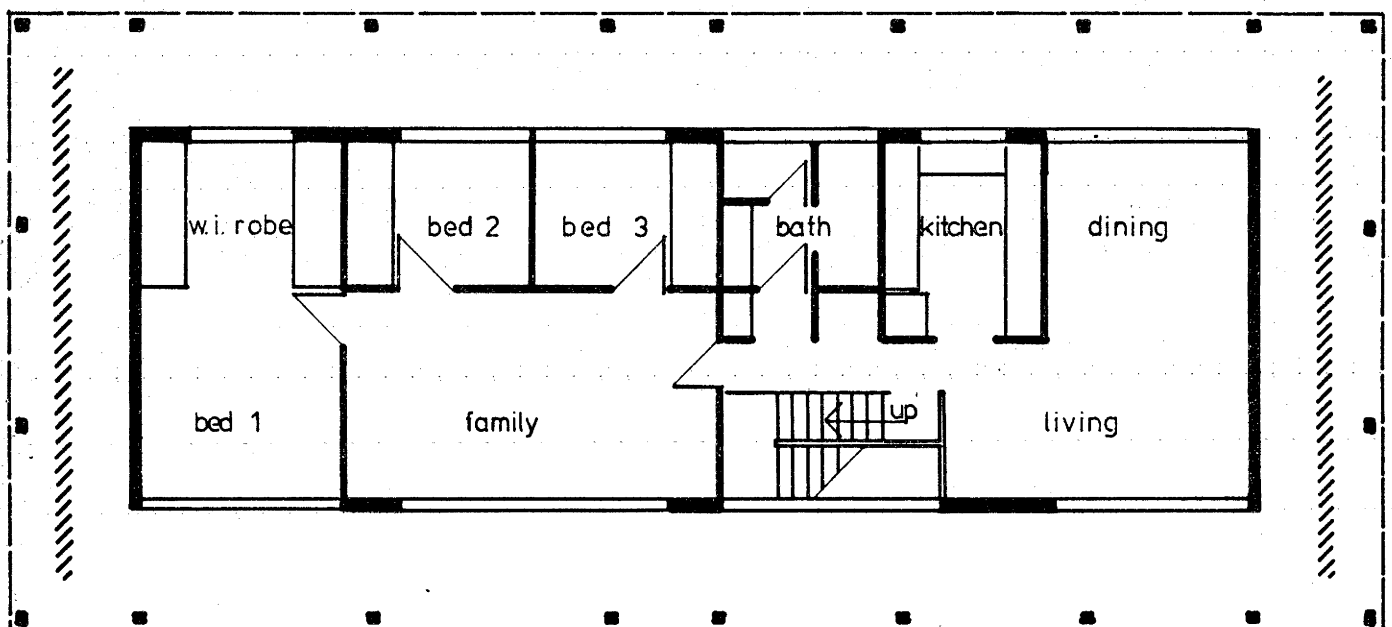
HOUSE B - ELEVATED OR GROUND LEVEL
 - NON AIR CONDITIONED HOUSE - FIGURE 9.

This design incorporates the desirable features of the elongated elevated home - cross ventilation, covered outdoor area beneath house etc. with additional advantages of shaded openings, and alternative living areas for older families.

Three versions were designed to cater for a variety of family needs, each of which can easily be adapted to ground level if desired.



ELEVATION

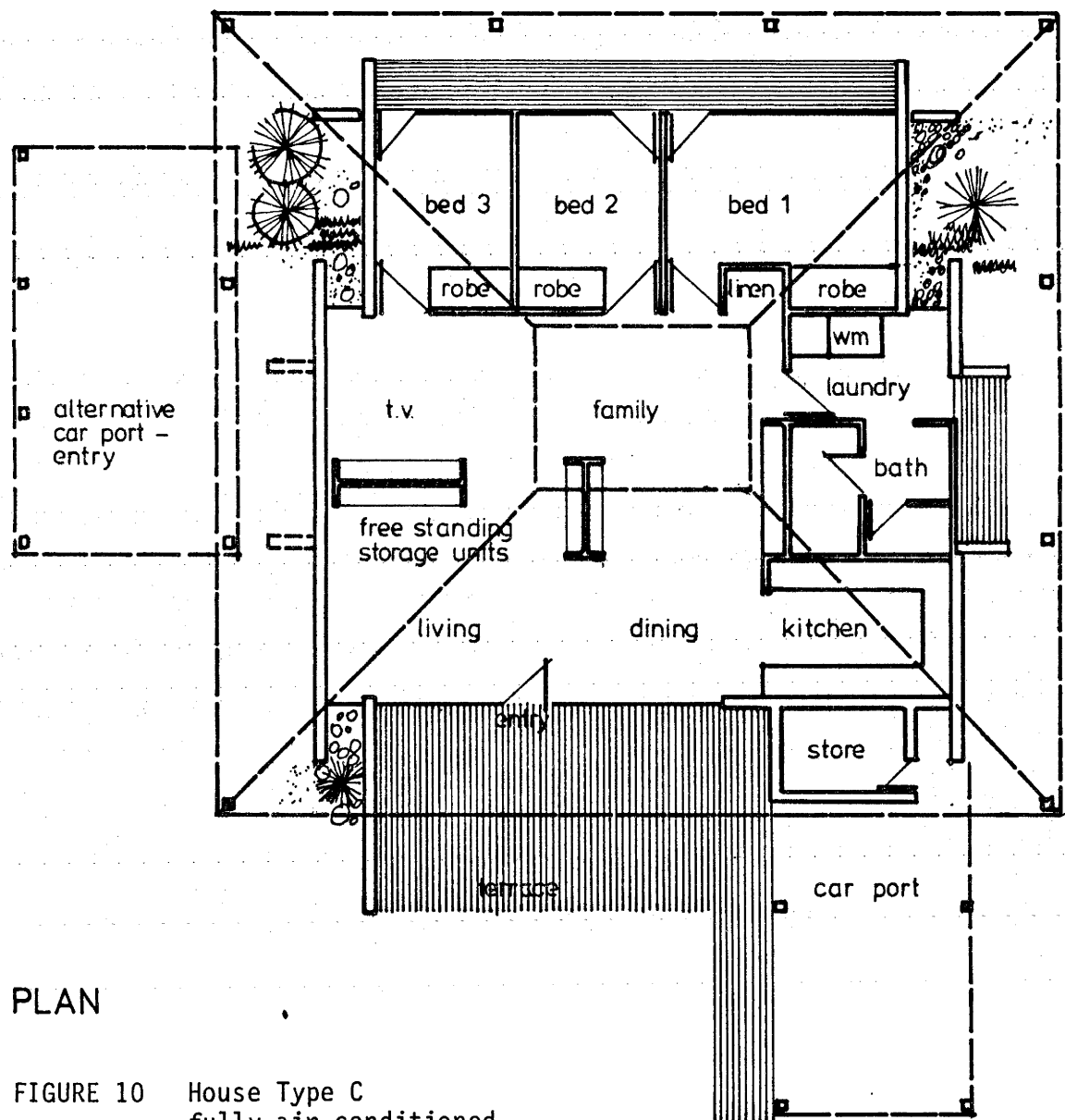


UPPER FLOOR PLAN

FIGURE 9 House Type B - non air conditioned.

HOUSE C - GROUND LEVEL - FULLY AIR CONDITIONED - FIGURE 10.

This design is compact, to reduce cooling load, while still allowing bedrooms to capitalize on the cooling north evening breezes. Living space is large and free to be arranged according to individual needs. The ablution area acts as a barrier to hot and dusty easterly breezes, and the location of the kitchen allows visual access to internal and external living areas for purposes of child supervision. The carport and store form a separate structure.



SECTION 3 STRUCTURAL DETERMINANTS

In terms of its impact on the community, cyclone "Tracy" was the most disastrous single event to have occurred in Australian history. The most significant aspect of the damage and the primary cause of the magnitude of its impact was the failure of housing. WALKER; 1975(a): I

3.0 STRUCTURAL DETERMINANTS

3.1 EXPANDING KNOWLEDGE

Cyclone Tracy was the primary instigator of the housing transformation, which is the subject of this report. The devastation caused by Tracy, stimulated a massive rebuilding programme at the local level and provided impetus to a growing field of investigation into structural systems, designed to withstand cyclonic wind loadings.

The effect of the complex loads generated in a cyclone, upon structural disintegration, has received considerable attention from academics, design practitioners and material manufacturers with, universities housing the resources for research and the expertise to guide its direction.

As a result, the science of building in the tropics has become quite sophisticated and well documented. It is not however the intention of this report to illustrate these principles in any depth, except to show how specific details in domestic construction have compelled traditional building to alter in view of future cyclone threat.

3.2 EXTENT & CAUSE OF DESTRUCTION

By the end of 1974 there were between 8,000 and 9,000 homes in Darwin. This total was comprised of approximately 40% Commonwealth Public Service housing as illustrated in SECTION 2.4, 35% Housing Commission, ground level masonry homes and the remaining 25% privately constructed homes in a variety of shapes and sizes.

Following cyclone "Tracy", it was estimated that only about 500 homes were habitable. Of the 8,000 - 9,000 homes;

- 53% were destroyed.
- 41% repairable but uninhabitable.
- 6% minor damage.

Devastation of this magnitude, necessitated the evacuation of about three quarters of the population of 46,000.

The ramifications of this community upheaval and rearrangement in social structure was to influence the way in which re-construction was to be tackled by the individuals involved. This shall be discussed in SECTION 4.0.

The nature of the physical disintegration however requires some attention at this point, so that the objectives of the emergent "new traditional" building methods can be appreciated. A summary of the typical failures which occurred and the degrees of inadequacy of the different housing types, is outlined in SECTION 3.3.

Damage was caused by the culminating effect of wind loads and flying debris, acting on structures designed to withstand loads induced by wind speeds of up to 30 m/s. It has been estimated that peak wind gusts of up to 70 m/s were produced in cyclone Tracy.

The magnitude of the positive and negative pressures on a building, are not only dependant upon wind speed, but also the manner in which these pressures act upon a structure. Dynamic, static, longitudinal and transverse loads, interplay at fluctuating intensities and alternating locations on a structure, which vary dramatically over a period of several hours.

The destructive influence of flying debris is more a function of time. The quantity of debris increased as the cyclone passed over the suburbs, snowballing as penetrated buildings exploded, multiplying the magnitude of the destructive force.

The strength in domestic structures was adequate to withstand the downward acting dead loads. Fixings served primarily a role of locating components which then relied upon gravity to hold them together. Traditional building practice was based on intuition and experience and had for many years been void of engineering.

Other factors which contributed to the extensive damage were the trend towards larger openings, flat roofs, longer roof spans and the speed with which buildings were constructed in the early seventies. The inadequacies of structures appeared to be less a matter of "jerry" building and more the result of a reduced specification, adopted as an economic measure.

3.3 TYPICAL FAILURES

3.3.1 SUMMARY

The failures common to most buildings under cyclonic wind loadings as outlined by George Walker at a Queensland Master Builders Association Convention in Cairns 1976 were;

- (i) extensive removal of roof cladding due to failure of its connections to the battens or purlins:
- (ii) removal of purlins and battens due to inadequate fastening to rafters:
- (iii) removal of entire roof structure due to lack of tying down of the roof structure to the walls and foundations:
- (iv) loss of wall cladding due to debris damage and inadequate fastenings:
- (v) blowing out of entire window assemblies due to inadequate connection to the surrounding walls:
- (vi) blowing out of walls due to inadequate connection to adjacent walls or lateral support:
- (vii) racking of walls due to inadequate bracing:
- (viii) lifting of walls from sub-structure:
- (viv) racking and collapse of piers due to inadequate bracing:

These typical failures varied in extent and nature according to each housing type. The degree of inadequacy of each type is outlined overleaf.

3.3.2 ELEVATED TIMBER FRAMED HOUSES

This house type was the most common and easily sustained the greatest proportion of damage. These were generally clad in asbestos sheeting with 26 gge corrugated iron to roof. Laundry blocks in masonry were generally incorporated under concrete or steel columns for lateral stability.

Structural integrity between the first and ground floor was often non-existent. The older homes in this category performed a lot better by comparison. These older houses generally had diagonal timber bracing integrated into the timber stud wall frames.

Sequence of failure:

(i) Roof, ridge capping & guttering peeled off.

Sheets were connected with 2" roofing nails at every 3-4 corrugations. Screws, where used produced better results - sometimes staying in the timber despite loss of cladding. Neoprene washers had no positive effect. Failure occurred in the second phase at purlin, batten and rafter connections. Those fixed by hoop iron were most successful. Where roof sheeting provided bracing, total collapse resulted. Roofs often lifted immediately after windows on the windward side broke. Aluminium window frames not fixed to wall frame fell out on leeward side - creating a serious problem when winds reversed.

(ii) Roof trusses

No failure occurred within the gang nail type truss. The connections with the wall plate were inadequate, causing trusses to turn over or be torn off, as the wind changed direction. Skew nailing was standard practice and where Trip-L-grip connectors were used, too few nail fixings held these in place. Cyclone bolts were installed with poor workmanship, rendering them ineffective.

(iii) Cladding

Penetration reduced shear strength, causing racking of the upper floor. Metal claddings were more satisfactory than asbestos cement. Connections at corners required upgrading as usually on a few nails were driven into adjoining studs.

(iv) Masonry beneath slab

Single blockwork collapsed as mortar bonding was inadequate. Failure here reduced lateral stability of entire structure.

3.3.3 GROUND LEVEL TIMBER FRAMED HOUSES

This type of housing only survived the cyclone more adequately than elevated houses when protected by multi-story flats, elevated houses or terrain and vegetation.

Vegetation and fences provided significant protection against flying debris.

3.3.4 GROUND LEVEL MASONRY CONSTRUCTION

(i) Double Brick

Performance was significantly better than some other forms, with only 10% of houses of this type were beyond repair. Roofs mostly hipped, where fixed to a concrete ring beam on 280 mm walls resisted failure quite well

Advantages of this construction form include;

- low set - protected by elevated building, vegetation and fences.
- shear strength of walls increased.
- aluminium frames more adequately fixed.

- hip roof possessing more desirable aerodynamic properties and inherent lateral stability

Disadvantages include;

- roof loss as above - skew nail fixing into wall plate.
- concrete ring beam - some stability although only fixed (inadequately) on corners.
- cavities had only a few ties often poorly anchored. - More stable at internal 90° wall connections.

(ii) Brick Veneer

The Housing Commission was largely responsible for this form of construction - only constructed after 1970. Most inadequate against this extreme form of loading. Loss 90% - mostly caused by racking after brick veneer failed.

Ties between timber studs and brickwork were inadequate and too infrequent.

There was no continuity in strength between floor and roof.

After 1970, a reduction in brick size to 90 mm and an increase in wall width to 300 mm meant the cavity width was doubled, which considerably reduced lateral stability. At the same time bond beams were only used on two side walls and gabled roofs replaced hipped roofs. 100% of this type of construction was lost.

(iii) Masonry Blocks

The Housing Commission in several years prior to Tracy was required to use 60% block component by contract. A major failing was minimum contact between block and mortar and inadequate strength of mortar. Sequence of failure as above.

(iv) Precast Concrete - Karlson Ucon homes

These were precast concrete wall and ceiling panels bolted in a reinforced concrete frame. Performance was relatively good, as panels were not penetrated. Some panels were removed as hold down bolts were not fixed adequately. Timber framed roofs were lost on all Ucon houses. Internal precast concrete walls lost lateral stability once supporting ceiling panel was removed.

(v) Other

Duraframe, a steel framed structure and other systems, incorporating sandwich panels proved to be total failures. The sandwich panels as components were resistant in themselves to debris penetration.

3.4 REACTIONS AND RECOMMENDATIONS

The immediate reaction to this extensive failure, by the building authorities was dramatic.

The recommendations, as set out in the Preliminary Report, prepared by the Department of Construction, were in essence:

- (i) To eliminate all debris shedding structures. Buildings which cannot be modified to achieve this standard must be destroyed.
- (ii) Because the protective effect of topography and local shielding was evident, special consideration must be given to front-line structures on beaches etc.
- (iii) To ensure structural integrity, it is essential to transfer all applied loads through the structure. Therefore cladding must not be relied upon as bracing.

It was recommended that a bracing system independent of the cladding be integrated into the structure, unless the shear stability of the cladding and its fixing be guaranteed throughout a period of intense loading.

- (iv) All roofs should be of 30° pitch, hipped, with no overhang, to reduce uplift loading.

Porous window shades are suggested for shading over windows. The attachment of sheeting especially at leading edges, must receive special attention.

- (v) A refuge shelter must be incorporated into all homes.

At one stage, after the nature of structural collapse had been assessed, it was recommended that the elevated house, should not continue to be constructed as a standard housing form and that asbestos and non-reinforced concrete cladding, prone to destruction, cease to be used.

3.5 DEVELOPMENT OF A CODE

Despite this extensive damage, investigation revealed that the majority of the structures had withstood loads in excess of those calculated for the wind velocities for which they were designed.

Clearly, the design wind load and the building standards needed to be reviewed.

3.5.1 DRAFT BUILDING CODE

By the 20th January, 1975, a Draft Building Code was presented for review at the request of the interim Darwin Reconstruction Commission.

This Draft Code was a modified version of the Northern Territory Building Manual prepared in mid 1974 which had not taken effect when the cyclone occurred. The basic changes effected by the Draft Building Code - Darwin recommendations, were:

- (i) Regional basic design wind velocities for a terrain factor between 2 & 3 were;

return period yrs	5	25	50	100
velocity m/s	42	53	60	65

- usual design velocity 60 m/s calculated on a 50 yr period
- especially exposed location - 70 m/s for 50 yr return period
- embedded location - 50 m/s for 50 yr return period

- (ii) A certificate issued by a Chartered Structural Engineer accompanied by calculations, was to be submitted with all construction documents for domestic structures.

- (iii) (a) All window openings were to be treated as dominant openings unless adequately protected against debris penetration.

- (b) Walls and roof were to be braced - independently of cladding failures, ie failure in any component must not incur loadings which exceed normal working stress in intact sections by more than 25%.

No allowance given to sheeting as brace.

A wall is considered sound if its structural effectiveness is not impaired by penetration.

THE DARWIN RECONSTRUCTION COMMISSION was a Statutory Authority established to co-ordinate and undertake the task of reconstructing Darwin. Hereinafter referred to as the DRC.

- (c) All fixings and attachments designed according to Clause (i) preceding page. (windows, doors, wall plates, gutters, fascias and verandah supports)
- (d) Roof sheeting is to be attached by screws, bolts or other applicable fixings - no nails to be used. External battens at ridges, eaves and gable ends are to be adequately anchored.
- (e) Windows or louvres are to be capable of remaining in fully open position when subject to Clause (i) wind loadings.
- (iv) A minimum 5m² refuge shelter is to be constructed in building class I, II, III, IV to above requirements.
Power and water services essential and operable during termination of other dwelling supplies is to be incorporated into the shelter.
- (v) A certificate from an appropriate authority is to be obtained prior to occupancy - to satisfy the above conditions.

3.5.2 DARWIN AREA BUILDING MANUAL

This Draft Building Code was adopted as the Darwin Area Building Manual in May 1975. This document dictated the building standard until February 1976, when some significant amendments were made, which considerably reduced the economic pressures of reconstruction. The changes effected by these amendments were:

- (i) Reduction in the Regional design wind velocities

return period yrs	5	25	50	100
velocity m/s	40	50	55	60

The minimum Terrain Category was specified as 2½, determining the minimum multiplier at the average of those given in Table 4 of AS 1170, for category 2 & 3.

- (ii) The design, construction and installation of windows and louvres no longer had to be such that they were capable of remaining in the fully open or closed position when subjected to calculated wind loadings applicable to the surface.

All openings were still to be regarded as potential dominant openings for the calculation of internal pressures unless adequate protection could be shown to be provided.

- (iii) Bracing no longer had to be arranged such that removal or displacement of any single component, would allow stresses to develop in the remaining part of the structure by more than 25% of the normal working stresses.

Cladding, including masonry could be considered to provide all or part of the bracing, provided that the effectiveness of the cladding as bracing would not be impaired by debris penetration and repeated loadings, shown to be present under cyclonic wind loadings. The proof test of fatigue incurred by repeated loadings was recognized to be - the application of 10,000 cycles of working load from zero to maximum followed by a static load test of 1.8 times the working load to the sheeting and its fixings. This test is designed to ensure against failure caused by low cycle fatigue, a loading not previously appreciated prior to cyclone Tracy. Fixings are vital in achieving success in this regard.

- (iv) Where roof cladding was being used to provide wind bracing according to the standard stated above, additional external roof battens, secured at ridges, eaves and gable ends were no longer required.
- (v) The upgrading of other Australian standards relevant to construction, now permitted calculations to be made in accordance with these standards, where previously, special calculations were required for structures in tropical cyclone zones.
- (vi) An engineer's certificate was required to certify that when a building was constructed in accordance with the working documents, it would be structurally sound and conform to the relevant codes, for all classes of building except Class I & X (ie domestic construction). Only Class I buildings of extraordinary design, or proposed on a site needing special attention, required an engineer's certificate.
- (vii) The Clause stating that a refuge shelter designed for a wind velocity of 80 m/s, was to be provided for Class I, II, III & IV in tropical cyclone areas, was amended to read may be provided with a refuge for Class I, II, & III buildings.
Thus a shelter was no longer obligatory.

".....where man builds and lives with reference to potential extreme geophysical events determines the character and extent of geophysical hazard to man. The extent of the hazard is also a function of how man builds..... the hazard can be reduced if not completely eliminated."

MILETI DRABEK HAAS, 1975: 4.

3.6 A NEW TRADITIONAL BUILDING PRACTICE

3.6.1 DESIGN PRINCIPLES

The culminating effect of the loadings created by wind flowing over a structure is the induction of pressure differentials, or the positive and negative pressure acting on that structure.

Figure 11 and 12 indicate the basic flow pattern around a typical domestic dwelling. The stagnation point as indicated in Figure 12 is the point of highest pressure where air-flow comes to rest and from where it is directed downwards, creating a draught as indicated in Figure 11 and is directed upwards, inducing a high positive loading under the eaves.

The pressure differentials which result from this action are illustrated as a pressure contour in Figure 13 on a flat roofed bluff structure. For the purposes of design it is useful to have a guide, as to the distribution of external forces to the various components of a structure. For this reason the statistics given below, outline this distribution expressed as a percentage of the dynamic pressure head (or total of positive and negative pressures on a structure).

1	Windward wall	+80%
2	Leeward wall	-50%
3	Side walls	-60%
4	Windward roof (10° slope)	-90%
5	Windward roof (20° slope)	-75%
6	Windward roof (30° slope)	-20%
7	Leeward roof (all slopes)	-70%
8	Roof with wind parallel to ridge (less than 20°)	-90%

9	Roof with wind parallel to ridge (greater than 20°)	-70%
10	($0 - 10^{\circ}$ slope)	-135%
11	(20° slope) corners of roof and ridge	-115%
12	($0 - 10^{\circ}$ slope)	-180%
13	(20° slope)	-150%
14	Under eaves (additional to pressure on a roof surface)	+80%

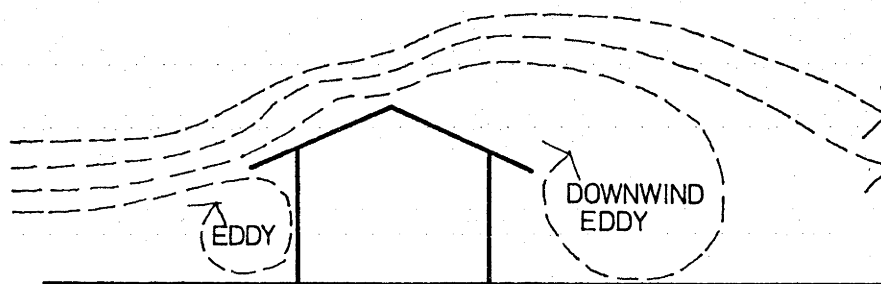


FIGURE 11 Wind flow pattern around a simple structure.

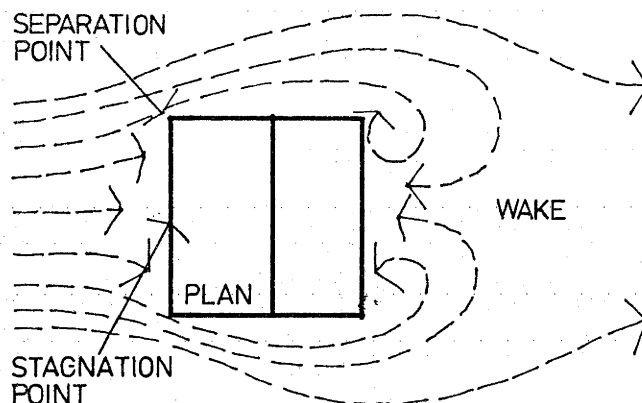


FIGURE 12 Wind flow pattern in plan.

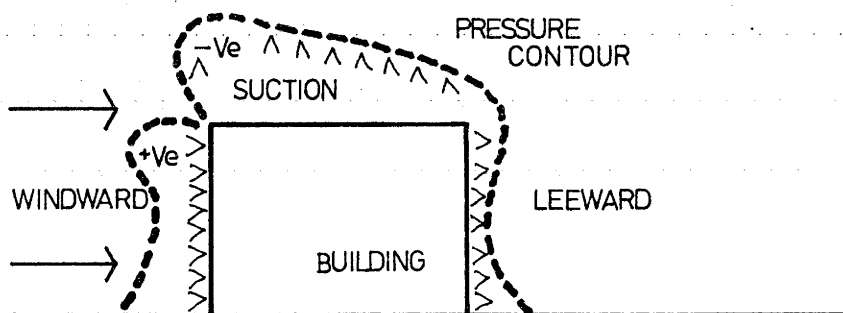


FIGURE 13 Pressure contour on structure.

From this table it is evident that critical loading points occur at the edges of the roof, at the ridge and along the eaves. Thus, these points require special attention to detail. Illustrations of the construction details evolved to withstand these excessive loadings are included in SECTION 3.6.3.

Other factors modify the pressure contour and the magnitude of the dynamic pressure head, and must be considered in component and connection calculations. These factors constitute the basic design principles which should become primary determinants in the design process.

These factors include:

- (i) Roof Slope: The flat roof as illustrated is subject to the highest suctional or negative forces. On the windward side this force decreases as roof slope increases until it becomes subject to a positive force when the roof slope exceeds 30° .
- (ii) Internal Forces: Internal forces have a magnifying or counteracting effect upon the pressures induced along the various building planes, depending on the size and location of an opening and whether or not it is opened or closed during a wind storm. It is almost impossible for a structure to remain sealed during periods of wind velocity of the magnitude created by a tropical cyclone. For this reason the internal forces created by dominant openings on windward and leeward faces must be considered in wind load calculations. Figures 14 and 15, illustrate the combined loading of internal and external wind forces.

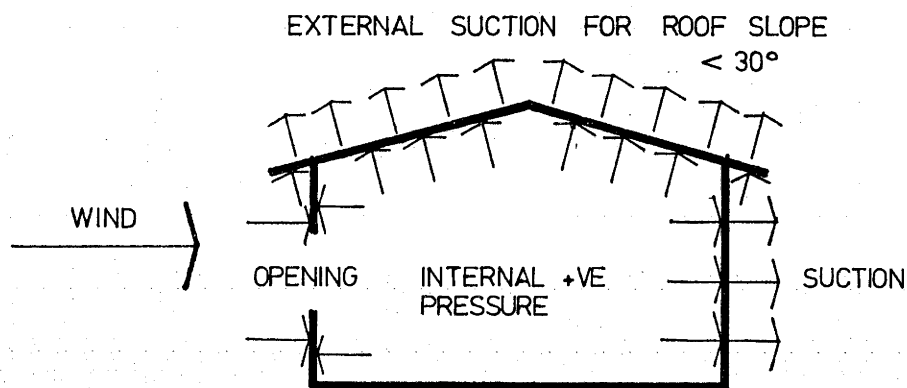


FIGURE 14 Resultant internal and external loadings - opening on the windward side.

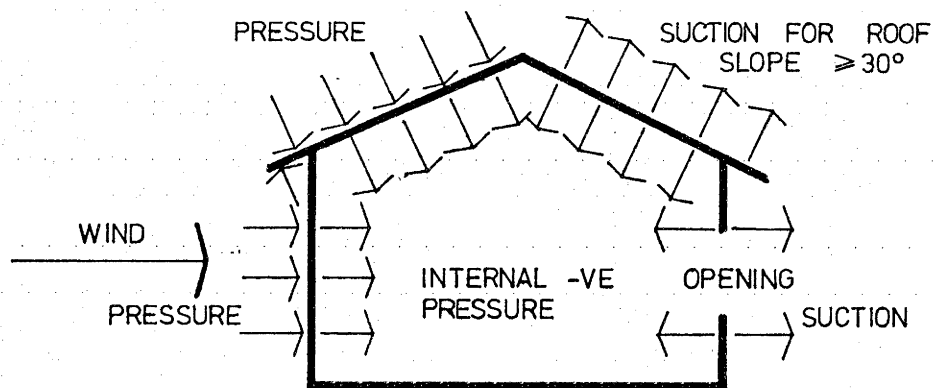


FIGURE 15 Resultant internal and external loadings - opening on the leeward side.

(iii) Building Height: The viscous forces, set up by the "roughness" of terrain, inhibit the free flow of wind across the earth's surface. The reduction in velocity or velocity gradient is a function of the terrain type. The most rapid change in velocity occurs close to the ground and therefore the difference in mean wind velocity striking a single story building and a two story building is significant.

The load created by down draught, which is induced at the stagnation point on the windward face is also a direct function of building height.

(iv) Plan Form: The magnitude of the downward eddy, induced on the leeward side of a structure is an inverse function of the buildings depth. A shallow building is subject to greater hazard turbulence than a thicker building of the same height. The depth of the downward eddy is however a direct function of the width of a building.

Re-entrant angles in the plan form creates further eddies of varying intensities which complicate the nature of wind loadings.

The factors outlined above are mainly concerned with the geometry of the building. The forms which emerge as ideal, in terms of building construction economy, as a result of this understanding of wind effects on buildings are:

- 1 Roof slopes not less than 15° and preferably approaching 30° .
- 2 Ground level structures subject to lower wind velocities.

3 Angular building, approaching square proportion or alternatively a polygon or circular form to reduce component loading.

4 Openings should be designed to remain sealed throughout the period of wind loading or alternatively if collapse is anticipated, located in such a way to allow them to operate as a positive or negative pressure release valve.

The second revelation of this pressure contour line is that loadings on a structure are either lateral or vertical in complete opposition to gravity which has traditionally held buildings together.

Because gravitational forces are so entrenched in our structural thinking, the uplift forces are not easily conceptualized. Engineers have, for the purpose of demonstrating this concept of loading, envisaged the house as being suspended freely by the footings with weights hanging from the roof plane as shown in Figure 16.

Our immediate response to this illustration, is concern for the connections on the vertical chain of structural integrity.

Clearly one weak point in this chain would result in partial collapse of the structure. The loads induced laterally, similarly create a need for a horizontal chain of structural integrity.

Refer Figure 16 overleaf.

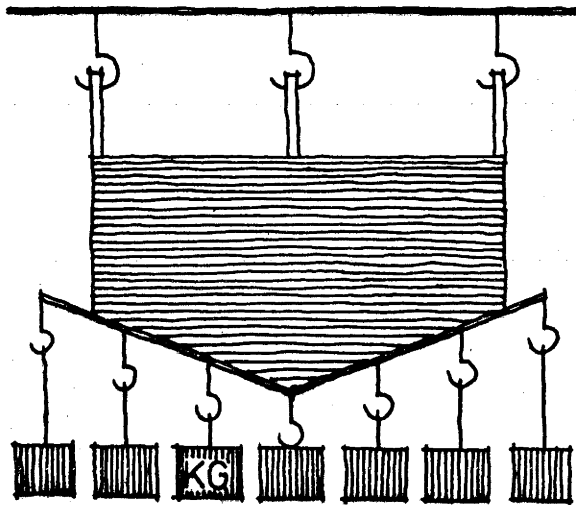


FIGURE 16 Diagrammatic illustration of uplift loadings. Elevated house suspended freely by footings with weights hanging from roof plane.

For the timber framed house
the vertical path of loading is:

- (a) Sheeting
- (b) Purlins
- (c) Trusses
- (d) Top Plate
- (e) Stud
- (f) Bottom Plate
- (g) Joists
- (h) Bearers
- (i) Footings

The horizontal load path is:

- (a) Cladding
- (b) Studs
- (c) Roof or ceiling plane.
- (d) Wall bracing or cladding.
- (e) Floor Plane
- (f) Stumps & sub-floor structure.
- (g) Footings

Each of these components has since been reviewed in the process of construction, to ensure that the component along with fixing can withstand these 'new' loads and another load previously unrecognised, that of low cycle fatigue.

3.6.2 DEEMED TO COMPLY STANDARDS

The introduction of amended building codes to upgrade the building standards, naturally caused confusion for the designers and builders who were accustomed to using traditional domestic construction techniques. If this code amendment was to be an effective measure in mitigating future disasters, it was essential to ensure that construction conformed to the code.

For this reason, the DRC produced a "Deemed to Comply" manual, which illustrates the manner in which components could be fixed together to meet the requirements of the new "Darwin Area Building Manual". The document consisted of two sections.

- (i) It contained manufacturer's recommendations for the use of their products as verified by the Department of Housing and Construction tests, conducted to ensure that products would perform in accordance with the requirements of the amended code.
- (ii) It illustrated details, suggested as solutions to typical domestic construction problems. These are not deemed to comply standards in the true sense and as such were, and still are, subject to alteration as experience reveals what is practical and comprehensive testing reveals more adequate solutions. Because of these changes, many of the suggested details which were illustrated in the "Deemed to Comply" manual are obsolete, and have been reviewed in more recently prepared documents.

The SAA "Manual for Guidance on Construction of Houses in High Wind Areas", (draft prepared September 1977), was based largely on the "Deemed to Comply" manual. This document now probably forms the most reliable guide to good construction practice for the community at large, in cyclone susceptible regions.

In spite of the fact that the devastation motivated many home owners, unskilled in any of the building trades, to rebuild their own homes, confidence in traditional methods had been shattered. Thus the early buildings reconstructed were relatively uniform in the structural sense at least. The uniformity was a direct response to those recommendations set out in the "Deemed to Comply" manual. The stringent new code severely inhibited architectural freedom. Structural integrity became the primary criterion in the evolution of post cyclone homes. As such, it is necessary to understand what constitutes the "new traditional building practice" that defined the restriction in design terms.

The details illustrated in SECTION 3.6.3 have been selected to indicate basically the manner in which the primary criterion was met for a timber framed elevated house.

3.6.3 CONSTRUCTION DETAILS

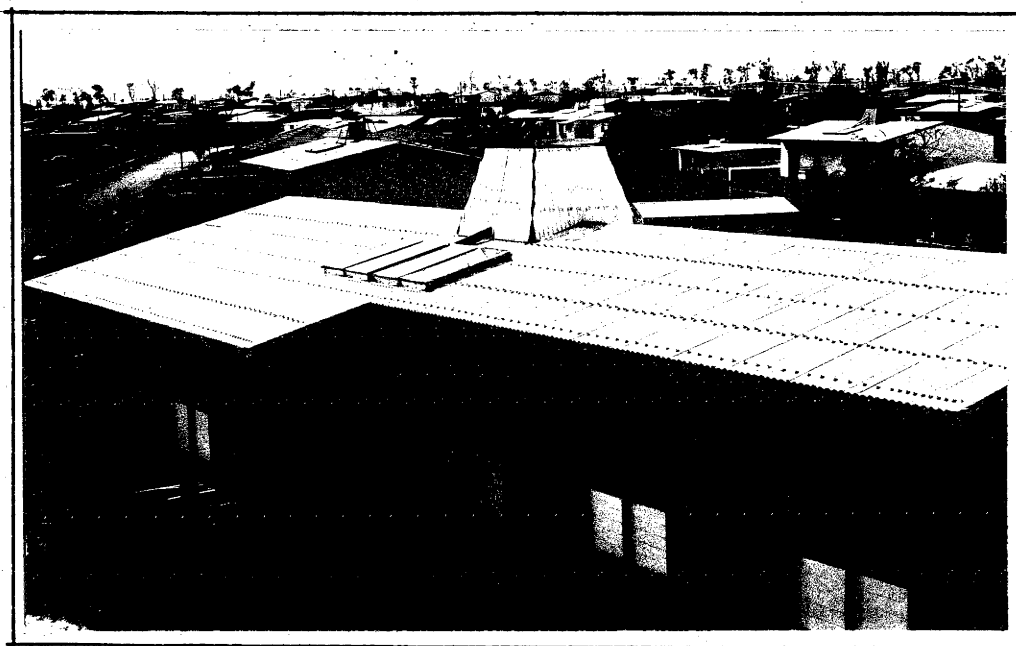
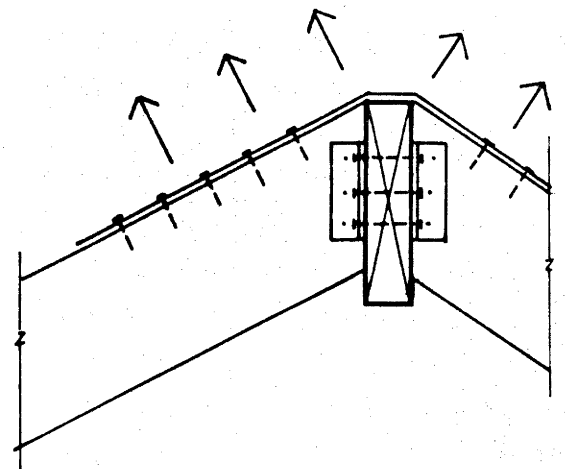
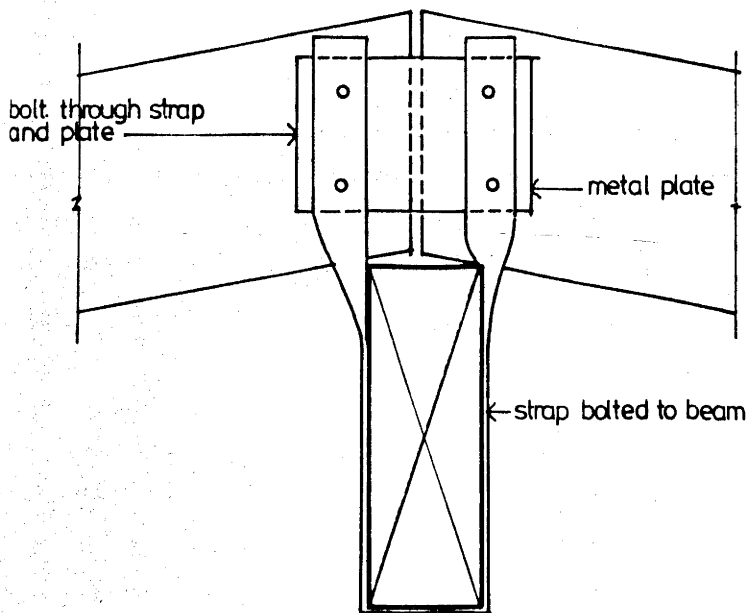


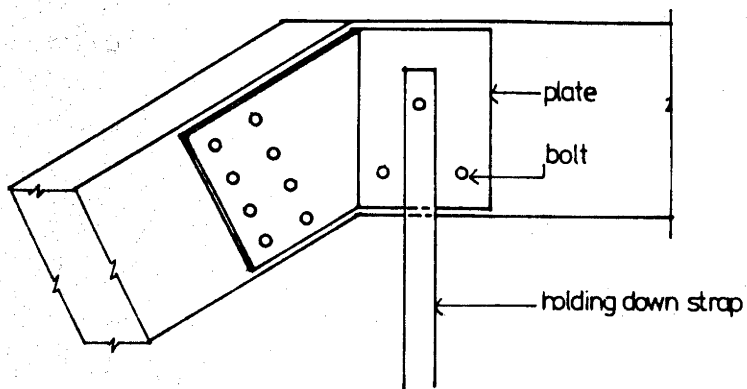
FIGURE 17 Typical post cyclone upgraded "C" type house, showing additional roofing screws along eaves line and leading edges.



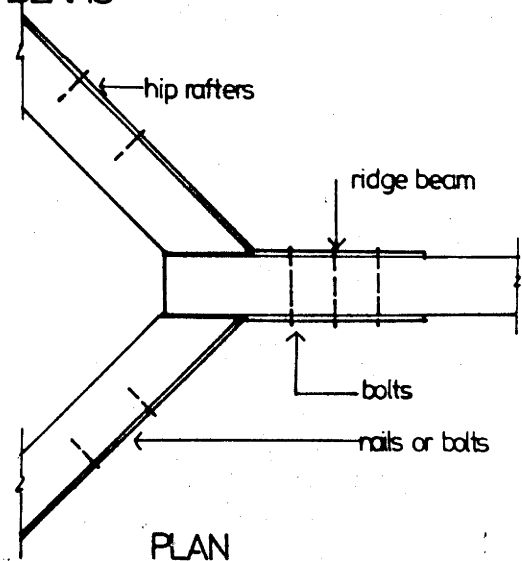
FIGURE 18 Substructure connection. U bolts tying down main bearers are anchored into the concrete filled block walls of the cyclone shelter. A mild steel angle encompasses the floor distributing the tensile loads from the cyclone rods to the bearers, piers and finally the footings.



FIXING RAFTERS TO RIDGE BEAMS

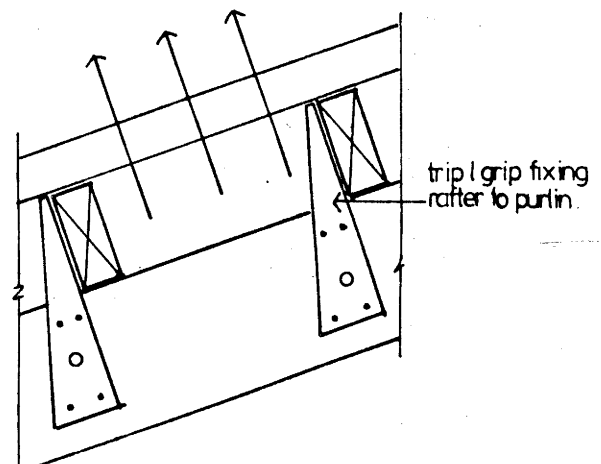
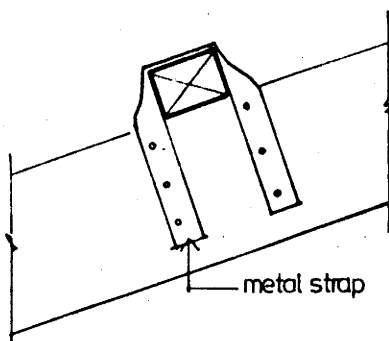


SIDE VIEW



PLAN

FIXING OF HIPS TO RIDGE BEAM.



FIXING TILE BATTENS OR PURLINS TO RAFTERS

POSITIVE FIXINGS

FIGURE 19. ROOF CONNECTIONS TO RESIST UPLIFT LOADINGS

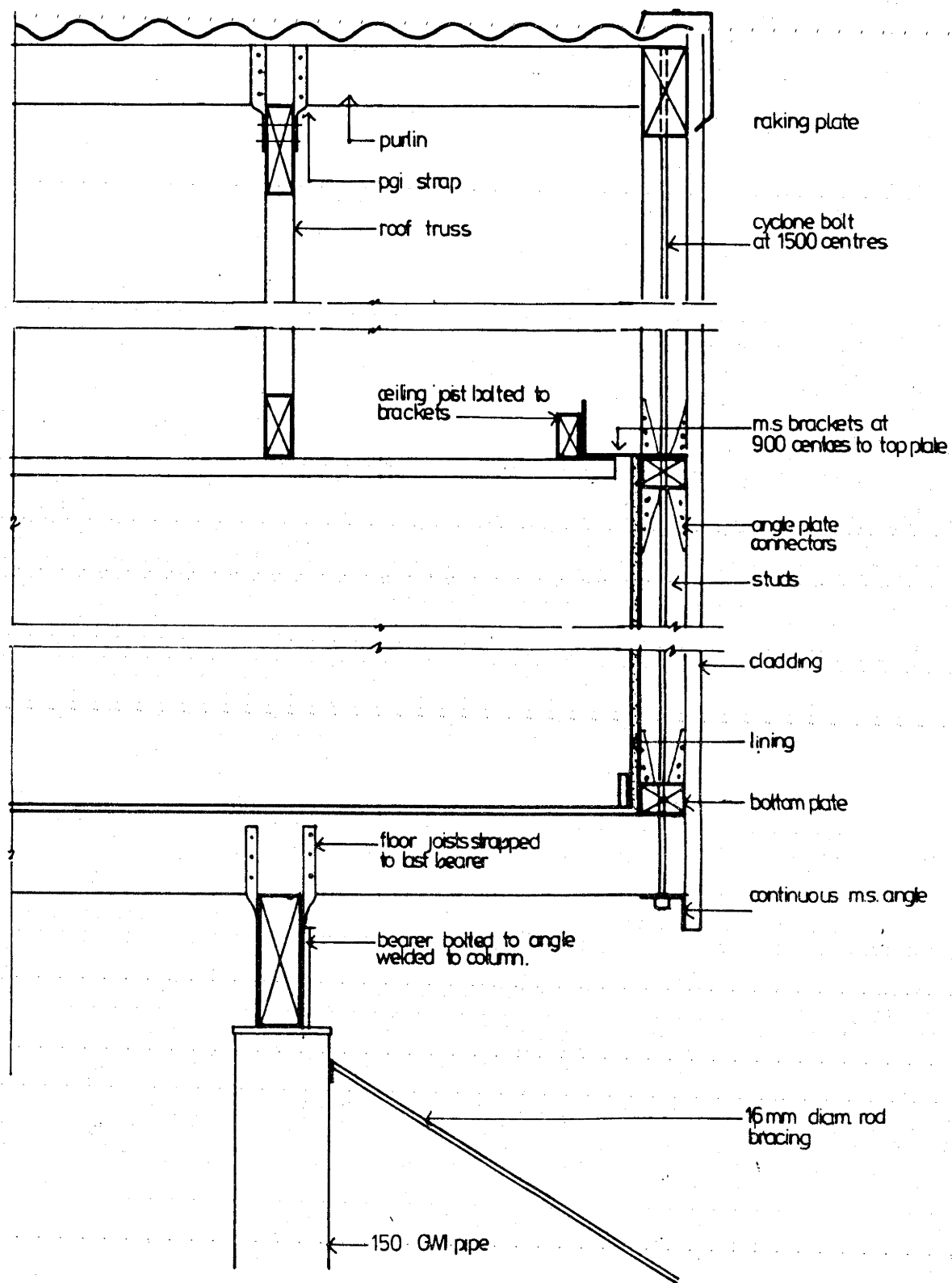


FIGURE 20. TYPICAL CYCLONE RESISTANT STUD WALL DETAIL.

SECTION 4 SOCIAL DETERMINANTS

".....disasters absorb people's attention, provide a medium for the build-up and release of emotions, and become collective representation of symbols by which past, present and future happenings become rated and dated" (FRITZ 1961:691)

MILETI, DRABEK, HAAS, 1975: 142

4.0. SOCIAL DETERMINANTS

4.1 OVERVIEW

Sections 1 & 11, have dealt with the architectural determinants of domestic construction in Darwin. Section 1 was concerned with illustrating the principles of climatic amelioration, and the manner in which this science had developed over time in the built form. Section II was concerned with the mitigation of cyclonic hazard through construction. The knowledge of these structural principles, did exist prior to 1975 and the awareness of structural inadequacy in Darwin's domestic structures was clearly documented, by the Institution of Engineers in a book entitled "What happens if a Cyclone hits Darwin" prepared in May of 1974.

A general awareness, and moreover a need for change was not perceived however, until the inadequacy was so abruptly demonstrated by Tracy.

If the recommendations of the document prepared by the Institution of Engineers, had been implemented through normal procedures of policy change and building code amendment, then the evidence of improved structural integrity and strength would have largely been concealed in the walls of the grey boxes, and the architecture at the domestic level in Darwin would have remained visibly unchanged. However, because of the dramatic way in which this need was demonstrated, the implementation of structural improvements was no longer the straight forward procedure, it may otherwise have been.

Tracy incurred enormous social upheaval and personal loss which was to complicate the issue of construction by:

- (i) creating the opportunity for many individuals to express their personal symbols of home.
- (ii) Modifying individuals perception of shelter needs in Darwin.
- (iii) Re-arrangement of the social order and population composition of Darwin.
- (iv) Influencing the means, materially, politically and economically through which change could occur.

If any meaningful comment is to be expressed about the architecture which has emerged post cyclone, then it is necessary to understand the context within which it evolved and the nature of the individuals who were responsible for creating the built form as it now exists.

The questions which arise are:

Who are the people who have rebuilt Darwin?

What were the immediate and long terms needs of these people?

What were the limitations on their freedom to fulfil their needs?

What does the built form express?

Much of this information is contained in reports prepared at all levels and for a diverse range of authorities. For this reason the sequence of events post cyclone are fairly easily established. However more difficult is understanding the impact of these events upon individual needs and perceptions and more specifically upon those individuals who have rebuilt Darwin in an unprecedented manner.

To draw this information together several procedures were adopted, the results of which form the basis for the architectural comment in this report. These included:-

(i) Exploratory research consisting of a literature search to embrace such subjects as;

- (i) the post cyclone sequence of events and the factors influencing the decisions made.
- (ii) the observations made/statistics collected reflecting the impact of these various decisions.
- (iii) the behavioural response of people in extreme environments as demonstrated elsewhere in the world, which present likely hypothesis for testing specifically in the Darwin context.

and interviews with a broad cross section of people involved in the post cyclone decision making process, or directly affected by it, or for whatever reason being an astute observer/participant capable of offering worthwhile insight.

- (ii) A survey, in the form of a questionnaire, followed by more formalized interviews, initiated primarily to draw together the social, political and economic influences, specifically affecting the circumstances of those individuals who were directly involved with the rebuilding of Darwin and to record in more detail the nature of the emergent architectural fabric.

4.2 THE SEQUENCE OF EVENTS - POST CYCLONE

4.2.1 EVACUATION

The decision to evacuate was made within 48 hours of the cyclone and the procedure completed (evacuation of 33,000 people) in five and a half days.

The incentive to evacuate was provided with return tickets to anyone who would depart. Greater impetus was given with rumours of disease. Women, with children, the aged, people who had suffered material loss, and those with limited building, planning or medical skill, were given first priority in evacuation.

4.2.2 SERVICES AND THE DISSEMINATION OF INFORMATION

Immediately after the cyclone, the Darwin Reconstruction Commission, hereinafter referred to as DRC, was set up to organize the reconstruction procedure.

Existing authorities, such as the Cities Commission, the Building Board and the Department of Housing and Construction acted as agents to the Commission in the development of housing design alternatives, planning schemes, upgraded building codes, finance distribution and advisors to the public. The evolvement of the new building code receives some attention in SECTION 3.5. Financial opportunities and planning schemes are discussed below in SECTION 4.2.3.

The individual home builder, while a victim of the decisions at the broader scale, had many, more onerous problems associated with his specific attempts to establish adequate living quarters for his family.

Almost spontaneously, private building co-operatives and church co-ordinated building associations, sprung up to alleviate the more pressing problems of material, equipment and labour shortages, which could not easily be solved by each individual on his own.

The pooling of resources was to make reconstruction possible for many who would not otherwise have managed.

One of these organizations had by March 75 developed into a powerful pressure group, who strongly defended the immediate needs of the people and organized a building fair to provide access for all locals to view building systems and consult expertise available.

The DRC, recognizing the need for dissemination of architectural building knowledge set up a Housing Advisory Service, through the Building Board to assist the individual builder.

To allow the occupants of Department of Housing and Construction and Housing Commission designed houses, to rebuild their destroyed homes, the respective bodies upgraded drawings of the house types constructed, which became available through the Advisory service, to anyone for a nominal fee.

Engineers were also freely accessible upon appointment, to the public for any structural queries.

In APPENDIX A, graphs displaying the number and type of technical enquiries made (through this service) and the number of plans released to the public as from the 15th March, 1976, are included.

The DRC also prepared documents, specifically designed to assist the home owner and building contractor. The "Home Building Guide", included perspective drawings of houses designed by the Royal Australian Institute of Architects, for which working documents were available for \$10. Eight alternatives were offered. Copies of four of these sketch designs are included in APPENDIX B. Other designs prepared by the Department of Housing and Construction and project home builders, were on display for the public to view and purchase.

These designs were mostly for ground level simple square and rectangular forms, incorporating drastically reduced opening sizes, some with storm shutters, others with deep eaves extending from a hipped roof tied down with peripheral columns.

A booklet entitled "Information for Chippies", was prepared to explain the basic elements of cyclone resistant construction.

Some of these details are illustrated in SECTION 3.6.3.

The "Home Building Guide" was updated as experience revealed the real prices of building components and methods of construction.

Suggestions regarding the viability of adopting various procedures in reconstruction were made as these were tested.

Some of these costs are given in SECTION 4.4.2.

4.2.3 FINANCE

By March 5, 1975, the Commonwealth Government had introduced legislation which was to provide a grant covering 50% of uninsured loss on dwellings, furniture and fittings, personal possessions based on the market value of the property on the 24.12.74.

Most dwellings were only 70% insured, and dwelling contents only 20% insured. The replacement of destroyed residential units was to comprise approximately 42% of the total disaster cost.¹

The Government, operating through the Home Finance Trustee made available a Reconstruction Loan, of up to \$42,000 (initially \$33,000) at a fixed interest rate of 6% for a maximum of 45 years.

¹ HAAS, COCHRANE, EDDY; 1975: 28

Only home owners or individuals negotiating the purchase of a home at the 24.12.74, were eligible, and the amount was calculated according to borrower's equity, the proposed cost of building, with the sum already being claimed on the 50% uninsured Repatriation and Compensation payout deducted from the maximum.

Another system of Commonwealth Government loans, operative pre cyclone continued to offer loans to a maximum of \$15,000 at 7 $\frac{1}{4}$ % for a maximum period of 25 years on a timber framed house and 35 years on a masonry house. This loan was available to anyone who had not previously purchased property in the Northern Territory.

The money claimed on an insurance policy, held by a Government as mortgagee of a home, was made available to the intending owner at 5% interest. This allowed many mortgages to be paid off increasing the proportion of privately owned homes in Darwin. Also where War Service Loans held a first mortgage on a house, the Government would lend on a second mortgage.

4.2.4 PLANNING

Planning for rebuilding a disaster ravaged community presents several types of atypical problems

"Reconstruction is made more difficult because the population is right on the spot and current needs have to be met which can interfere with formal plan." ¹

Devastation of the magnitude experienced in Darwin is perceived by planners as a golden opportunity to reset the city in such a way as to alleviate all the points of conflict.

¹ MILETI DRABEK HAAS; 1975:

These conflict points in Darwin included:

- An imbalance in commercial and residential areas.
- Inadequate traffic network between the distinct residential and commercial zones.
- The potential hazard of storm surge realized as a result of Tracy. Planners, quite sensibly, saw this time as the ideal opportunity to reclaim all areas in a potentially hazardous zone for conversion into public open space.
- Noise pollution, between highways, airport and residential areas was a problem which could be buffered by introducing green belts.
- The airport, centrally located in the city region, not only created a noise problem, but aggravated traffic problems and encouraged a suburban sprawl. This situation could now be reviewed.
- Zoning for medium density housing, and commercial areas to stimulate the tourist industry in regions of topographical interest and close proximity to the city, were considered desirable.¹

As a result, a scheme, which proposed all of these changes, was presented as a guideline, for feedback, to the public both in Darwin and in the southern states for reviewal. The scheme involved massive disruption of existing services and of many dwellings still intact, especially in regions proposed for surge zone reclamation and tourist precincts. This presentation was made in March 1975, and provoked a volatile reaction from the Darwin citizens.

¹ KING; 1977: 48

What was strongly evident from this exercise was the urgent need for reconstruction and not redevelopment. Clearly "The remains meant more to the owners than they did to the planners".¹

An amended scheme, presented in May of 75, reaffirmed these perceived needs. Planners persisted for a while to achieve some of the changes they believed were important for the community.

Thus uncertainty for the landholder prevailed for months as the objectives of the DRC scheme remained in conflict with the old Darwin Town Planning Scheme.

Some homes beyond the surge line had been reclaimed and others had had use restrictions placed on them. Finally the conflict was ended when at the end of 75, the DRC issued an existing use rights regulation.

.....land, building or works may be reinstated or maintained and used for the purpose for which they were being used immediately prior to the 24 December 74, and a building or work for which a building permit had been issued prior to 24 December 74 may be constructed and used for the approved purpose.

DRC LAND USE SCHEDULE.²

Although surveys undertaken in 1975 revealed a dramatic increase in the number of intact houses during the first five months of 1975, many had been grossly inconvenienced during this 12 months period of proposed land use changes.

This type of resentment was clearly held by the residents, for the DRC, who in many ways appeared to hinder attempts to re-establish homes and allow "normal" lives to continue.

Individuals did tend to perceive this action on behalf of the DRC as deliberate.

¹ KING; 1977: 74

² KING; 1977: 65

Certainly genuine attempts were made to activate procedures, although lack of knowledge and misjudgement in some decisions, such as the planning proposals, did tend to cause a stalemate.

It has been observed by social researchers that in post disaster situations when uncertainty prevails there is a tendency to request too much in order to ensure that one shall have enough.

This phenomena was very obvious in Darwin. When a well established practice of building proves to be totally inadequate, people, particularly concerned with the engineering of new systems are careful, not to allow a recurrence of disaster. The lack of confidence created by this extensive failure, meant individual freedom was drastically reduced.

Contractual relationships emerged as the "norm" with a consequent feeling of distrust and avarice, not evident in non contractual dealings, more characteristic of the pre cyclone period. This general lack of co-operation aggravated the conflicts which already existed concerning planning at the community and individual level.

It has been suggested that social mobility is increased and custom tends to be dissolved in a post disaster period. In Darwin this situation appeared to be short lived. As the community re-established itself custom, expressed in the built form, became more clearly defined, than before.

One would assume that this is partly due to the opportunity which now existed, for reconstruction and a reaction to the destruction of personal identity, immediately following the disaster.

4.3 BEHAVIOURAL RAMIFICATIONS

An extreme environment of the kind created in Darwin, post cyclone will naturally have a dramatic effect upon the human dynamics of a community.

Trends in human behaviour have been studied in many parts of the world during periods immediately following a disaster. Many of these observations appeared consistent with the forces at play in Darwin. These were to influence the manner in which re-construction was managed at the individual and collective level.

".....victims in general, respond to the situation of disaster in a highly active manner usually independantly of bureaucratic decision making processes." ¹

This behaviour was very evident in Darwin, with the spontaneous creation of building co-operatives and associations. The fact that a large proportion of the population, who remained in Darwin, were involved in the building industry, or committed to the Navy and later the Army, meant that this therapeutic activity was further stimulated.

Unfortunately, the life of this post disaster altruism is usually short-lived. Inevitably the relief operation is ".....assumed by bureaucratically organized units who reflects concerns, action, and requirements that are a sharp contrast.....indeed an insult.....to the mood of the therapeutic community." ²

The result of these more formalized procedures, creates frustration which naturally is born by the bureaucratic organization, who retreat further into the system for protection from the emerging negativism.

¹ & ² DRABEK MILETI HAAS. 1975: 101.

4.4 THE RESULTANT RECONSTRUCTION CLIMATE

4.4.1 DELAY

- (i) Initially reconstruction was hindered by limiting re-entry controlled by the permit system as a preventative measure against looting and disease - until adequate accommodation could be re-established. Many enthusiastic evacuees had their morale dampened in this process, some presumably re-established themselves in southern cities during this period.
- (ii) Proposed land-use changes restricted reconstruction in some areas for up to 12 months.
- (iii) Uncertainty on behalf of the DRC's structural advisory agents caused stopwork notices to be distributed to individuals often attempting non conventional construction and delays in the issue of building permits.
- (iv) Some sources of finance suffered delay in distribution caught in the system.

4.4.2 COSTS

Excessively high costs were a natural outcome of a high demand for material and labour, and limited supply. Limited supply was aggravated by the unreliable transport system and the monopolization of building materials by the DRC who were concerned about minimizing delay on supply for the bulk housing contracts, once these had been initiated.

The process of structural upgrading, was to prove expensive especially in accordance with the first, more reactionary code, dictating design wind speeds of 60 m/sec, and a cyclone shelter. Estimates indicate costs approaching \$10,000 for structural upgrading over and above normal costs.

Included in this cost of course was a considerable sum to professional fees, for the engineer's certificate of compliance.

Darwin home buyers/builders were extremely vulnerable to the economic demands of a limited professional force and contractor force, because of the urgency of their needs.

Some "normal" costs associated with building were however eliminated by the distribution of upgraded plans and documents.

The overall effect was to almost double the cost of a "standard" home from between the pre cyclone to the 1975 equivalent. A more detailed break down of costs is included in SECTION 6.

4.4.3 MATERIAL SUPPLIES

Materials were imported, utilizing shipping and road networks.

Bulk ordering became the only reliable method of obtaining supplies at a "realistic" price, thus accounting for the private building co-operatives which were established.

The one positive effect of the disaster was the influx of building products not traditionally used in Darwin. The demand also warranted the production of some products locally.

(i) Locally produced materials include;

- concrete blocks, & bricks & tiles.
- steel claddings. Hunter Douglas cladding produced of light gauge steel for the Northern Territory & Northern Queensland, not aluminium as produced elsewhere in Australia.

Manufacturing facilities for this product were set up in Darwin post cyclone.

- precast concrete wall panelling.
- precast concrete Melcast modular building system.
- roof timber trusses - manufactured from Malaysian, New Guinea & Western Australian Timbers.
- some extruded aluminium opening frames.
- light gauge steel debris/sun screens.

(ii) Imported Materials

Those building materials, which were to dramatically alter the appearance of buildings because of their availability included:

- ACI Decramastic tiles.
- profiled asbestos cement sheeting and boarding.
- profiled metal cladding.
- profiled hardboards and marine plys (including such trade items as Brik-clad).
- hopper and sliding windows.

(iii) Salvages Materials

Because the clean-up operation was so enormous, and owners were, on the whole absent, salvage operations were not extensive.

The long periods of exposure, caused by reconstruction delay, rendered a lot of material, particularly timber, unusable.

This naturally incurred an additional cost penalty.

4.4.4 CONTRACTORS

Contractors of small, medium and several large capacities operating in Darwin pre cyclone, were ready to engage in contracts of various sizes for the DRC. The bulk contracts, however were let to only the large contractor organizations including some who were not yet established in Darwin. This meant that a considerable number of contractors and sub-contractors were available for the restoration of housing in the private sector. Darwin became an attractive work environment for the many unemployed sub-contractors in the south. The influx of these did tend in many ways to reduce the standard of workmanship, to which the lay home builder became extremely vulnerable. The availability of money as indicated in SECTION 4.2.3 tended to encourage sub-contractors to increase charges counteracting the benefits of this liquidity. At this scale, protective control against this derogatory process was difficult to achieve.

The high turnover of sub-contractors also contributed to the difficulty in maintaining standards. The other influence of this influx of sub-contractors into Darwin was on the nature of the homes which ensued.

Construction methods were determined by contractor skills. Some contractors and sub-contractors arrived in teams for the specific purpose of constructing project/system type homes designed in the southern states or overseas.

4.4.5 DESIGN ALTERNATIVES

(i) UPGRADED PLANS

As was previously mentioned, upgraded plans and documents of

pre cyclone, Department of Housing and Construction designs, were made available through the Housing Advisory Service to all owners or intending owners of these homes. Only structural modifications were made to the documents, illustrating how structural chain of integrity, was to be improved by reducing the number of window banks and incorporating structural cladding to reduce vulnerability to debris penetration, and incorporating internal and sub-structure shear walls to prevent failure from lateral forces. The impact of this class of redesign shall be discussed more fully in SECTION 7.0.

(ii) COMPETITION DESIGNS

Prior however to the release of the upgraded plans, competition designs by the Department of Housing and Construction were displayed for public viewal. These homes were in the main ground level, and featured cyclone shelters, usually incorporated into the bathroom, cyclone resistant construction and facilities for air conditioning at a future date. The sale of the associated working documents were comparatively fewer than the upgraded designs. The impact of these designs, however could well have been quite extensive, as they were the first indicator of sound design, for cyclonic regions. The extensive failure of the elevated house undoubtedly remained vivid in many minds, which tended to support a movement to the ground level house.

(iii) SYSTEM HOMES

The two alternatives discussed above were dependant upon the availability of materials and contractors and the subsequent price fluctuations.

For this reason, systems, offering price, time, and structural guarantees provided a real alternative in the housing market, irrespective of their climatic suitability to Darwin.

The excellent market in existence at this time attracted system homes, sales personnel from all states in Australia and overseas. The impact of these house designs collectively was significant.

(iv) PROJECT HOMES

Local contractors were able to produce homes at reduced prices by standardizing materials and designs and by guaranteeing a constant order to material suppliers. For this reason, contractors became dictators to a small sector of home buyers who were not confident enough to administer their own construction or who were unable to afford professional advice. Locally designed project homes were therefore to provide another real housing alternative.

(v) INDIVIDUALLY INSPIRED DESIGNS

The final alternative was to evolve ones own house design with varying degrees of assistance and influence from builders, friends, architects and engineers.

Naturally this class of design is more diverse and is a more accurate indicator of specific home needs for the class of home owner who could afford, financially and/or through building knowledge and familiarity to create a home in a more intimate way.

4.4.6 CUMULATIVE INFLUENCE UPON THE BUILT FORM

The post cyclone sequence of events, and the subsequent influence that these events were to have upon the reconstruction climate are fairly easily established. However to understand the cumulative impact of these factors upon the built form, it is necessary to understand the individual home owner level.

- (i) the procedure adopted in reconstruction
- (ii) the reason behind the selection
- (iii) the constituents of the fabric

For this reason a survey programme was initiated to investigate the activities, which occurred in the 3½ years post cyclone period. The objectives of the survey, the procedures adopted and the information revealed are documented in the ensuing sections.

SECTION 5 SURVEY PROGRAMME

5.0. SURVEY PROGRAMME

5.1. OBJECTIVES OF THE SURVEY

The survey was designed to draw together the social political and economic influence discussed in the preceding chapters of this report, which were to affect the manner in which house forms evolved. Each house being the most tangible record of a specific human experience and the expression of the meaning in human terms of that experience. With the objectives of the research study expounded in the introduction to this report, in mind, the formulated objectives of the survey can be outlined as such:

To determine:

1. What characteristics of a house were perceived as important in a home in Darwin.
2. Who were the people actively involved in re-construction.
 - what are their skills
 - what was the extent of their experience with tropical living
 - what was their cultural background
3. Did time spent away from Darwin influence design/construction decisions through;
 - exposure to new ideas
 - the lessons of experience by others
 - avoiding delay and bureaucratic hassles.
4. Who assisted them in design.
5. What were the strong architectural influences.
6. What factors hindered individuals in re-construction.
7. What proportion of design/construction did they do themselves.
8. What were the component costs.
9. What alterations were made to original designs to overcome inadequacies.

IO. What is the domestic fabric which constitutes the new suburban architecture.

II. Have any developments in housing been made which warrant special attention in view of future mass produced housing.

5.2 SURVEY PROCEDURES

5.2.1 QUESTIONNAIRE

A questionnaire designed to indicate general trends affecting the built form and an overall assessment of the climatic and structural success of housing, was distributed to 3 separate suburban areas in Darwin. A copy of the questionnaire distributed and an outline of the intended purpose of each question included in APPENDIX C.

A cover sheet was attached to each questionnaire to allow certain physical characteristics about the house to be recorded so that trends in the functions of comfort, protection and display could be compared according to other influencing factors.

5.2.2 DISTRIBUTION

About 180 questionnaires were distributed by hand in each of 3 areas selected to represent a cross section of suburban characteristics in Darwin.

AREA I. WANGURI - This area was only developed in the early 1970's, and suffered almost total destruction in the cyclone, 80-100% of dwellings suffered damage exceeding 60% of its value. It was one of the first areas to be reconstructed and at first site is representative of the most reactionary or expressive class of reconstruction.

The majority of homes are now privately owned, (pre cyclone about 30% privately owned) and is now almost completely redeveloped.

AREA II RAPID CREEK - This area was first developed in the mid 1960's and about 60-79% of the dwellings sustained damage in excess of 60% of their value. A larger proportion of homes were privately owned, although only about 20% were originally privately constructed. There are more lots, housing piers and floorboards only, abandoned in this area than other areas included in the survey. Rapid Creek was one area subject to confusion about land reclamation due to potential storm surge risk.

AREA III FANNIE BAY - This area was one of the first suburbs developed in Darwin and as such was almost entirely privately owned, although, again houses were originally constructed as Public Servant accommodation. 60-79% of dwellings sustained damage in excess of 60% of their value. This area affords greater topographical interest and proximity to city and beaches than the other areas under consideration, and as such this area was subject to considerable debate in replanning proposals which in effect delayed reconstruction in this area.

5.2.3 COLLECTION

Collection of answered questionnaires was done by hand, ensuring direct contact with most respondents. Some questionnaires were distributed to occupants who were not eligible to respond because the house was either rented or purchased after the reconstruction had been completed.

About 22% of questionnaires were distributed to households in this category and of those remaining about 78% responded in Rapid Creek and 64% in Wanguri.

It must be noted that response to questionnaires in Fannie Bay was not as high generally as the other 2 areas. This was aggravated by the fact that the occupation of the residents in this area (largely professional and private enterprise) made it difficult to find owners at home, the larger lot sizes reduced the area that could be covered per day, and the generally higher standard of living enjoyed by home owners in this region meant that they were more independent of the post cyclone building industry determinants.

For this reason, time spent collecting questionnaires in Fannie Bay was not warranted and thus collection was abandoned in this area.

The trends evident from statistics formulated from collected questionnaire data is tabulated and discussed in SECTION 6.0.

However the distribution and collection of questionnaires did prove to be more beneficial as a research procedure than anticipated because of the direct contact allowed with the owner builders in their homes. This contact prompted discussion at a more detailed level and was usually accompanied by a tour of inspection through the homes constructed. This contact, increased familiarity with the construction systems and materials used, provided the opportunity to assess the effectiveness of different climatic controls, and the extent to which they are manipulated to achieve more efficient results.

It also allowed observation of the manner in which the spaces created were actually used and the opportunity to understand the design modifications made to overcome the inadequacies of pre cyclone homes.

5.3. INTERVIEW

The casual contacts made during questionnaire collection revealed the names of many home-owner builders;

- who had experienced specific problems,
- who had achieved particularly successful results,
- who were actively committed to re-construction or
- who could offer some insight into the re-construction procedures because of their particular interest in the built environment.

Thus the second stage of the survey procedure evolved as a series of interviews. Interviews were more formalized when the collection of questionnaires was complete and the trends in re-construction procedures became evident from the tabulation of data collected. An Interview Schedule was compiled and is included in APPENDIX D.

The interviews basically fulfilled the latter objectives of the survey outlined earlier. Naturally, a multitude of observations and the trends revealed from the questionnaire could be clarified.

The interviewees were all involved, in different capacities, with the re-construction of their own homes and came from different areas of Darwin. Some were post cyclone and others pre cyclone residents. Each home owner's situation was unique and as such, each interview tended to divert from the schedule prepared. All points were discussed however with different emphasis with each of the 23 home owner-builders interviewed.

The comments and observations from the interviews will be integrated into the discussion of building procedures and trends, and in the analysis of the existing fabric.

SECTION 6 HOUSING TRENDS

6.0 HOUSING TRENDS

6.1 PERCEPTION OF HOUSING NEEDS

The initial objective of the survey was to determine what characteristics of a home were considered to be of most importance in the Darwin setting. The immediate needs resulting from the devastation, of the intending home builders, were naturally to influence the extent to which the desirable characteristics could be achieved. Question I and question I2 of the questionnaire were designed to elicit the perceived desirable characteristics and the more urgent influencing factors respectively.

The tables I & 2 overleaf compile the typical answers to these questions with the number of responses to each illustrated in descending order of importance.

Many respondents did not answer question I2, however casual contact with home builders and interviews indicated support of this trend in priorities. The later factors becoming clearly more important as the urgent need for cyclone protection was lost.

Clearly the two tables are in conflict on several issues, which indicates that many homes are less than adequate from the point of view of comfort. The resolved compromise shall be discussed in more detail then the resultant fabric is analysed.

COMMENT	N° OF OCCURRENCE											
	5	10	15	20	25	30	35	40	45	50	55	60
I. <u>Good ventilation</u> (air-flow, catch prevailing breeze) designed for tropical living - louvre banks												
2. <u>Plenty of outdoor living areas</u> (large verandahs, elevated)												
3. <u>Structurally sound to code</u> (concrete roof, cyclone shelter)												
4. <u>Spaciousness</u> (high ceilings)												
5. <u>Prevent heat build-up</u> (timber framed, sun shading vegetation)												
6. <u>Air conditioned/Insulated</u>												
7. <u>Aesthetic</u> (not to look like a grey box)												
8. <u>Low maintenance</u> (ease of cleaning-waterproof)												
9. <u>Privacy - reduced noise</u>												
10. <u>Natural light</u>												
II. <u>Solar hot water heater</u>												

TABLE I CHARACTERISTICS PERCEIVED AS MOST IMPORTANT
FOR THE DARWIN HOME

COMMENT	N° OF OCCURRENCES									
	5	10	15	20	25	30	35	40	45	50
1. STRUCTURAL STABILITY (window protection, tie down roof, cyclone shelter, house at ground level)										
2. COST (to be able to do it yourself to avoid labour cost, utilize existing material)										
3. TIME										
4. FIND RELIABLE CONTRACTOR/ PROFESSIONAL										
5. MATERIAL SUPPLY										
6. SPACE REQUIREMENTS (allow for future extensions - car parking)										
7. RESALE VALUE (don't over capitalize)										

TABLE II FACTORS PERCEIVED AS MOST URGENT IN RECONSTRUCTION

6.2. POPULATION COMPOSITION

6.2.I. ASSOCIATION WITH DARWIN

Wanguri - Of people who were contacted 22% had purchased since cyclone or were renting.

- Of remaining 78%, (64% answered the questionnaire). half were pre cyclone and half were post cyclone residents, therefore ONLY 27% of the Original Residents had remained in Darwin since 1974.

Rapid Creek - Of the sites privately owned and more than 60% damaged 40% were either still in post cyclone condition, housing rental properties or had been purchased since completion of house.

- Of remaining 60%, (78% answered) of which; 55% were pre cyclone residents, 45% were post cyclone residents, therefore ONLY about 33% Original Residents.

Fannie Bay - Not as reliable because return so low, but prediction would be about, 45% Original Residents.

According to the overall number of answered questionnaires 46% did not live on present sites before the cyclone.

Of those who were pre cyclone residents,
the majority in; had lived there;
Wanguri 1-2 yrs or less.
Rapid Creek 50% 2-10 yrs, 29% more than 10 yrs,
30% less than 2 yrs.
Fannie Bay 85% more than 10 yrs.

6.2.2. CULTURAL BACKGROUND

These were classified into five categories;
Australian, Northern European (consisting mainly of English and German descendants) Southern European (comprised mostly of Greeks with some Italians), New Zealanders, and others comprised of Chinese, Indians and American. There appears to be an inconsistency in the fifth category, however the numbers in this section were pooled because of the insignificant influence these minority groups had upon the sample taken.

AREA	BACKGROUND				
	Australian	Northern European	Southern European	New Zealanders	Other
Wanguri	57%	22%	13.5%	2.7%	5.4%
Rapid Creek	62%	17.2%	10.3%	3.4%	6.8%
Fannie Bay	53%	-	-	-	?

TABLE III CULTURAL COMPOSITION OF SUBURBS

6.2.3 IMPACT UPON DESIGN

- (i) There was a slight indication that those people who had lived in their homes for 5-10 years pre cyclone, built homes which were more like their original homes and therefore more climatically suitable. This trend was not significant, as many newcomers purchased existing piers and floorboards and reconstructed.
- (ii) By rating each house on a 1 to 5 scale of apparent stability – 5 being an elevated elongated, light weight construction with no vegetative protection and 1 being a ground level masonry - concrete or hipped roofed home with small recessed, or completely protected openings and/or well protected by vegetation and 4,3, & 2 being at apparent structural levels between the two extremes, a very strong association was evident between the stability of a home and the cultural background of the occupant. No houses were given a 5 rating, and 1 & 2 and 3 & 4 were combined and tabulated below:

ETHNIC BACKGROUND	STABILITY RATING	
	1 & 2	3 & 4
Australians	56%	44%
South European	48%	51%
North European	80%	20%

TABLE IV INFLUENCE OF CULTURAL BACKGROUND ON SHELTER PRIORITIES

(iii) Climatic Considerations

Similarly to house stability - each home was given a rating from 1 to 5 based on climatic criteria.

1 being climatically "ideal". - elevated

- orientation to the north or 15° west of north
- light weight construction
- walls shaded
- reflectivity high
- cross ventilation

5 being - ground level

- sun penetration high
- high thermal capacity
- exposed walls and roof
- dark colour
- obstructed breeze

From this exercise there was no apparent association between climatic suitability and the amount of time home owners had lived in Darwin or under similar conditions elsewhere.

(iv) Display

The energy expended upon display tended to be greater with Greeks and Italians, although this conclusion is drawn as a result of observation rather than association revealed through statistics collected.

(v) Newcomers were less restricted by existing material on site than pre cyclone residents. Newcomers who were intending home building showed a distinct preference for a vacant lot, followed by a lot accommodating a ground slab, and finally a site accommodating piers and floorboards.

6.3 SOCIAL TRENDS

6.3.I INFLUENCE OF TIME SPENT AWAY FROM DARWIN

There was no apparent influence upon the nature of the homes constructed by those who were absent from Darwin for a period of time. Those who did remain in the south for a relatively lengthy period did tend to build immediately upon their return, while others who had never left Darwin, except for rest and recreation leave, were still just finishing their home in 1978.

Commencement date however had a significant influence upon the emergent architecture.

Those home builders who commenced construction of a later date tended to bypass a lot of the excessive costs allowing them to contract out the building, either with or without architectural supervision, keeping their own active participation in construction to a minimum.

If an existing house was being upgraded immediately construction was possible, families tended to stay away longer from Darwin than otherwise. The male to female ratio did tend to remain constant throughout Darwin regardless of the extent of devastation.

Discussion with owner builders indicated the need for some kind of recreation leave before serious re-construction could begin. Many, particularly Greek families did go home to Greece to visit their families before re-construction was begun.

6.3.2 COMMENCEMENT DATE

The change in codes, costs and attitude was clearly reflected in the built form over time. The major building amendment occurred in February 1976 and the percentage of ground level to elevated homes are given in the table below.

COMMENCEMENT DATE	HOUSE TYPE	
	Elevated	Ground level
Before February 1976.	39%	54%
After February 1976	57%	30%

TABLE V INFLUENCE OF BUILDING CODE AMENDMENTS ON BUILT FORM

The structural appearance was to dramatically alter also. Considering again the system of rating homes on the I-5 scale according to their apparent structural characteristics.

Table VI indicates the trend away from heavy cyclone proof housing.

<u>Commencement date</u>	Structural rating (% in each class)*		
	I	3	5
Before February 1976	32%	10%	0%
After February 1976	19%	22%	0%
After July 1977	0%	44%	6.4%

* I - Cyclone Proof

3 - Cyclone Resistant

5 - Evidence of Vulnerability to Debris Penetration.

TABLE VI INFLUENCE OF TIME ON STRUCTURAL PRIORITIES

July 1977 was the date the DRC disbanded, leaving the responsibility for maintaining standards to the local authorities.

* These classifications are made purely on external appearance.

6.3.3. DETERMINATION OF COMMENCEMENT DATE

The sources of delay, included in the questionnaire proved to be reasonably comprehensive. The only other causes of delay which were added by respondent to the list were sickness and effects of the wet season.

All respondents indicated that they were victims of two or three sources of delay. The contribution of each source is not easily identifiable from the data. The difference in the number of responses to each cause of delay is only marginal. The cumulative effect however seems to have caused a delay of about 12 months to most home builders.

34% of homes constructed were commenced between August 1975 and February 1976 and 30% were commenced between February 1976 and August 1977, with only 20% being commenced before August 1975.

The order in which delay sources were most significant were;

1. disputes with contractors and sub contractors
2. land use policy indecision
3. supervision by authorities
4. approval of working documents
5. material supply
6. finance
7. sickness and inclement weather.

6.4 HOUSING TRENDS

6.4.1 DESIGN INFLUENCES

The most commonly source of design inspiration was the upgraded Department of Housing and Construction and Housing Commission working documents. Most of these were modified to suit individual needs, which shall be looked at in more detail in SECTION 7.

Influences from architects, engineers, builders and project home companies were about equal. There were no trends relating to the source of design inspiration except that system or project homes tended to provide less internal and external living area.

The small system homes, tend also to integrate insulation into the main structural or cladding component making them more efficient to air condition. There was evidence that the project system homes were more likely to be air conditioned, in part at least, than other homes, with the exception of those homes which were inspired by a topographical feature or view often necessitating orientating the building across the path of low incident sun rays.

(i) EXISTING MATERIAL

Existing material influenced the house type reconstructed. 63% of the lots in the survey were housing damaged piers and floorboards and of these, 68% of reconstructed houses were elevated.

The remaining 37% of lots were either vacant or housing a concrete slab of which 94% were reconstructed as ground level homes.

Some owners who were left with piers and floorboards, were so clouded by the issue of structural integrity, that they chose to remove existing material and rebuild a new sub structure, incurring an additional cost penalty.

The influence of engineers in this matter was considerable, as their advice was often excessively conservative, when considered in retrospect.

Many who were advised to upgrade existing material, did so before superstructure could be reconstructed.

(ii) ARCHITECTS, ENGINEERS

All home builders were required by code to consult professional services at some stage in the reconstruction procedure. The general effect was one of extreme conservatism in design.

Many clients expressed resentment about the excessive fees they were charged. However satisfaction with the service was often acknowledged.

(iii) BUILDERS

Owner builders, who were contracting their work to a builder found the advice and service of the builder most satisfactory. Many indicated that the builder was of the most valuable of the consultations made.

The advice offered by builders varied considerably. Those well established firms, were eager to continue to build timber framed elevated homes, as the employed tradesmen, were generally experienced with this form of construction.

The influx of sub-contractors mostly skilled in masonry construction trades, influenced some builders and especially sub-contractor teams, to build of masonry.

Thus builders were to dictate the nature of design.

(iv) DRC ADVISORY SERVICE & SELF HELP PROGRAMME

This service was clearly designed to assist the owner builder who was actively participating in the construction of his home.

Many, who consulted these services, however, found the nature of the advice too general to be of value to the owner builders, who were mainly confronted with specific detail problems. Refer to APPENDIX A, for a list of the enquiries made.

Similar criticism was leveled at the written reports and advice booklets which were produced. This written material did have the positive influence of educating many on the basic principles of hazard mitigation through sound construction.

(v) MATERIAL SUPPLIERS

Material suppliers, keen to sell their own product, were unfortunately perceived as being the most misleading and unreliable of the building industry advisors.

(vi) BUILDING CO-OPERATIVES

These organizations clearly made re-construction possible for many, who had little inclination towards the practical issues of construction. However, these organizations tended to suffer from the same sort of delays and hassles, as the members of the community were suffering individually.

6.4.2 PERSONAL CONTRIBUTION

About 39% of the respondents were actively involved with the construction of their homes, the effect of which is more "unaffected" expression of the home owners aspirations and skills.

Initially this class of owner builder comprised the bulk of home owners, re-constructing pre cyclone elevated homes from upgraded working documents.

A smaller portion of this class of home owner was an experienced bricklayer and naturally, masonry homes, usually very "southern" in design, were built.

The Greek owner builders were far more predictable in the house type that they were to produce. This is largely due to the fact that Greek tradesmen tend to dominate the concreting and masonry trades, and the fact that tenacious extended family ties, effectively eliminates external influence. The impact of their unique form of building has considerable impact when produced at the scale which is obvious in some residential areas in Darwin.

Apart from the Greeks, there were no indications from the survey that those who fitted this class of home owner were from any particular domicile background or association with Darwin, although the majority had had some experience with building either at the design, drafting, administrative or construction level.

Those with less confidence to embark upon a full programme tended to channel their energy into the modifications and finishing of system homes.

Many owner builders are only now completing their homes, and have spent several years living in temporary accommodation.

This situation developed for several reasons:

- (i) many very wisely waited for costs to stabilize
- (ii) many considered a host of alternatives, in search of a more appropriate system
- (iii) many sought a means of by-passing the major contractor as an economic measure

Generally the result is a community far more "house conscious" than most, more aware of real values in housing and generally more ready to accept radical ideas, because of their heightened level of understanding.

6.4.3 COMPONENT COSTS

From the survey it would appear that persons commencing reconstruction in the first 18 months after cyclone Tracy were paying between \$8,000 and \$10,000 in excess of normal costs for structural upgrading. It must be noted that the labour cost component is abnormally high in all costs quoted.

The real cost of "cyclone proofing" a home in 1978 is in the vicinity of \$2,000 per house.

Standard homes constructed post cyclone were in the vicinity of \$55,000 - \$60,000 compared to \$32,000 for the same product pre cyclone. A standard ground level brick and tile home, worth \$20,000 in one of the southern cities would be sold for \$40,000 in Darwin post cyclone. Freight and structural upgrading has been estimated to constitute \$10,000 of this increase. System houses, ranged from between \$30,000 and \$65,000 for homes between 11 sqs to 15 sqs.

In March 1976, John Cooper, as agent to the DRC prepared a summary of unit costs as a guide for intending builders.

These are listed below in descending order of cost and are based on a 100 sq m home.^I

- Option 1 Letting a contract to a private general contractor for an individual home design. Vary from \$440 to \$520 per sq meter. Average cost per home: \$48,000.
- Option 2 Letting a contract to one of the many package dealers for the building of one of their standard designs. Vary from \$329 to \$426. Average cost per home: \$37,000.
- Option 3 Letting a contract to a small local building group where all members of the group are engaged full time in the building process. Vary from \$270 to \$370. Average cost per home: \$32,000.
- Option 4 Becoming a builder owner and letting a series of sub-contractors to the respective trades. Only one home available for study. Cost per 100 sq meters \$26,000.
- Option 5 Home builder on a do-it-yourself basis with sub-contract labour when required. Vary from \$180 to \$214 per sq meter. Average cost per home: \$19,700.

These figures were compiled from sampling taken in the early months of 1976 when re-construction activity and cost were at a peak.

The unit cost of domestic construction for a house of equivalent standard and specification in 1978 would be in the vicinity of \$395-\$415 / sq m, if contract was to be let to a private general contractor for an individual design.

^I DRC; 1976: 3-4

Innovations by the private sector in the utilization of precast concrete for ground level housing, designed, with respect for the local conditions were being built by letting sub contracts for separate trades, for approximately \$230-\$250 / sq m at the time this report was compiled.

Indications are that costs could now be drastically reduced with mass production of locally innovated systems. This shall be discussed in more detail in SECTION 8.

6.4.4 HOUSE SIZE AND COMPOSITION

(i) AREA

Houses constructed by the private sector, post cyclone have generally increased in area from the pre cyclone counterpart. 45% of homes visited were between 12-16 squares with few smaller and about 15% exceeding 20 squares.

External covered living area varies greatly.

26% of homes had less than 5 squares of outdoor living space.

29% between 6 & 10 squares.

22% between 11 & 15 squares.

This indicates an increase in covered outdoor area generally, although some home owners who opted for cost, time and structural guarantee, by purchasing a system home have incurred a penalty of limited space.

(ii) CLIMATIC CONTROL

42% - not air conditioned.

54% - partly air conditioned (usually 1 bedroom)

7% - fully air conditioned.

All homes not fully air conditioned, and most homes fully air conditioned had ceiling fans. Several homes (especially Greek) had these installed in outdoor living areas.

About 85% of homes have some form of reflective insulation in the roof and/or walls.

(iii) STRUCTURAL MEASURES

(i) Cyclone Shelter - 36% of respondents indicated that their home incorporated a cyclone shelter while 55% indicated that they did not.

(ii) Certificate of compliance - 25% of respondents indicated having possession of a certificate of compliance.

(iv) INSURANCE

94% of home owners have their homes insured for more than 70% of the estimated value of the home.

7. 0. HOUSING FABRIC

7.0 HOUSING FABRIC.

7.1 GENERAL

With an understanding of the pre cyclone domestic architectural scene in Darwin, one can appreciate the magnitude of the transformation that has been achieved largely by the private owner builders.

The basic housing precedents and the multitude of factors influencing this emergent "new" architecture have been expounded upon in the preceding sections.

In this section a more detailed analysis is given of the composition of this "new" architecture.

Initially in SECTION 7.2, the change in facade is considered and illustrated in terms of the basic architectural ingredients of available materials and construction techniques utilized within the restraints of the new code.

Secondly the change in facade is considered as the reflection of the utilitarian function of a home in tropical Darwin.

To illustrate the above two points, pre cyclone standard homes have in the main been selected, so that the modifications implemented in reconstruction can be easily recognized.

In SECTION 7.3, an analysis of housing fabric is illustrated according to the primary meaning which the home possesses for the occupant/owner. This has been done for several reasons.

Firstly it illustrates the diversity of domicile needs, determined by environmental exposure, culture and the building knowledge of the individual or family for whom the house was constructed.

Secondly it illustrates the changing priorities in housing in the years since December 1974. To do this, the classifications have been arranged in a sequence which I have identified as the basic trend in housing forms in Darwin. Clearly, discrepancies do exist, as this section deals largely with intangible symbols of home, some of which will exist independently of time and location.

With this trend established, one can hopefully understand the present state of housing and possibly be guided in the development of appropriate future forms.

The first three classifications, presented as "A house is.....", represent the first reactions to immediate housing needs post cyclone and as such are indicative of a localized set of conditions. They are of specific interest as a historical record of the impact of cyclone Tracy, which these buildings form.

The second three classifications, presented as above, are of interest to the architect, more for their sociological significance. They are the overt expression of psychological home needs. For this reason they are of more academic interest than direct value to the building industry.

The third three classifications represent the area most worthy of attention in view of future development in the building industry.

This classification is largely indicative of an increased awareness of housing needs appropriate to local environmental determinants and local economic restraints.

It is this classification which is further pursued in SECTION 7.4, Future Developments.

7.2 NEW HOUSING FORMS

7.2.1 FACADE CHANGES

Figure 21 illustrates a pre cyclone C19 (ref Fig 5), or "one room deep" type house in its cyclone damaged form.

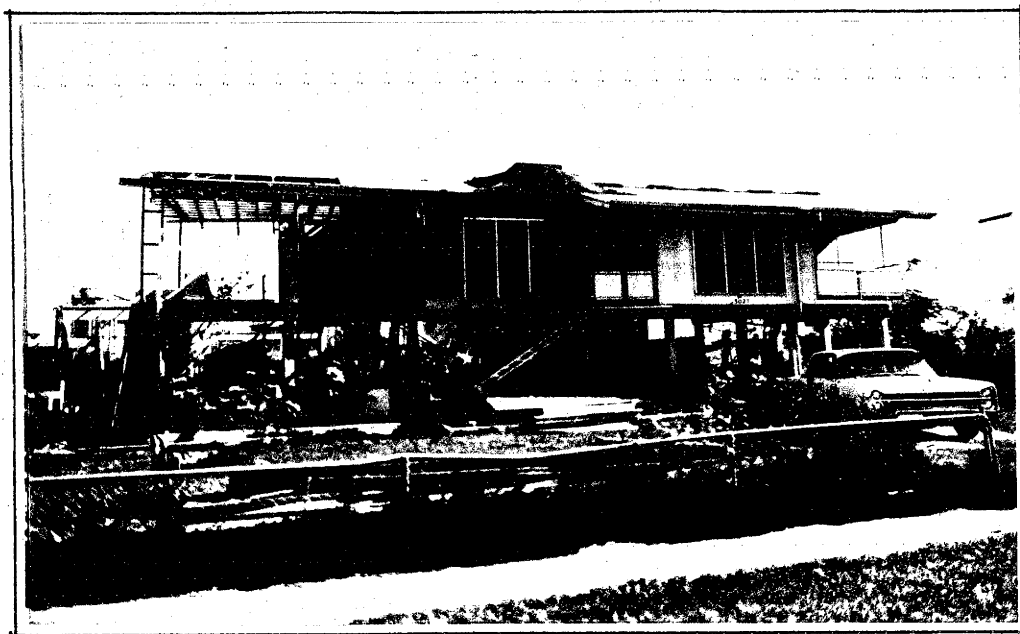


FIGURE 21 Cyclone damaged C19 house

Figure 22 illustrates this same house in its reconstructed form. The plan layout and basic elevation structure have remained identical. A structural steel cladding has replaced the pre cyclone "grey fibro". Window sizes have been reduced in area to meet the requirements of the new code.



FIGURE 22 Reconstructed C19 House

Standard Public Service upgraded houses are clad in the same Lysaght steel finish as that indicated in Figure 22. It is interesting to note however, that where the private sector have selected this finish, they have done so in a colour finish not included in the Public Service range. Figure 5 in SECTION 3 - illustrates the post cyclone standard C19 house.



FIGURE 23 Damaged "M" type house.

Figure 23 illustrates a standard M7 house in its post cyclone damaged state. Figures 24 and 25 illustrate two upgraded versions of this same house type, constructed from the cyclone remnants.



FIGURE 24 Reconstructed M7 house.

Figure 24 is less radical in its modification, although private ownership, catalyzed by the cyclone, has stimulated an interest in garden display, making a very positive contribution to the streetscape.

This home was one of the first to be reconstructed and as such it not only uses structural steel cladding externally, but is also reinforced with a leaf of structural ply, fixed to the inner side of the 100 mm x 50mm timber studs. A gyprock finish is then applied over the ply. This excessive structural reinforcement is typical of the early post cyclone over reaction.

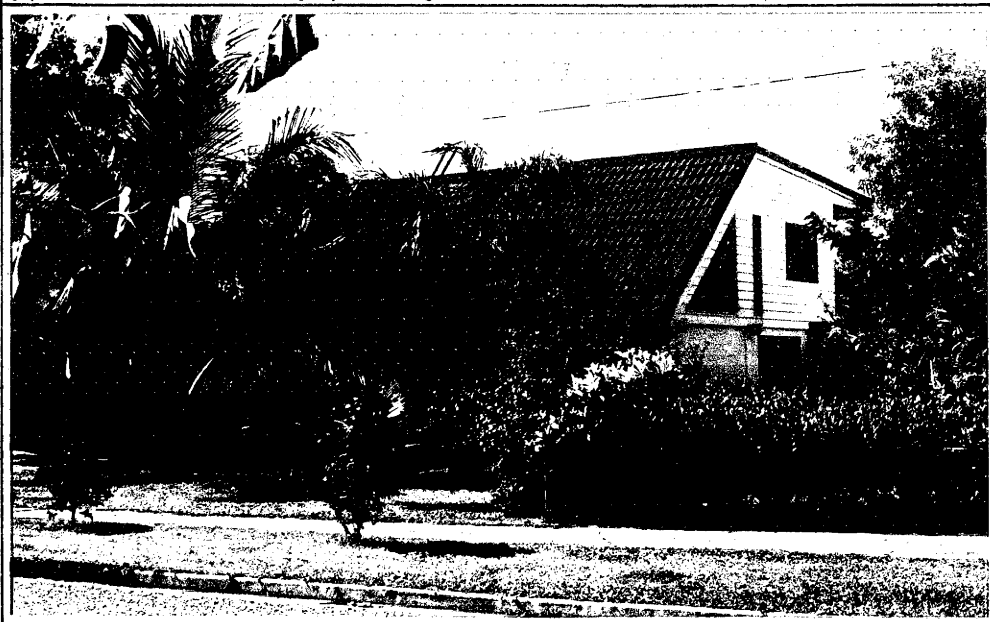


FIGURE 25 Modified M7 house

Figure 25, also an "M" type house has been reconstructed on ground level to incorporate the temporary living quarters, built immediately post cyclone, into the final design. This house utilizes two popular post cyclone claddings; Decramastic tiles to the roof and Hardi-plank in a wood grain finish, (an asbestos cement plank) to the upper story walls.

The illustrations in Figures 21 to 25 effectively display the influence of new materials and construction techniques determined largely by the more appropriate code, and applied to existing standard house forms. The modifications in this class of reconstruction are on the whole less fantastic than those housing forms which developed without precedent in Darwin. However, the impact upon the streetscape is none the less beneficial, at least in terms of relieving the flimsy monotony.

The use of alternative materials to "grey fibro" and corrugated roof sheeting, is the primary modifying factor in the housing transformation. The one major contribution has come from the extensive range of "non structural" decorative claddings which have become available. A saving of approximately \$600 on a standard elevated house, can be realized with the use of structural metal cladding such as the one illustrated in Figure 22, replacing the need to use a structural ply membrane beneath a non structural decorative finish. This has become the standard finish of the recently constructed Public Service home. This fact is a deterrent to its common use in the private sector. The private sector have favoured claddings more domestic in appearance, in preference to commercial looking steel profiles. These are applied over 6 mm structural ply which forms the bracing component in the wall.

Further comments on the reasons for material selection shall be included in SECTION 7.3. A more comprehensive coverage of available materials was included in SECTION 4.4.

The most basic and dramatic modification to general construction practice was the strong swing to masonry construction at ground level. The precasting of major wall and roof components has also dramatically influenced standard building practice.

Other more specialized methods are illustrated in latter parts of this section and SECTION 7.4.

The pre cyclone traditional building methods were basically modified to withstand greater loadings induced by cyclonic winds. These were discussed more comprehensively in SECTION 3.6.

The influence, however of these changes upon the facade is considerable. Not only was the intrinsic wall structure strengthened, but the wall/window ratio was increased to allow a more even distribution of uplift loads, generated on the roof, throughout the whole structure. The reduced opening size also increased the inherent strength of the glazed or solid infills.

Thus the consequent compactness of facade, which can be identified in Figures 22 and 24 forms the facade "norm" in post cyclone Darwin.

The functional purpose of the home, expressed in plan form however warrants closer attention as the changes in plan are reflected in elevation, reinforcing the visual change in the suburbs.

7.2.2 FUNCTIONAL MODIFICATIONS

A) MODIFICATION OF EXISTING ELEVATED HOMES

(i) Living Space

Generally an increase in living area has been achieved by;

- (a) enclosing existing balconies.
- (b) resuming kitchen areas and extending for a new kitchen.
- (c) building in a games room downstairs or converting a post cyclone temporary flat, into additional living and sleeping areas.
- (d) extending the existing line of the house.
- (e) resuming redundant sleeping areas.

To a lesser extent, external covered living areas have been increased at the elevated level by increasing verandah area, often by enclosing the main entry stairs. External living area has been reduced in some homes where upper balconies have been resumed for indoor living space or areas beneath the home enclosed. This has improved the internal areas in all cases. Many, however regret having lost verandah areas and some home owners propose to extend outdoor space as a second stage.

(ii) Room Relationships

Kitchens have been opened up, allowing closer interaction with living areas. In a number of homes, families have rebuilt their kitchen and "hard" living area beneath the house. This overcomes one of the major inadequacies associated with elevated homes, that of awkward access to garden, to laundry, entertainment area and allows easier supervision of and intimate involvement with children's play.

(iii) Conflict of Privacy and Climatic Control.

The lack of intra-home privacy created by optimizing cross ventilation has become accentuated as families have grown older. This has been overcome by many who have built additional bedrooms downstairs.

The resulting exposure to neighbours afforded by efficient cross ventilation creates tension, which necessitates the use of curtains and blinds. This unfortunately reduces the effectiveness of cross ventilation considerably.

Small eaves and reduced verandah areas, aggravate this problem, as windows often remain shut to avoid the risk of water damage to internal finishes, should a storm erupt while occupants are absent.

Gutterings have been installed to prevent the falling sheet of water being driven into the home. This problem was a major source of discontent in pre cyclone homes.

Reduced window area, corresponding to the raising of window lines, has alleviated water penetration problems at the expense of cooling breezes. It is more common now to install a 3 louvre deep bank to allow vertical air flow - the more beneficial breeze effect. Alternatively long narrow windows or louvre banks allow breeze entry in the lower half of the room without seriously diminishing the stability of the wall. This window type is common on east and west walls of elevated homes.

For those home owners who have built themselves or have been able to afford it, the verandah, has become identified as the most successful means of overcoming many of these problems.

With a partially enclosed periphery, the verandah can provide continuity of facade, additional protection to ground level areas, reduced exposure to neighbours, reduced water penetration and allow greater cross ventilation especially during the "wet". Living area is also subsequently increased.

(iv) Noise

Noise nuisance from rain has been almost eliminated in many homes by replacing water damaged, hardboard ceilings with Gyprock or other insulating ceiling panels.

A small percentage have opted to clad roofs with Decramastic or concrete tiles for sound reduction and aesthetic reasons.

(v) Access

In addition to cost motives and a hesitancy to return to an elevated position caused by threat of future destruction, many householders were inconvenienced by the need to mount stairs regularly. For these three reasons, about 34% of pre cyclone elevated homes have been reconstructed beneath piers and floorboards. Modifications to these will be discussed further in SECTION 7.4.

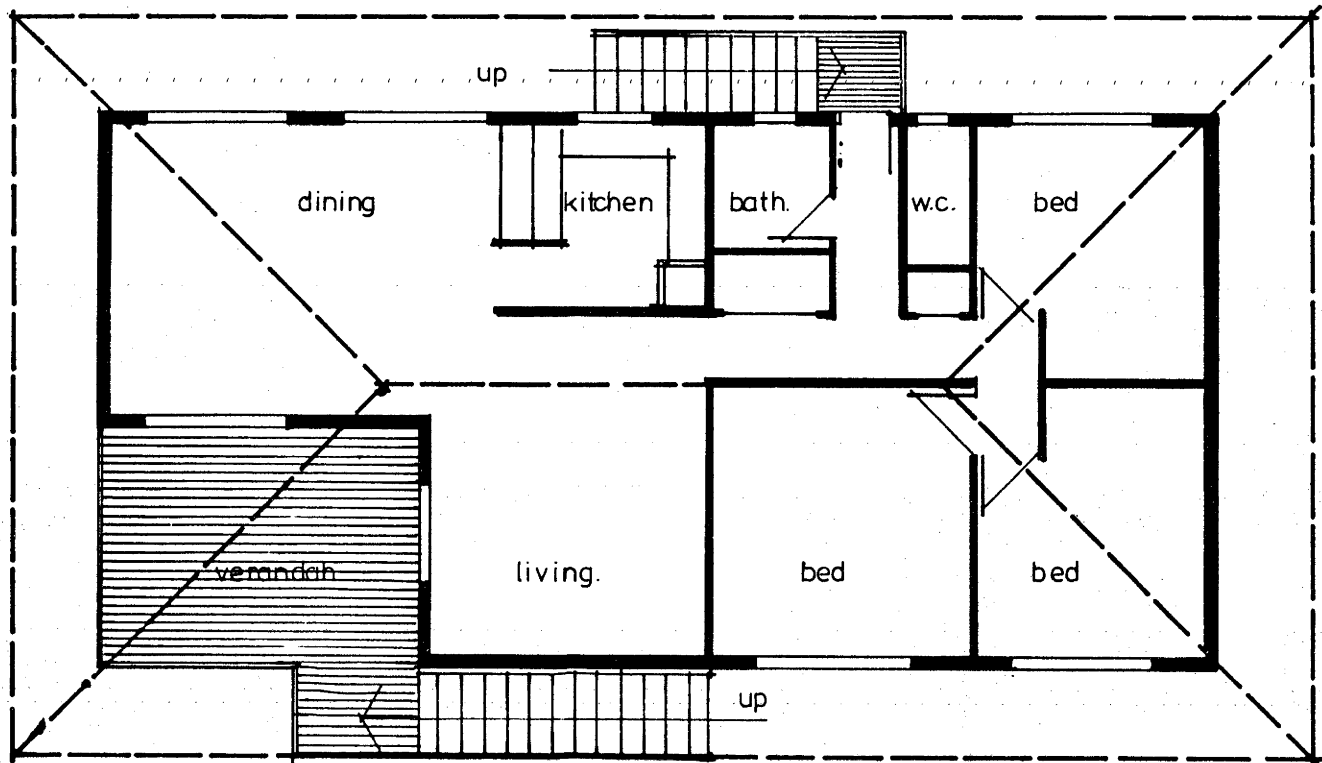


FIGURE 26 (a) Original upper floor plan.

Figure 26 illustrates some typical modifications to plan, which are indicative of changing family needs. Such changes include increased living area internally & externally, ensuite and modifications to direct breeze through the kitchen.

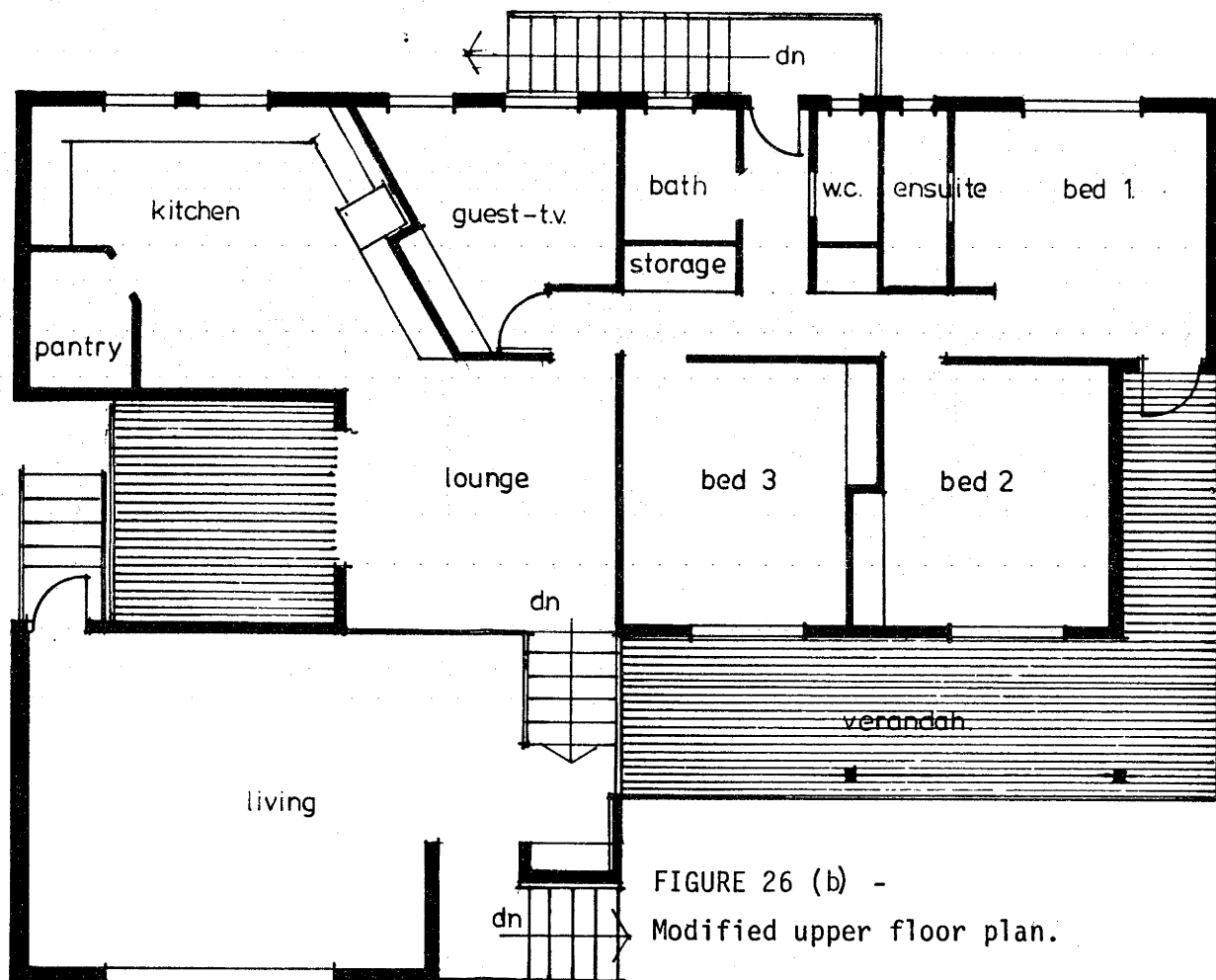


FIGURE 26 (b) -
Modified upper floor plan.

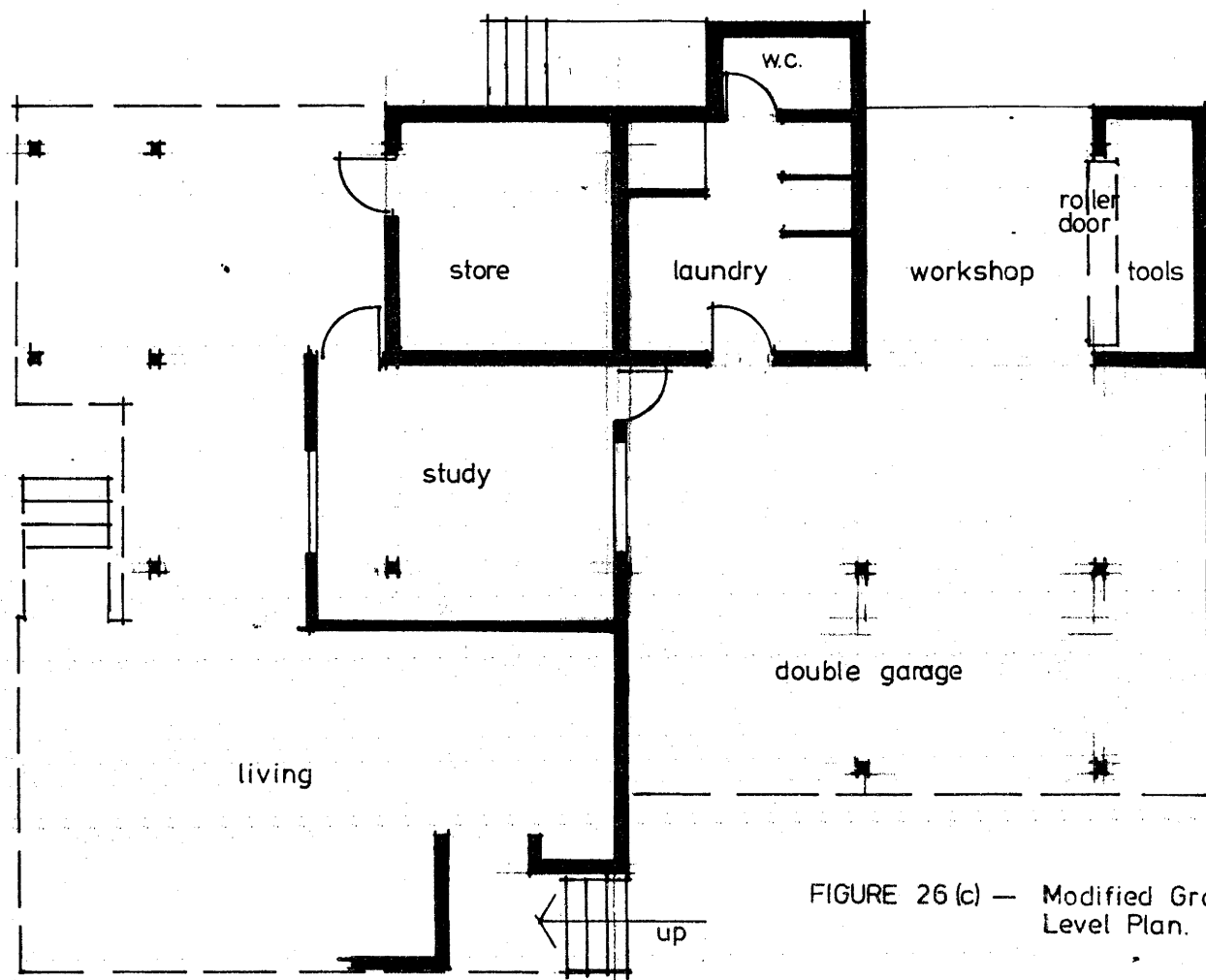


FIGURE 26 (c) — Modified Ground Level Plan.



FIGURE 26 (d) Front elevation of this reconstructed "M" type house.

This house has been constructed of a light weight concrete, sprayed on-to a weld mesh steel reinforced frame.
This roof is finished in a colour bonded, profiled steel roof decking, especially suitable for the long spans created by these extensions.

While this procedure was common under the Government bulk reconstruction contracts, few private individuals attempted this method. The results are very satisfactory. The internal areas finished in timber veneer panelling creates an ideal internal environment for this harsh tropical region.

B) GROUND LEVEL HOMES

Not as many of these were visited as the elevated homes, however some strong inadequacies are evident by the manner in which these have been altered.

Almost without exception, living areas have been increased, often introducing a new floor level to achieve increased ceiling height without altering roof structure and to add interest to an otherwise predictable home.

Verandahs have been added for the reasons described above, in SECTION 7.3.1.

Internal courtyards have been created to induce air movement brought about by the pressurization of air in covered courts, and convection currents brought about by heat differentials caused by differing reflection off alternate walls in uncovered courts.

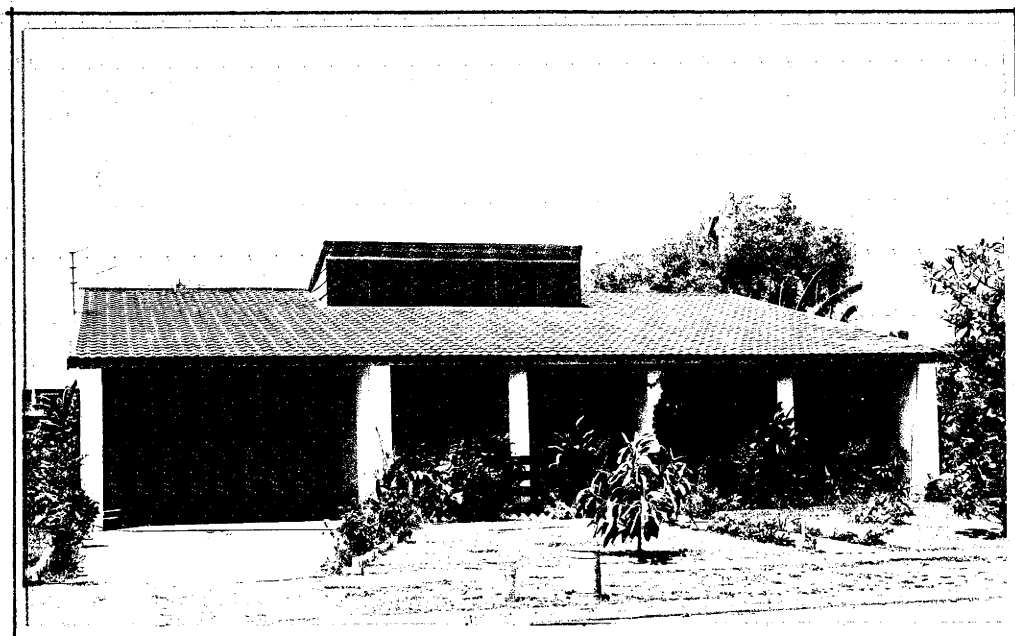


FIGURE 27 Modified Housing Commission Home

Figure 27 is a pre cyclone Housing Commission brick and tile house, extended and upgraded in reconstruction. Note the full length verandah added for sun protection and the skylight, designed to induce air movement through the house. This new roof line now shields 26 squares of living space. Pre cyclone, this was a 12 square home. A new bedroom wing forming an open courtyard and the enclosure of the existing carport for use as a games room, are the major ways in which this increased area has been achieved.

C) NEWLY CONSTRUCTED HOMES

Initially newly constructed homes were in the majority ground level. Constructed of concrete block or utilizing one of the many system components.

Some incorporate large - all embracing verandahs to shade walls and large low openings to encourage air movement. Unfortunately, however many of these homes have simply been built as replicas of southern designs, partly as a result of;

- (i) a desire for something different by Darwin standards.
- (ii) lack of suitable designs in Darwin.
- (iii) urgency of providing accommodation.

As such, these homes which are characterized by limited external shading, small window openings, walls and roof of high thermal capacity, have become a burden to their owners. Many have expressed regret at;

- (i) not retaining louvre banks.
- (ii) not building up on piers again.
- (iii) investing so heavily in cyclone protection at the expense of comfort.

There will of course always be those individuals who can tolerate these conditions, so that they may house their antique furniture, shag carpets and generally escape, at least psychologically the "unbearable tropics". Others live lifestyles which have little dependance upon the home environment, and others can also afford air conditioning making any house type habitable.

The majority of Darwin home owners do not consider fully air conditioned homes desirable. Most however enjoy the benefits of air conditioning from a small unit in the sleeping areas.

New houses presently being constructed tend to be an even composition of elevated and ground level homes.

Both types are larger than equivalent pre cyclone homes. Family homes are in the order of 14-20 squares. Many are larger, but few are smaller in area. Many built now have covered outdoor areas equal in size to the internal area.

Small homes (often system homes) are made bearable by upgrading old piers and floorboards as outdoor living areas or by elevating standard smaller homes.

Figures 27 and 28 illustrate the manner in which the burden of limited space afforded by low cost homes (relative to "one-off" homes) have been alleviated.

The continued popularity of precast systems, and in particular the concrete Melocco units, used at ground level, elevated or a combination of both, is indicative of a need for precast components which can offer flexibility in the design to accommodate individual needs, and the economies of local mass production.

In SECTION 7.4 all these Newly Constructed house types are illustrated according to their primary design criterion.

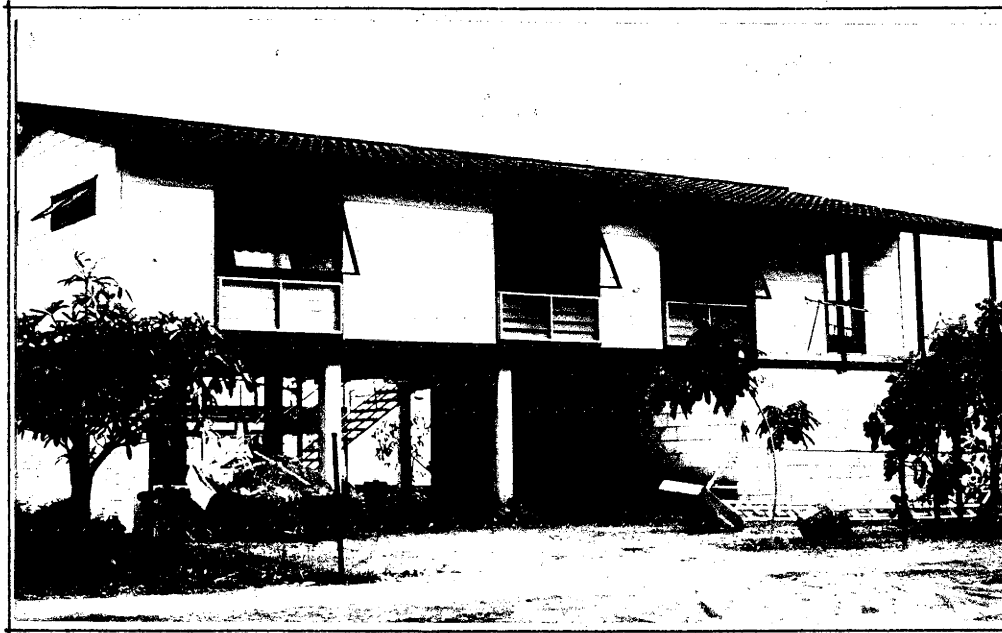


FIGURE 28 Standard system home elevated on existing piers.

Hundreds of these interlocking pine board system homes were imported from New Zealand into Darwin post cyclone. Adaptations of this standard home for the tropics include the lower bank of metal louvres for breeze deflection through the home and the relatively blank east and west walls.

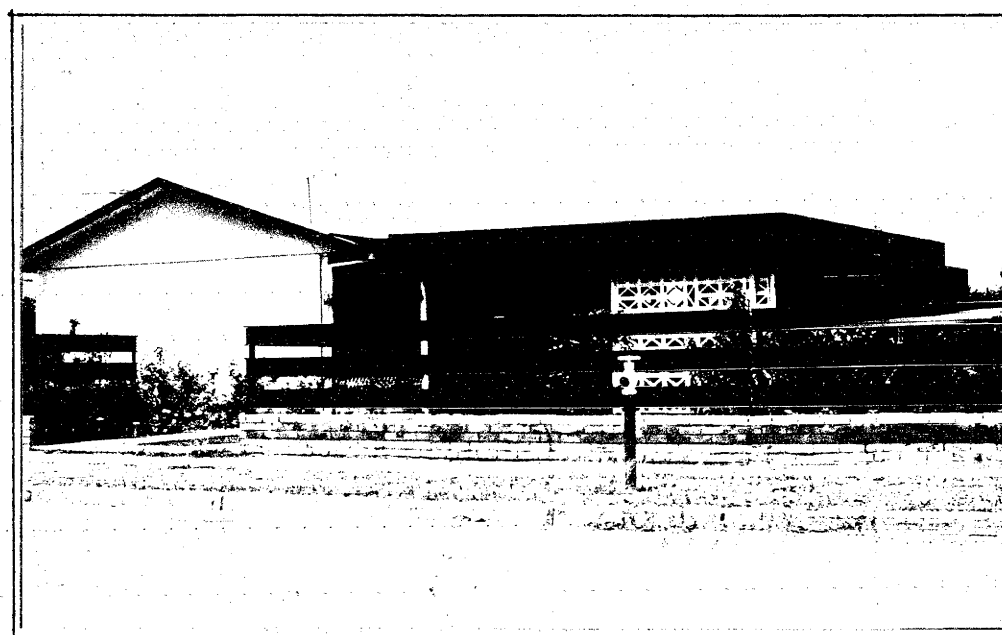


FIGURE 29 System Built home, adjacent to existing piers & floorboards

This sandwich panel system home manufactured in Perth W.A. offers only limited outdoor living areas in its standard form. By semi enclosing the existing piers and floorboards a very pleasant environment has been created with the additional benefit of reducing the heat load on the adjacent new home.

7.3 A HOUSE IS

7.3.1. A FORTRESS TO RESIST CYCLONIC WINDS

The loadings induced by air-flow over a structure, as discussed in SECTION 3.0 clearly indicate the advantage of low set, square structures, in minimizing the loadings on each component. The sealing of a structure eliminates the reinforced loading created by internal pressures. Whether or not people understood these principles is questionable, however, they definitely did appreciate the inadequacy of the light weight elevated home.

The three examples selected to illustrate this initial over reaction to the structural inadequacy of pre cyclone house have all been constructed by owners who lost their original homes in the cyclone. Of the newcomers, few built fortresses for reasons of cyclone protection.

A cultural specific factor was evident in the houses primarily built to be "cyclone proof", as these early homes clearly were.

The Greeks who appeared to suffer the most from the losses and disorientation incurred, clearly expressed a reaction to cyclonic vulnerability.

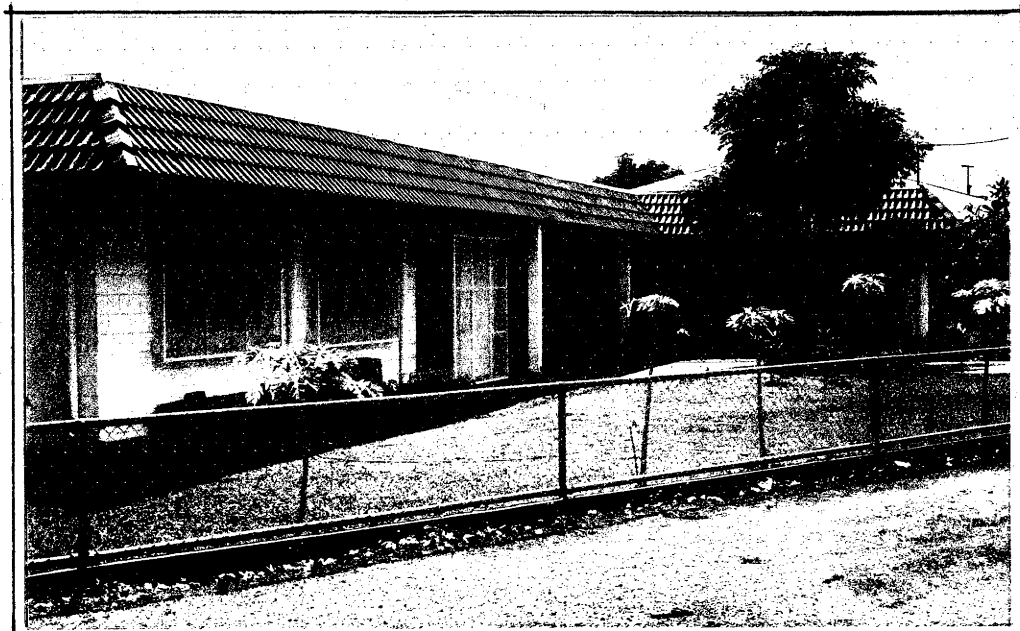


FIGURE 30

Originally this was a ground level house with a trussed roof which failed. This house is now roofed with an exposed reinforced concrete slab, hidden behind the tile fascia.

This house was constructed in 1974 for a cost of \$35,000 and reconstructed in late 1975 to include new roof, debris protector screens, and concrete infill in existing walls for \$75,000.

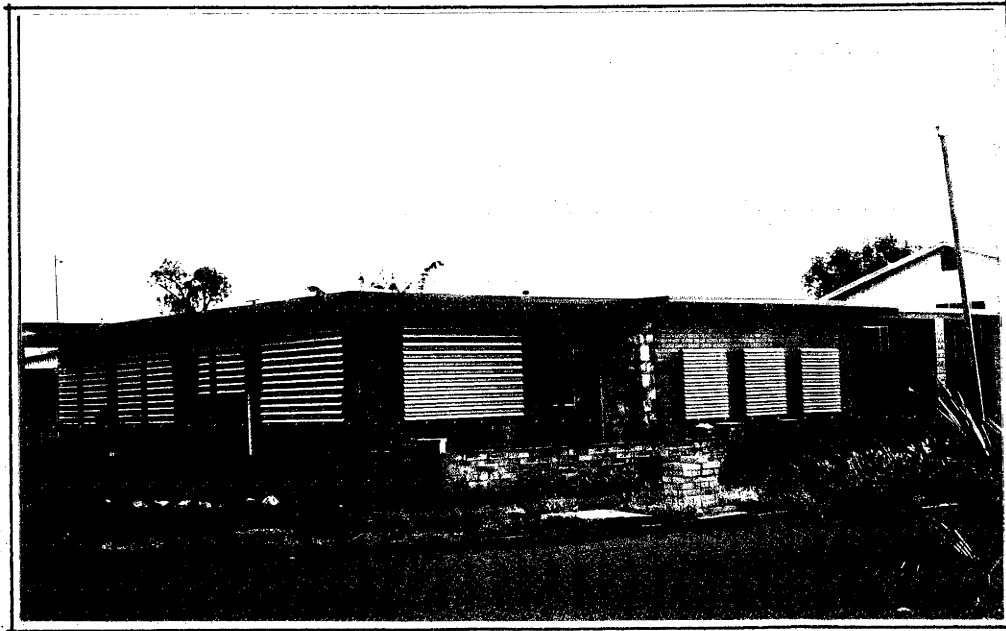


FIGURE 31

In this home all openings are completely protected by light gauge steel sun louvres, which create an introverted environment in total contrast to the typical "tropical" living environment. A 250-200 mm concrete roof, is a major heat source, which has necessitated the installation of an insulating suspended ceiling.

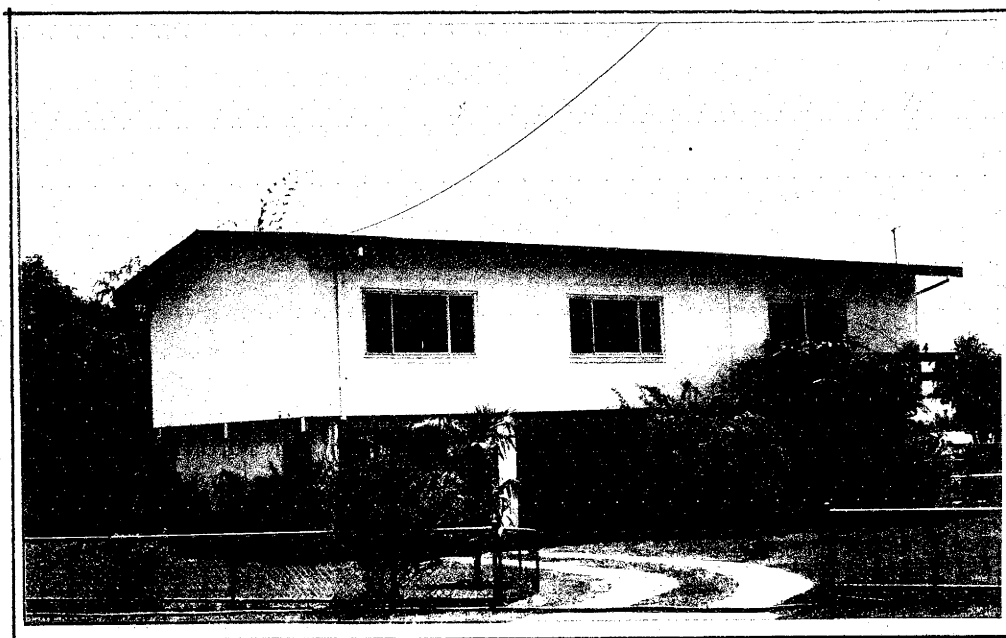


FIGURE 32

This pre cyclone elevated home is reconstructed in reinforced concrete, infill concrete block walls, designed to withstand the loadings created by windspeeds of up to 71 m/sec. The metal clad roof covers an integrated concrete slab ceiling. Note that the present code requires that structures be constructed to withstand loadings created by windspeeds of 55 m/sec.

7.3.2. WHAT WE CAN AFFORD — NOW !

Table II in SECTION 6.1 indicates the significance of cost and time as major factors influencing the criteria for house selection.

Families who remained in Darwin after the cyclone, often resorted to living beneath piers and floorboards until reconstruction could proceed. These living conditions were quite adverse, motivating many to rebuild as quickly and as cheaply as possible.

The newcomers, faced a different problem. They were not eligible for the financial assistance, which was to make cost the most important factor in the selection of a house. Older people who did not feel capable of embarking upon a major rebuilding programme, were forced to select a home from the time/cost budget range.

Thus two alternatives emerged. To infill between existing piers with either concrete block or timber frame construction. Or to purchase a system home which offered price, time and structural guarantees.

The utilization of existing material was an obvious measure to reduce costs. Existing piers and floorboards were incorporated into the frame of the house in some instances, or utilized as covered outdoor living space in others, as illustrated in Figures 28 and 29. Existing material has also been kept and upgraded, in many instances when a system home has been purchased to elevate the home, or to provide additional outdoor space.

"A" framed houses were in several instances thrown over existing piers and floorboards. This allows a mezzanine to be constructed internally, with considerable space benefits. These homes, were generally inspired by a belief in the inherent aerodynamic qualities of the "A" form, rather than cost benefits, although only the use of existing material made this more spacious home attainable for many.

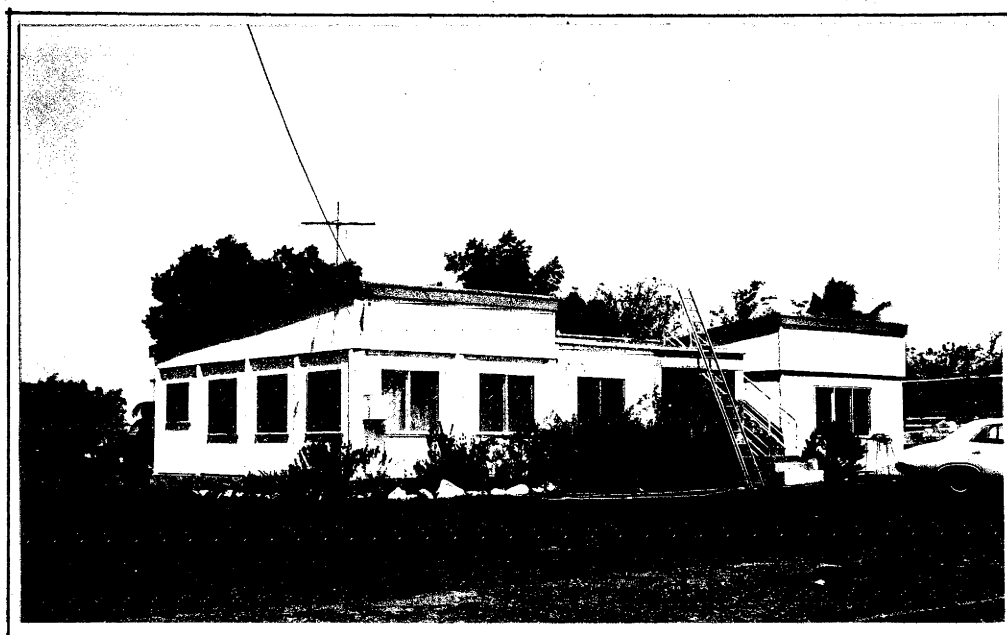


FIGURE 33

Existing piers and floorboards form the basic plan of this simple, fibro home. Piers have been left exposed and floorboards covered with a simple skillion roof. A breezeway has been created through the centre of the home. The original stairs to the elevated level have not yet been removed. Screens have been installed over louvered windows, more abundant on this home than many of similar vintage. This house otherwise is typical of hundreds in the older areas of Darwin.

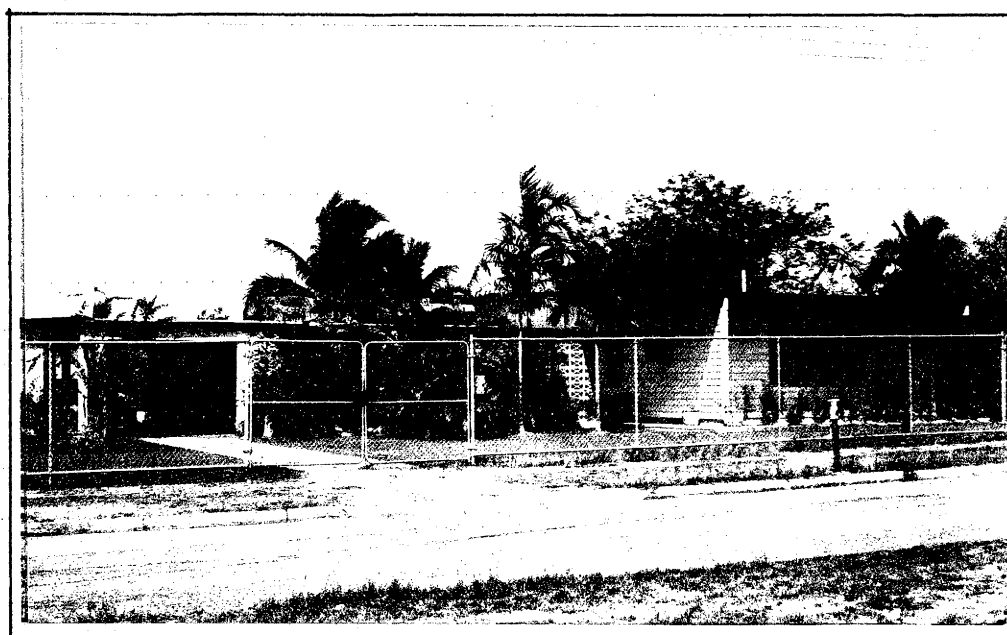


FIGURE 34

This simple timber frame house, clad in asbestos cement boarding has been constructed adjacent to existing piers and floorboards, kept for use as a car shelter, workshop, outdoor living and entertainment area. An outdoor covered area is also particularly useful in the wet season for drying clothes.

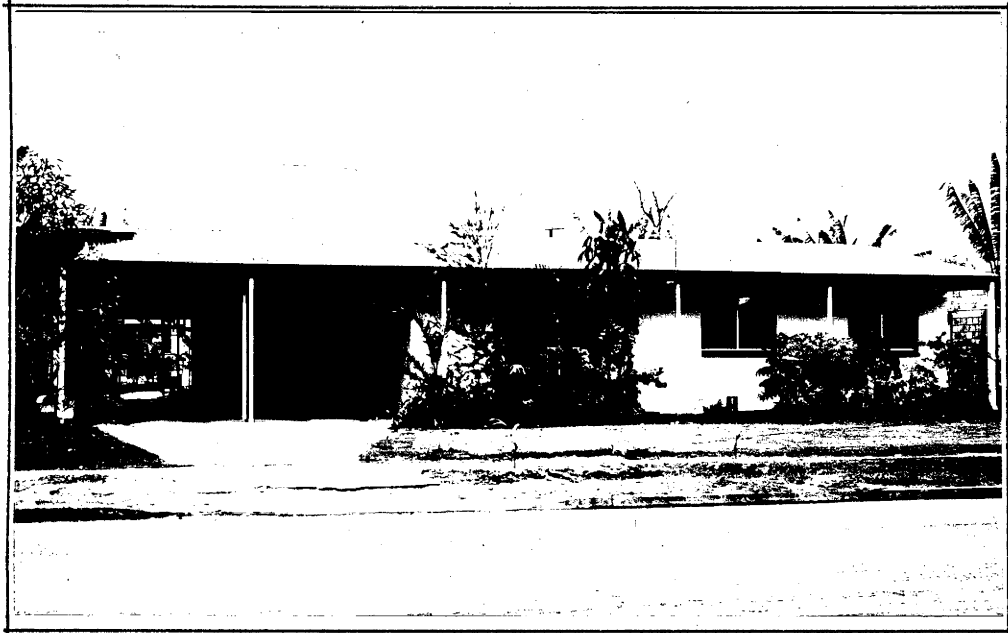


FIGURE 35

This figure illustrates one of the most commonly constructed low cost homes. Initially this 11 square home could be purchased for \$28,000, and was one of the few houses available for this price, which did not incorporate as a major component, materials or systems from the southern states or overseas. Cosmetic treatment to this basic house has achieved considerable variety throughout the suburbs.

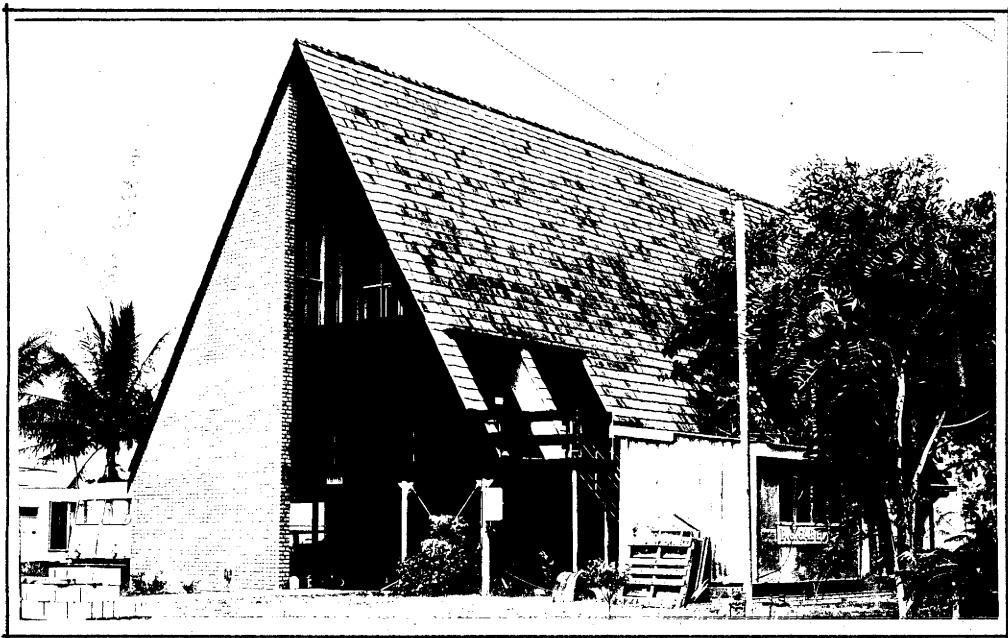


FIGURE 36

Although this figure illustrates a more extravagant home than the average in Darwin, it is included in this section to indicate the variety of forms resulting with the imaginative use of existing material. The initial saving incurred by utilizing piers allowed greater expenditure on other elements of the home. Most piers required structural upgrading in the form of cross bracing and enlarged footings although the cylindrical steel piers as illustrated in this photograph were generally free of failure.

7. 3. 3 . A SOURCE OF INCOME

The high demand for housing in Darwin caused excessive price increases. Even the simplest three bedroom ground level houses were selling for between \$45,000 and \$60,000 depending on the standard of finish, during 1975-1976. The easily obtainable finance supported a heavy investment into housing, which cannot now be resold on the open market. Over capitalization created by excessive costs, and the need for "cyclone proofing" has grounded many people in Darwin, unable to release themselves from the bondage of \$42,000 loan, being paid off over 45 years. A distinct discrepancy exists between the real value and the market value of homes, at the present time in Darwin.

Thus a demand has been created for a solid (in appearance at least) home in a lower price bracket. This class of reconstruction is having some impact upon the residential scene particularly in more recent months, as owner builders who have learnt from the unhappy experience of others, and project builders, have realized the importance of maintaining the resale value of a home.

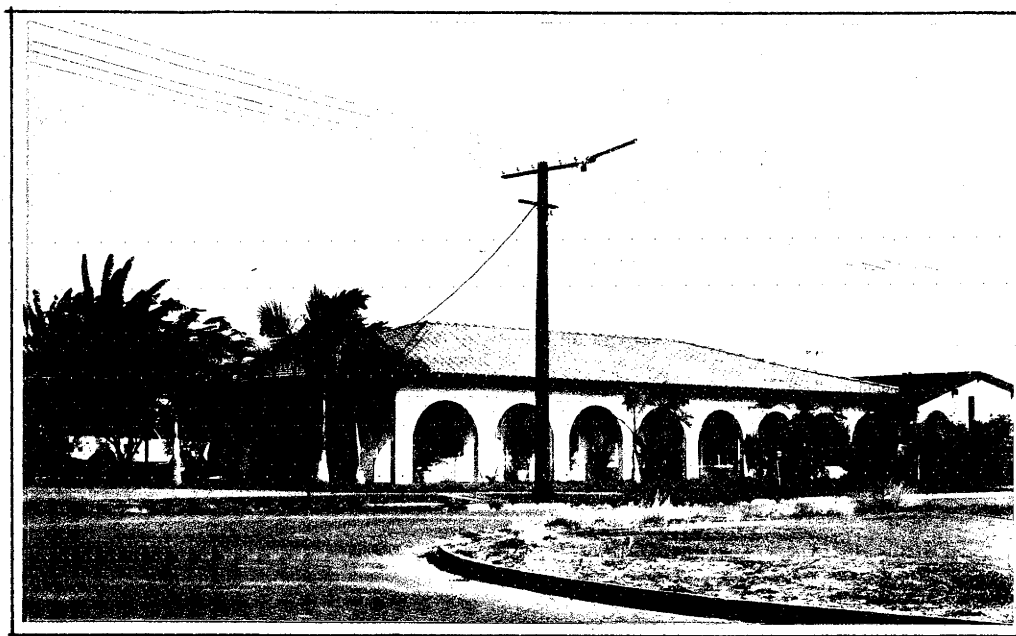


FIGURE 37

The colonnade of arches is a commonly exploited facade treatment, which continues to maintain its popularity with the home buyer. In this case a very simple 12 square house has increased its value by the construction of an arched verandah effecting additional benefits of sun protection and increase outdoor living area. This was a popular way of upgrading the appearance of damaged Housing Commission homes.

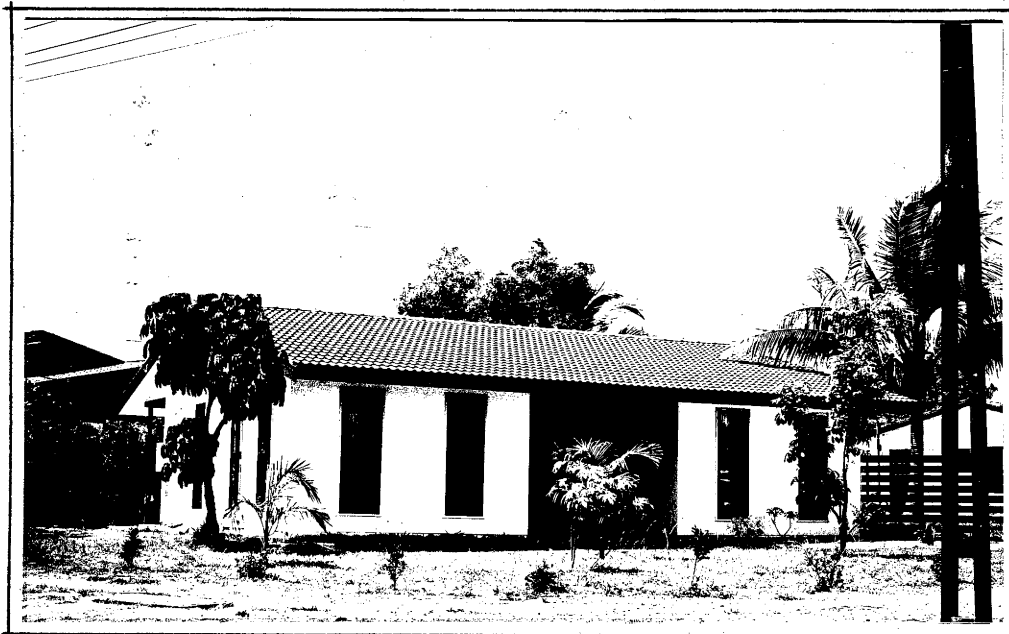


FIGURE 38

This small three bedroom house of light weight fibro construction was built with resale in mind. A solid appearance is obtained with the light application of Spanish render. This relatively maintenance free finish was applied by the inexperienced home owner for about \$1,500. Vertically elongated openings achieve breeze entry from the lower half of the wall without increasing the vulnerability to failure which large opening expanses are subjected to. The half courts at the front and rear assist in capturing breeze which can then be directed through the house as required. This home offers "something different" in the \$30,000 - \$35,000 home market range.



FIGURE 39

The Greeks who are masters of private enterprise, achieve cost saving by repetition in design. These three homes, identical in form, feature masonry and hipped roof construction in traditional style, with porticoes in blue, green and apricot to distinguish between the three. Because the traditional Classical forms are so well defined, individual identification between Greek homes is frequently achieved purely by colour application over blockwork, brickwork or cement render.

7.3.4 AN EXTENSION OF SELF

Anonymity was clearly the most characteristic feature of Darwin's residential areas. Although Table II does not indicate the need for individuality as a high priority, clearly many owner builders have expended considerable energy in the expression of self.

The nature of self expression varies considerably. Some houses very clearly reflect the specific skill of the occupant. For others, definition of territory is a major priority which is a very natural reaction to the sense of exposure and lack of privacy which the elevated homes, constructed in monotonous rows, afforded. The most significant impact has resulted from the expression and display of the traditions and aspiration of a cross cultural population which exists in Darwin. The Mediterranean influence is particularly strong. A deeply rooted tradition in masonry construction and an appreciation of colour (especially Greek National blue) and texture in a variety of decorative combinations is very obvious. The arch in all forms has made a major contribution to the display in many homes. Others less concerned with facade treatment have created a $\frac{1}{4}$ acre tropical paradise, where an affinity with nature is strong.

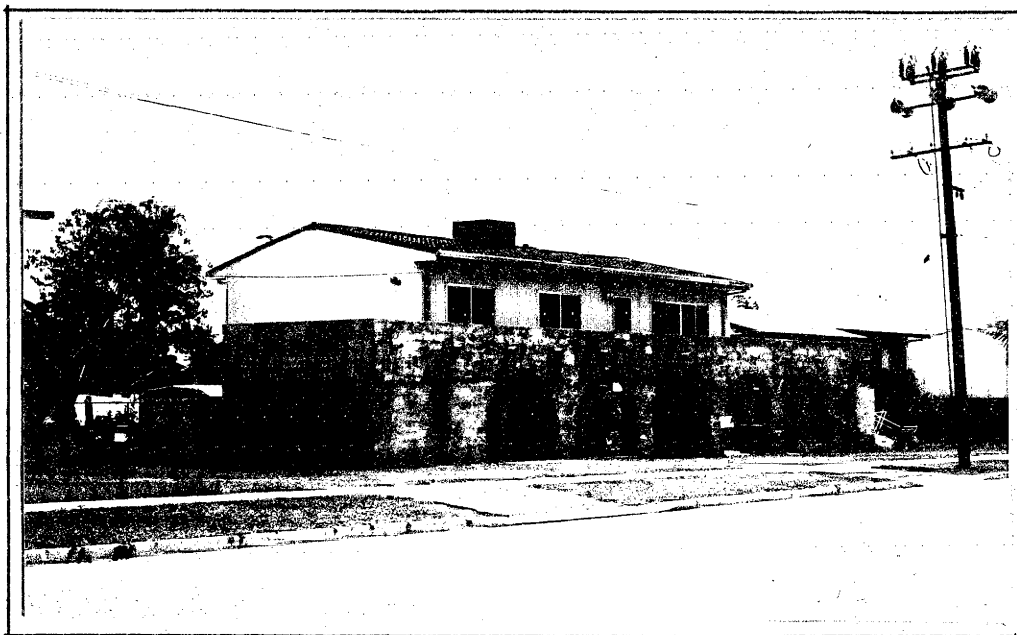


FIGURE 40

A very clear definition of territory. This home was not extensively damaged in the cyclone. A structural metal cladding and a braced Decramastic tiled roof have been used to upgrade the home structurally.

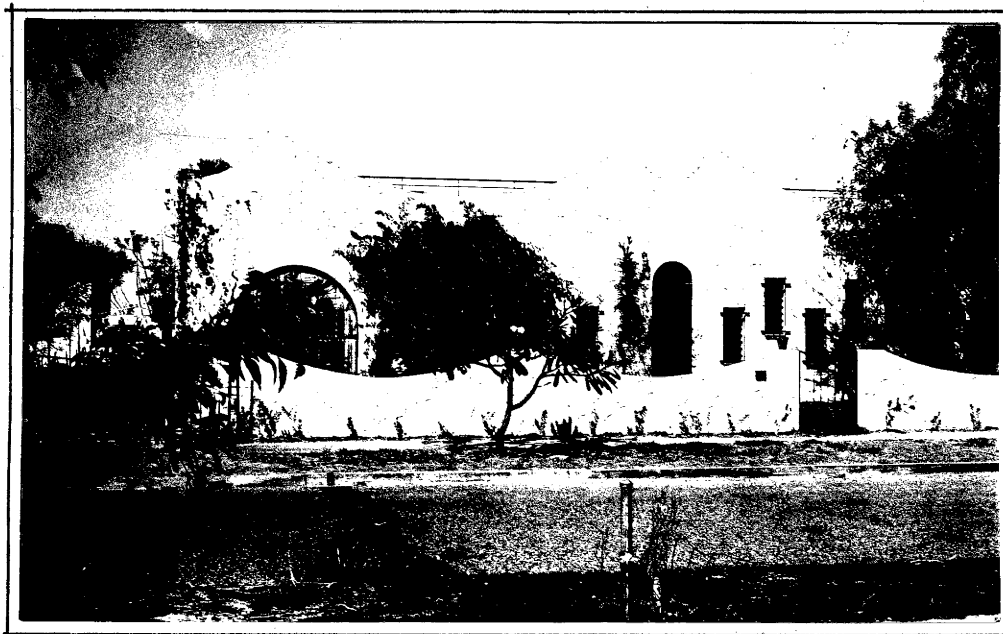


FIGURE 41

An extension of self at 3 levels. This Italian owner displays his background with the Mediterranean style structure incorporating small deep openings, his specific skill of cement rendering, and the fluctuating temper of his own personal life and that of his wife represented by the sculptured sky line of the front facade.

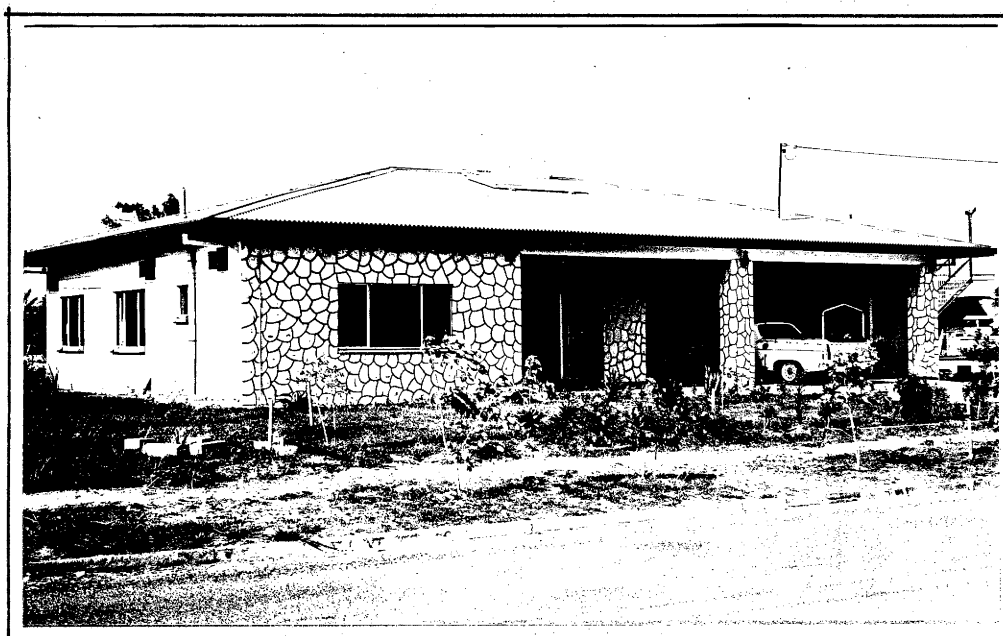


FIGURE 42

If stonework construction is not appropriate to the local geographical characteristics, then imitation will satisfy the deeply rooted need for a masonry home. The hipped roof is characteristic of Greek construction in Darwin. Builders of Greek origin do tend to dominate the building industry in Darwin.

7.3.5 A MONUMENT — FOR THE CHILDREN

To many home owners the act of creation is of more importance than the creation itself. Some perceive the construction of ones own house as a desirable exercise in discipline.

For some the home is the total life support system. To the Greeks, who characteristically develop very tenacious family ties, a home is the most vital link which holds the immediate and extended family together. These homes are meticulously cared for, display all personal effects and absorb all the energies of a lifetime. As such they become the monument of the family head, who has created it. It is perceived by him as the most priced gift for the children, to whom he dedicates his life's work.

Without even the intention of creating a monument, many, inspired by a very practical need, have learned a skill, or revitalized an old skill, to produce highly individual components, such as fences, shutters or an entire house. These components are usually characterized by a high level of workmanship and stimulate an interest in the home which may not previously have existed.

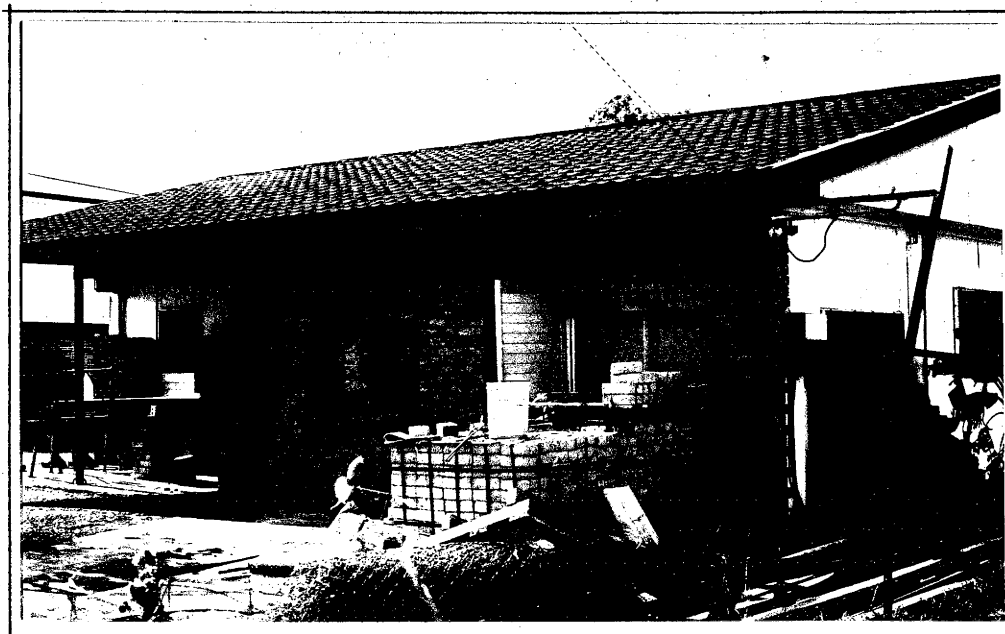


FIGURE 43

This below piers and floorboards, temporary dwelling, of lightweight construction is being reclad in concrete bricks manufactured locally to create a sense of solidarity, perceived as a vital characteristic for a home. This house is completely the work of the owner whose belief it is, that one must build ones own house with only the help of the "Lord". It would seem that the appearance of solidarity will suffice as the selection of Decramastic roof certainly does not incur any monetary savings and is in fact more labour intensive to install than sheet materials of equivalent structural performance. The debris resistance quality of these tiles is possibly superior to the concrete equivalent.

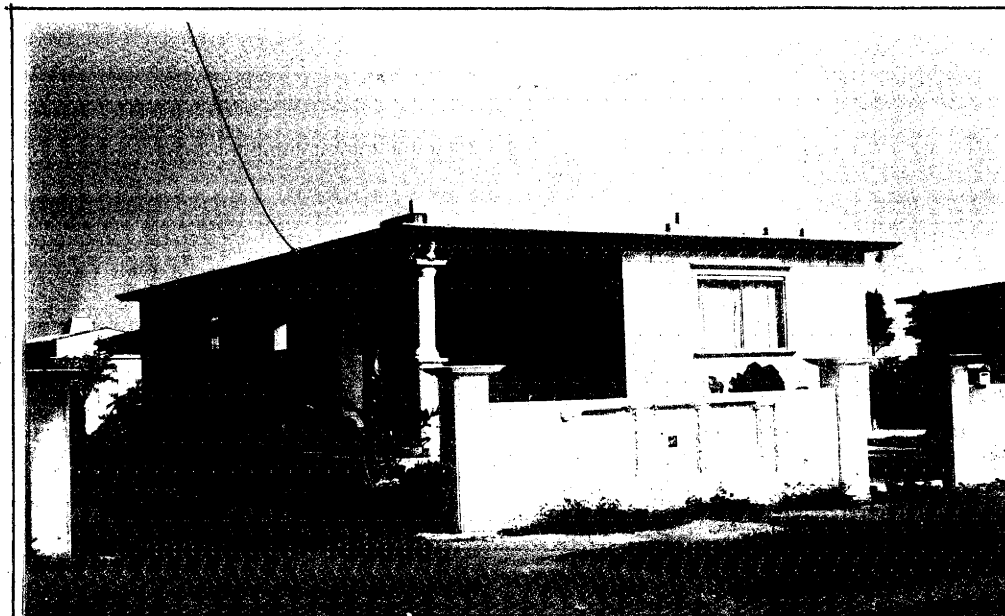


FIGURE 44

Greek expression at its best. This highly individual house of fully concrete filled, blockwork walls, with a concrete slab roof, is a giant heat store, making internal conditions quite unbearable. The slider window reduce the breeze access area to half that of the window size, and the height of the window eliminates breeze flow across the lower part of the body. The occupants recognize these disadvantages, but the solidarity, the motifs and blue trim colour are vital supports to their psychological needs.

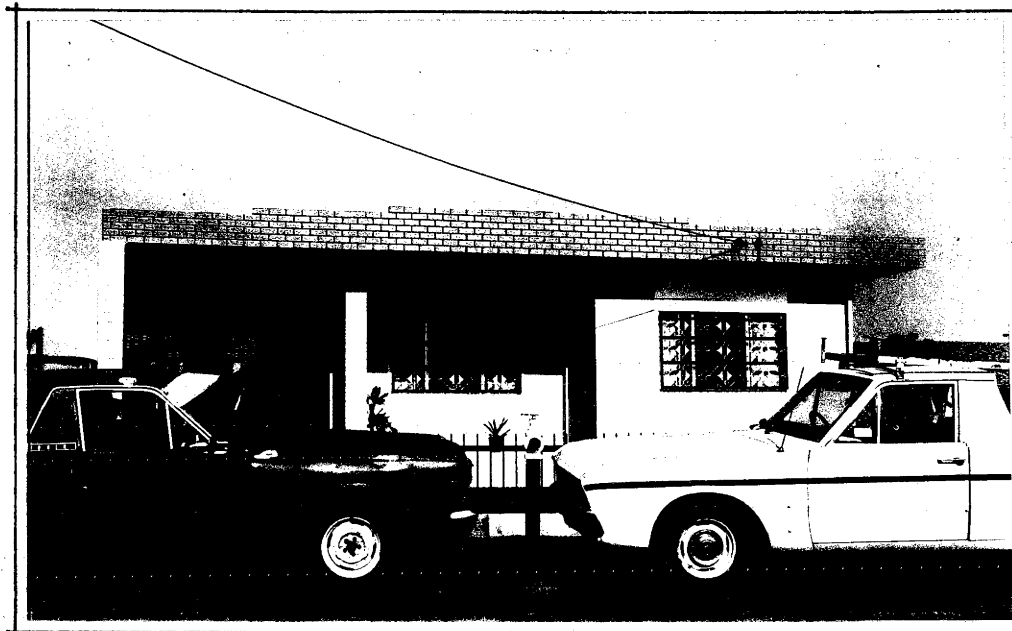


FIGURE 45

Another Greek home of rendered blockwork, painted in pink and apricot. The "self supporting" brick balustrade, fulfills a safety requirement for floorboards converted to an outdoor living deck. While the Greeks do build masonry homes of high thermal capacity they do make the most use of outdoor areas for living and dining.

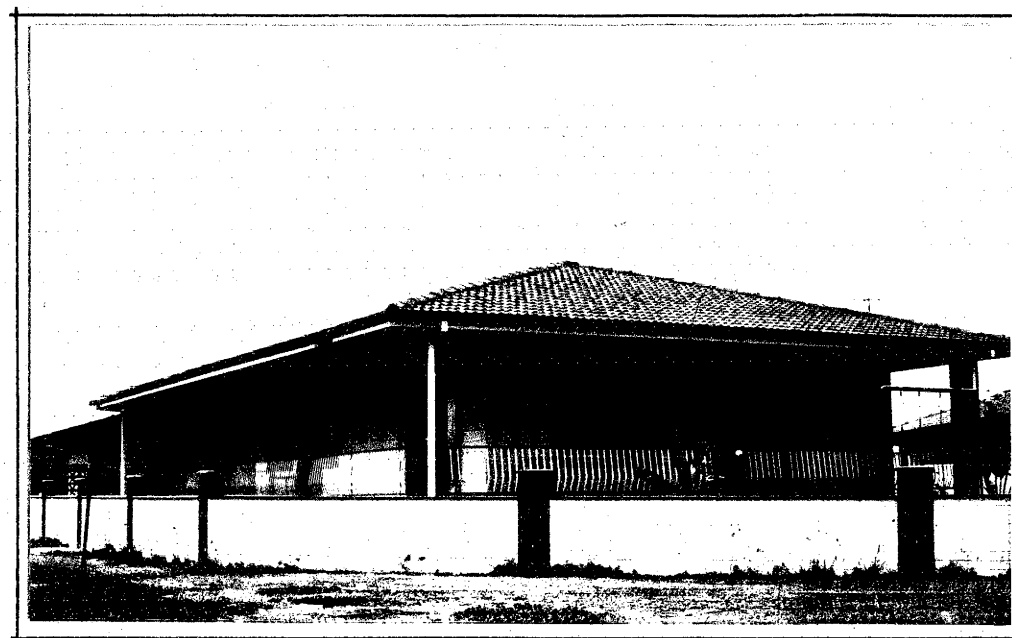


FIGURE 46

The excellence of this occupants joinery skill is clearly evident in these superbly finished window shutters - surely only attainable if made by oneself. It is interesting to note that all shutters remained closed over observation for several weeks while occupants were obviously home!

7. 3.6. A HOME AWAY FROM HOME

Many perceive the tropics as a climate unsuitable for European habitation, but remain in the tropics for economic reasons.

As a result, these people are unable to adapt to a tropical "under shade tree" living arrangement and have brought with them, their antique furniture, shag pile carpets and family heirlooms. Those who were forced to live in an exposed elevated house, soon learned of the detrimental effect that those conditions of high atmospheric moisture was having upon these furnishings. For this reason an architectural form, more appropriate to the southern states was frequently constructed. This type of "inappropriate" design was built mostly by newcomers to Darwin who were only aware of the extensive failure of lightweight, elevated homes, without ever knowing the inherent climatic advantages afforded by them.

Air conditioning, ducted throughout is a necessity in these dark brick and tile homes. This additional cost is warranted for those who require a "cosy" internal environment of psychological comfort. These homes do afford real advantages of glare reduction internally - a welcome contrast to the external environment which is particularly tiresome.

Before cyclone Tracy, clay bricks were manufactured in Darwin.

These however contained a high manganese content producing a dark coloured brick. Now that only concrete bricks are manufactured locally, clay bricks need to be imported from the south if desired.



FIGURE 47

A typical 16 sq "southern" house in dark brick and tile. This housing solution can only be afforded by the more financially comfortable, as it is fully air conditioned and constructed of imported clay brick and tiles. A very obvious mark in the otherwise highly reflective environment.

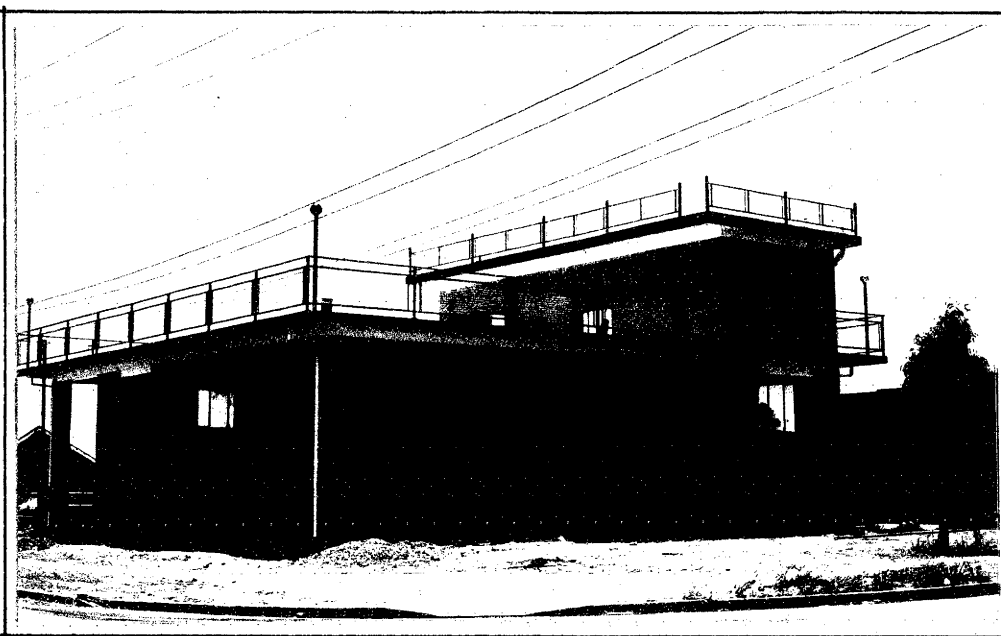


FIGURE 48

A fortress built in locally manufactured concrete bricks in a style straight from the Mediterranean. Note the strong emphasis on hard outdoor living areas. Greek homes are characteristically finished in ceramic tiles or concrete. These surfaces can be kept to a high level of cleanliness, an outstanding feature of the Greek home.

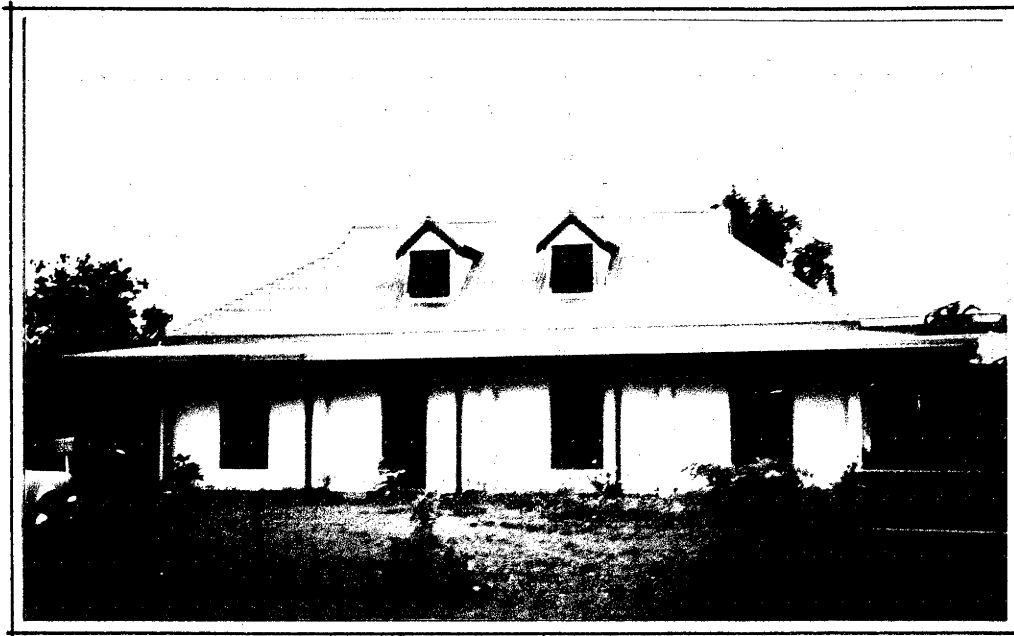


FIGURE 49

This illustration indicates, how many utilized existing cyclone damaged material with quite pleasant and diverse results.

Piers and floorboards have been roofed with a high pitched Dutch gable roof to create additional storage space in an otherwise small home. Dormer windows allow ventilation of upper area. The limited area beneath the "M" type elevated house restricts layout to that of a standard three bedroom "spec" built type home. To gain a regulation ceiling height beneath the floorboards some excavation was necessary - creating a step down into the house.

The verandah has been designed to act separately to the roof which reduces the uplift loading being transferred to the old footings. The Dutch gable has become a very popular roof form as it combines the lateral stability of the hip roof, without the additional labour and timber costs.

Truncated trusses are carried into the hip. The external walls are timber framed stud panels between piers, insulated with mineral wool and clad in asbestos sheeting with a light Spanish render coating to produce a more solid looking home. The result - a home quite unique in its setting, relatively economic and incorporating appropriate design principles for the tropics.

7. 3. 7. A MACHINE TO LIVE IN

As the inadequacies of the designs primarily inspired to resist cyclonic wind loadings, were realized through occupancy, a strong trend towards more climatically suitable designs emerged.

These have been classified as "Machines to live in", as the homes retain the basic principles of construction and design most appropriate to the tropics, altered to support activities and life styles more sophisticated than those previously encountered in Darwin.

These designs usually incorporate the benefits of the old elongated elevated house, with modifications to alleviate the functional inadequacies of these homes as outlined in section 7.2.

It is with this class of reconstruction that lessons for future design development can be extracted. Figures 50 to 53 inclusive, illustrate modifications to existing elevated homes and Figures 54, 55 and 56 illustrate ground level homes which have emerged as practical solutions to housing, in the tropics.

The contribution of professional expertise to the design development varies considerably. The elevated homes are in the main constructed from upgraded drawings acquired through the Housing Advisory Service and modified to the individual home owner's requirements by a drafting service. Many of these homes were constructed by the owner with casual assistance from hired labour or sub-contractors.

The ground level homes illustrated under this classification have all been designed by architects, all of whom have a special knowledge of design in tropical regions.

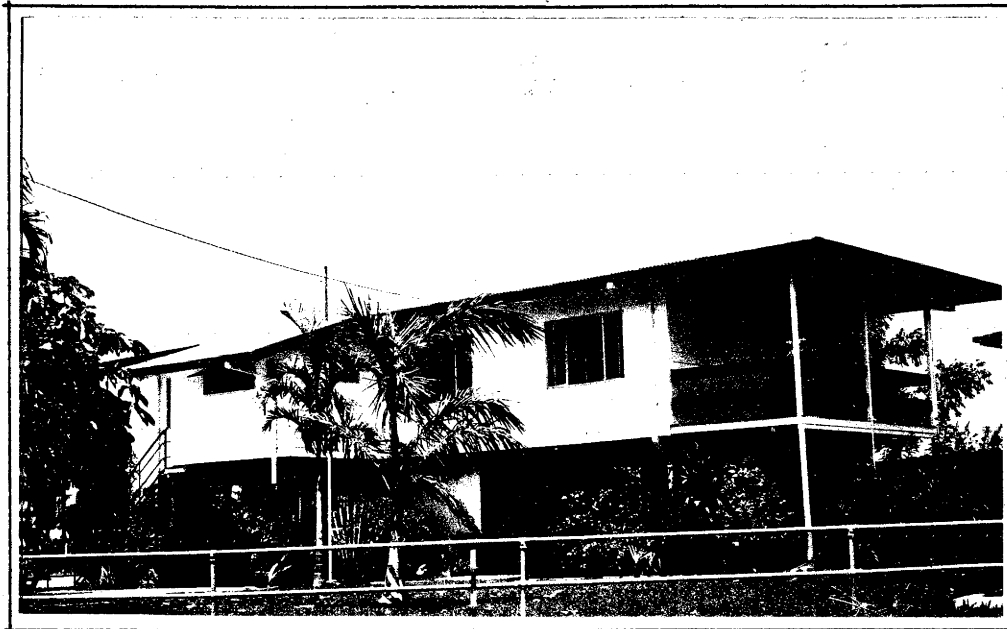


FIGURE 50

This "C" type house is reconstructed according to upgraded plans. Modifications to layout include the extension of a full length verandah along the south side and the west face (north side facing camera). The west facing verandah was originally the third bedroom which had become obsolete as the family had grown older and left home.

A hipped roof at a greater pitch has replaced the pre cyclone gabled roof, selected for aerodynamic reasons. The walls are clad in structural ply on the outer side of the 4" timber stud wall with Weatherex boarding, providing the weather shield and decorative finish. Ventilation has been somewhat reduced by the sliding windows, installed higher on the facade than the original openings. However, additional small openings have been incorporated on the east facing wall and the west facing kitchen projecting wall. This assists cross ventilation at all times allowing some breeze normal to the end walls to be directed through the home. On the east face the window is protected by a light gauge steel sun protector.

The substructure has remained unaltered in plan. All connections have been upgraded, additional cross bracing has been placed between piers and a mild steel angle encompassing the underside of the floor perimeter installed, to distribute the tensile loadings from the cyclone bolts into the piers and subsequently the footings. Three additional tie down piers have been installed along the west face to counteract the uplift forces which would be generated beneath the verandah eaves.

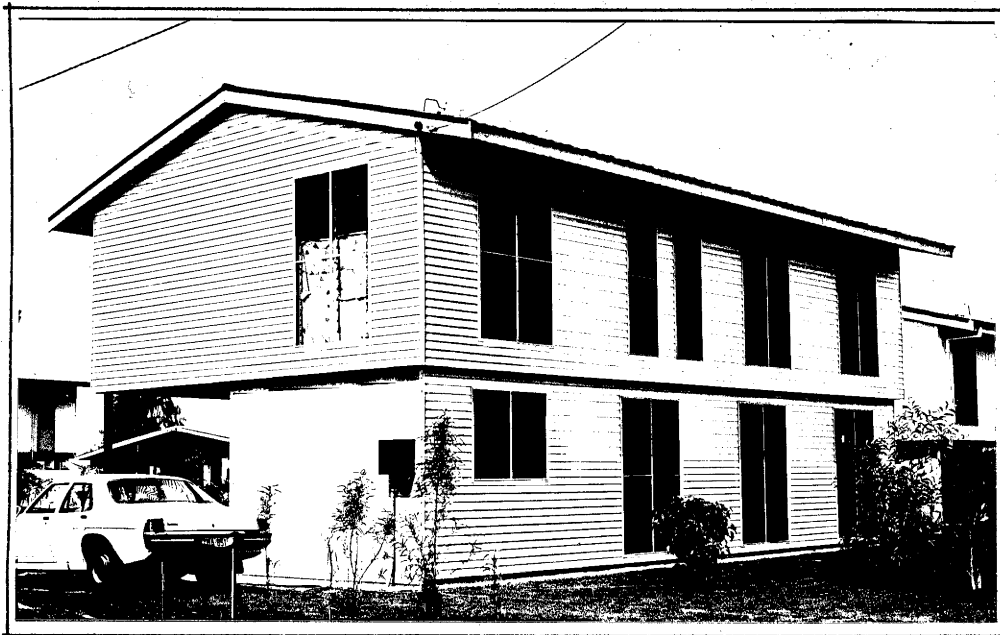


FIGURE 51

This residential site originally housed an elevated home pre cyclone, which was subsequently demolished to allow new footings and a steel substructure to be built, with an increased ceiling height to the ground floor.

Reconstruction of the substructure allowed the main floor bearers to run perpendicular to the line of the house to increase the upper storey resistance to raking. This was standard practice adopted post cyclone in all newly constructed elevated homes.

All internal and external walls are braced with an 8 mm structural ply - one on the internal side of the studwork and one sheet on the external side. Greater thermal properties have been achieved with this practice making those homes which were commenced early, more comfortable than they may otherwise have been.

The external claddings on this house were selected for ease of erection. The reconstruction was almost entirely undertaken by home owner. One regret has been expressed by many who chose to clad their homes with Hunter Douglas profiled light gauge steel panels. That being susceptibility to buckling under impact from normal domestic activity and play.

This home very successfully combines the thermal advantages of sleeping in an elevated position with the convenience of service areas such as kitchen, living areas and the laundry downstairs.

Louvre banks have been installed to optimize cross ventilation. A cyclone shelter, used as a store is constructed at ground level braced with 17 mm marine ply and roofed with a concrete slab.

The total cost of reconstruction was \$42,000 - determined by the low interest loan amount available.



FIGURE 52

As with Figure 51, this "M" type house has retained the advantage of elevated sleeping areas with improved convenience by rebuilding a large open kitchen and living area beneath the house. All openings between piers can be opened out completely to allow unrestricted air-flow. The hopper window, second only to the louvre bank for cross ventilation efficiency, has been selected for aesthetic and practical reasons. Louvre banks are considered by most householders to be a cleaning burden. Privacy has been achieved in this open living arrangement with dense vegetation surrounding the house, which the owners believed buffered flying debris during the cyclone.

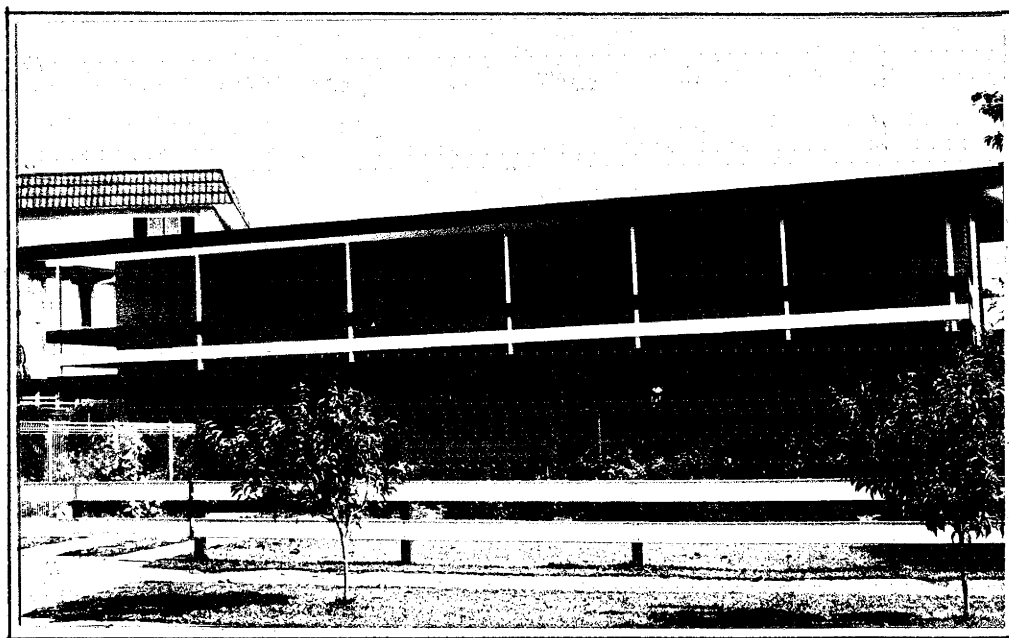


FIGURE 53

This "one room wide" house has been improved by constructing a full length verandah along the north and south facades. This is a very common modification to elevated homes.

It allows windows to remain open during the wet season, as they are protected from driving rains, it eliminates the need for obstructing curtains or blinds to block sun penetration, increased outdoor living area and produces a more elegant elevation by comparison with the "grey fibro boxes" which had evolved pre cyclone.

Internal finishes of hard board have been replaced by Gyprock, improving sound insulating performance, especially in the ceiling, where heavy rains on the corrugated iron roof can generate noise of an uncomfortable magnitude.

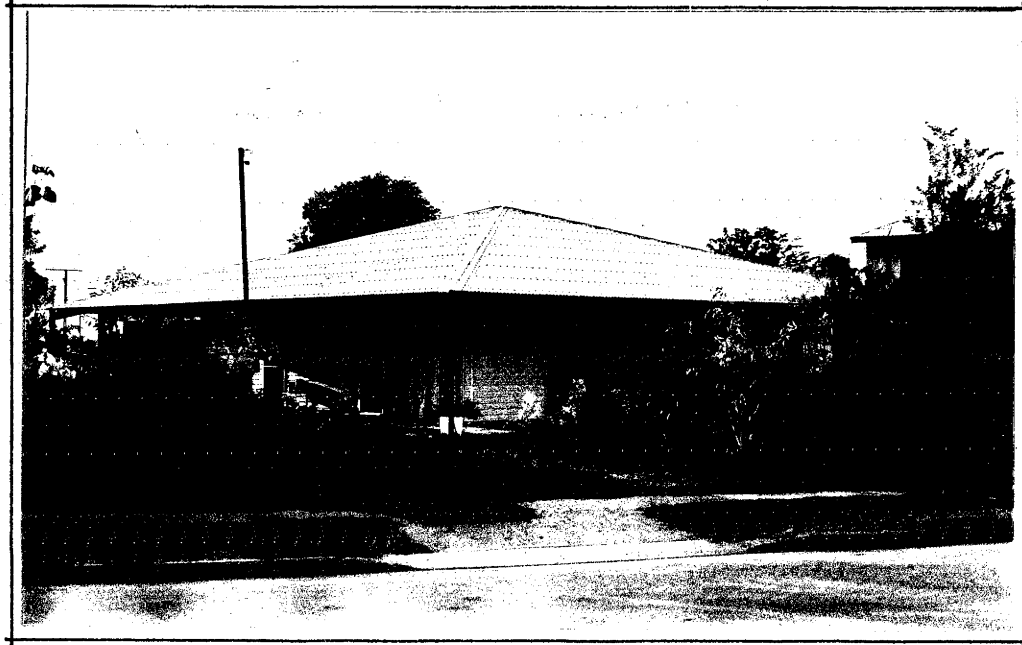


FIGURE 54

The ground level house was designed to fill a very urgent gap in tropical housing. Clearly the ground level home is still preferred by many, who are at the moment forced to accept the inappropriate designs which are available. This simple form optimizes solar reflection, stability with its square form and cross ventilation by allowing openings to be installed on all four sides which are protected from sun penetration for most times during the day by the all embracing verandah. The internal area is smaller than the area of the average home, although adequate outdoor areas are provided, a portion of which will always be protected from driving rains, dust or intense solar radiation.

It is built of framed construction and is clad in a debris resistant steel profiled sheet. This is a simple concept worthy of much greater attention in considering future housing forms.

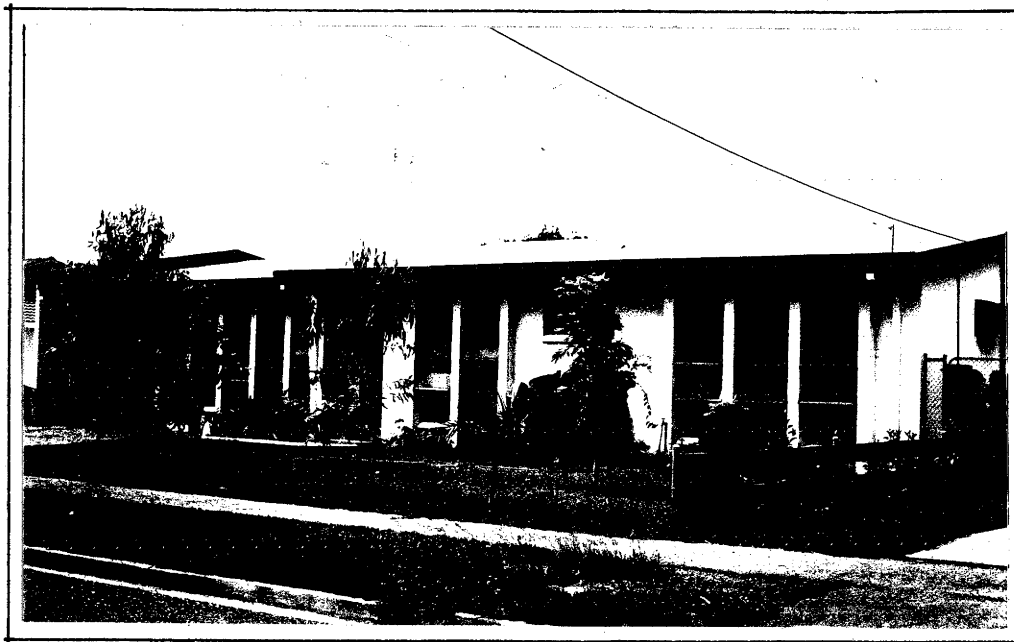


FIGURE 55

This house fulfills the need for a masonry ground level arrangement appropriate to the tropics. The north and south facades have been opened up to encourage air-flow. The hopper window, a popular alternative to the louvre banks, as discussed earlier, is a hazardous proposition for ground level home, because of the horizontal projections often at eye level. This has been overcome by building brick projections which not only provide safety, but also stiffen the walls, assists in directing prevailing breezes into the house and shields windows to a limited extent from flying debris.

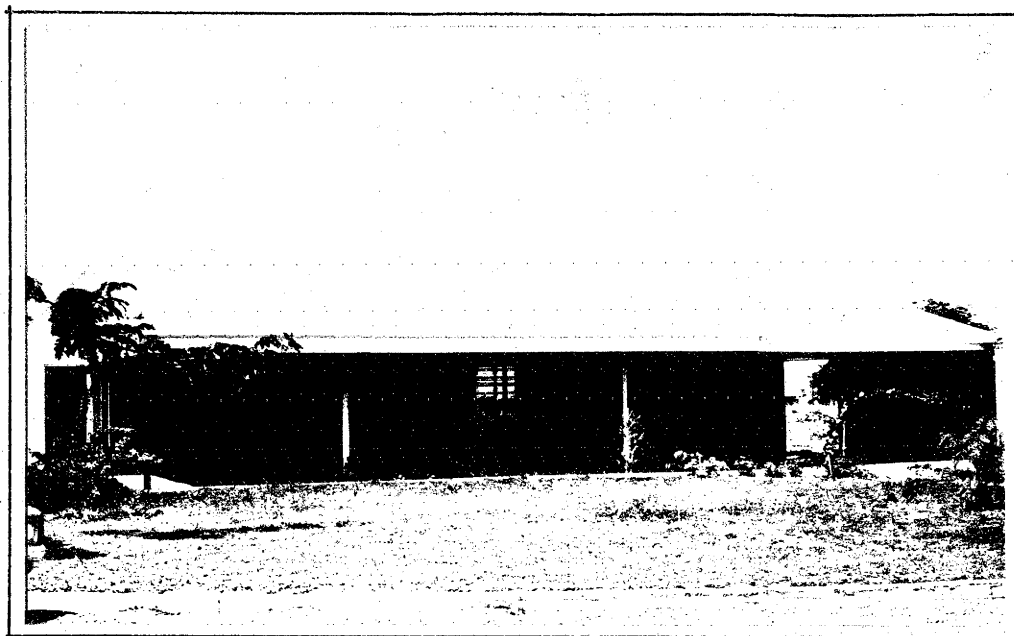


FIGURE 56

A more recently constructed home taking a strong swing back to the "under shade tree" principle of living. The large white roof optimizes reflection and shades all walls. The walls almost entirely louvred optimize air movement through the home. Lack of privacy could well be perceived in this living arrangement unless a visual barrier across the front could be created with vegetation or a fence.

7. 3. 8. THE ENGINEERED RESOLUTION OF CONFLICTING,
CLIMATIC AND STRUCTURAL NEEDS

The conflict between climatic and structural requirements, was in the early days of reconstruction to render many homes climatically uncomfortable as structural considerations emerged as top priority. The threat of cyclone and the destructive forces it creates is very real, however the likely occurrence of a cyclone of equal magnitude (in terms of destructive forces incurred) has been estimated at one every 50-90 years. This means that discomfort could be tolerated for this period of time. An immense sacrifice for protection from one relatively unlikely event.

It would seem that the majority of owner builders (both familiar and unfamiliar with Darwin) expect a recurrence of cyclonic forces at some time in the future. All owner builders interviews in this survey had given serious thought to the problem of mitigating such a hazard at the domestic level.

What many have realized however is the need for a comfortable living environment for the majority of time when cyclone threat is not imminent. As a result many concepts emerged over time, offering a resolution to these conflicting requirements. Figures 58 to 61 illustrate several ways in which successful design was achieved, by considering this conflicting problem as a basic design criterion.

Figure 57 overleaf illustrates a pre cyclone method of resolving this problem with the application of vertically pivotted metal louvres externally. This Figure is included to illustrate a principle which was further exploited post cyclone with promising results.

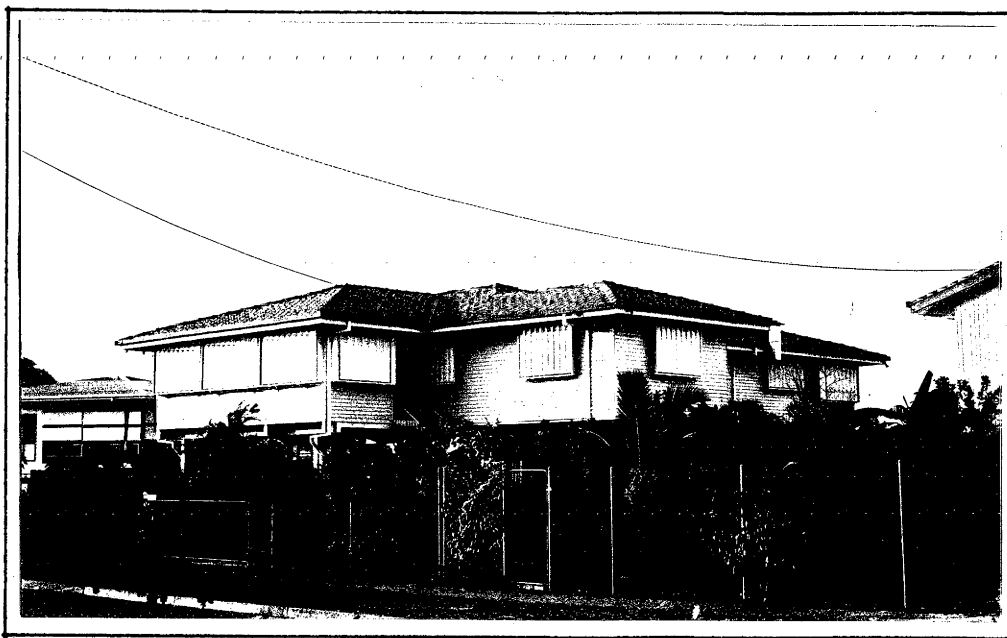


FIGURE 57

This principle of a close down sunshade was exploited further with several systems which were developed to enable an all embracing verandah to be bolted down over virtually open walls when protection is needed. Thus the under shade tree effect of maximum protection from solar radiation and optimum cross breeze is achieved with the potential of creating a sealed bluff body aerodynamically advantageous in resisting cyclonic wind loadings.

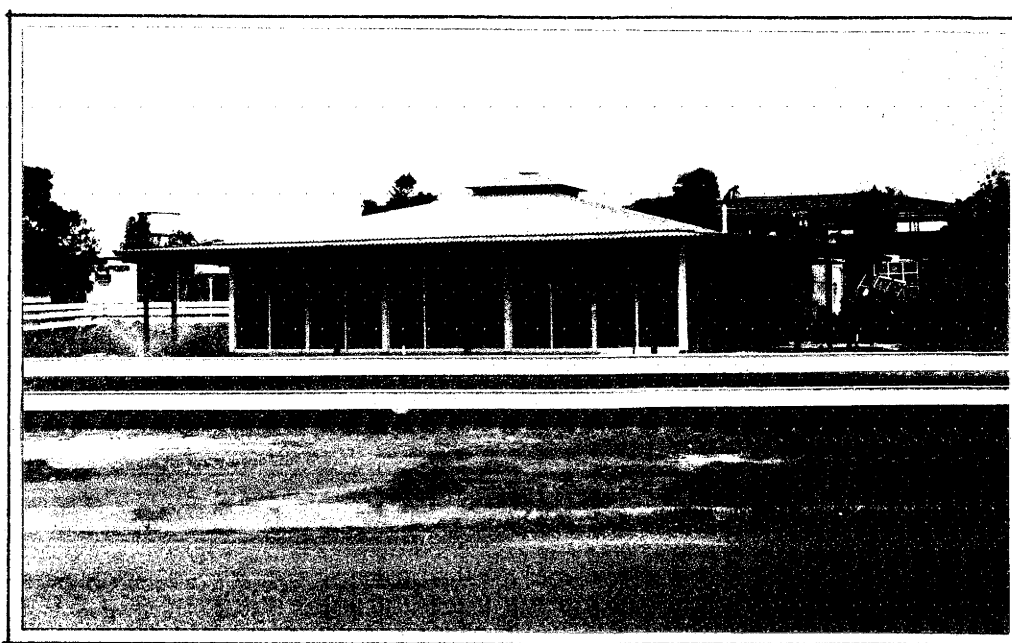


FIGURE 58

The house in Figure 58 illustrates this principle of hinged verandahs, enabling a sealed bluff body to be created during cyclones.

Experiment has shown that 2 adult persons together can easily operate this system. The roof is also ventilated to assist the movement of air, including the expulsion of hot air on normal days. This house, designed by an Architect, was built as a prototype and has until now not been used for the intended purpose of cyclone protection and thus its performance has not been tested. There appears however to be no reason why this principle cannot be further exploited in areas where conflicting climatic and structural needs exist.

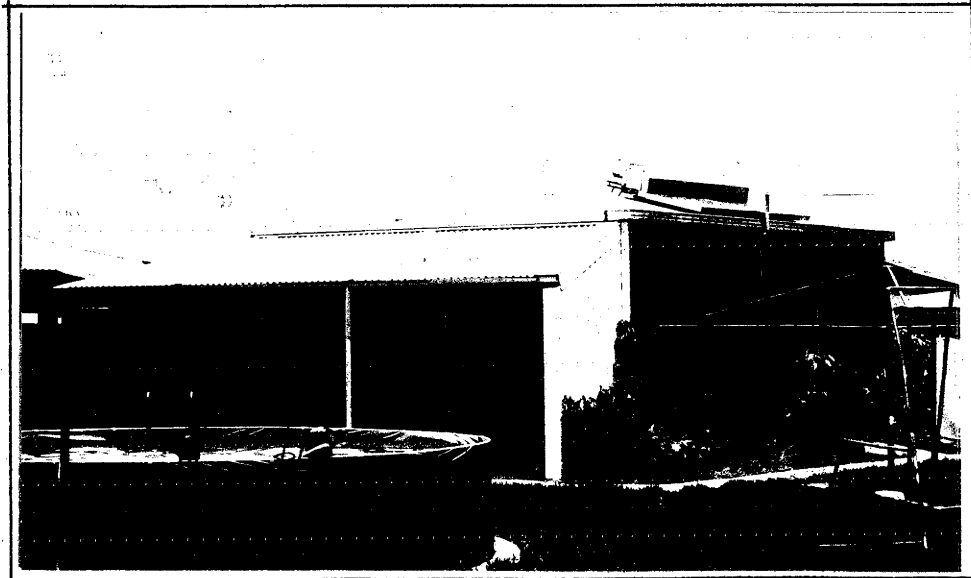


FIGURE 59

Figure 59 illustrates a project home which is designed to operate in a similar manner. In this case the steel verandah post supporting the verandah section between the concrete block corner section to cover openings. When erect, the covered space is integrated into the home by filling between the concrete panels with flyscreens. This particular design suffered from inadequate internal space - 8 squares only - which at \$32,000 was not competitive in the post cyclone market. Clearly however the principles were appreciated by the lay public, as many were to pay deposits for the erection of this house. The unconventional shape meant a lot of material cut to standard dimensions, was wasted which reduced the unit area value.

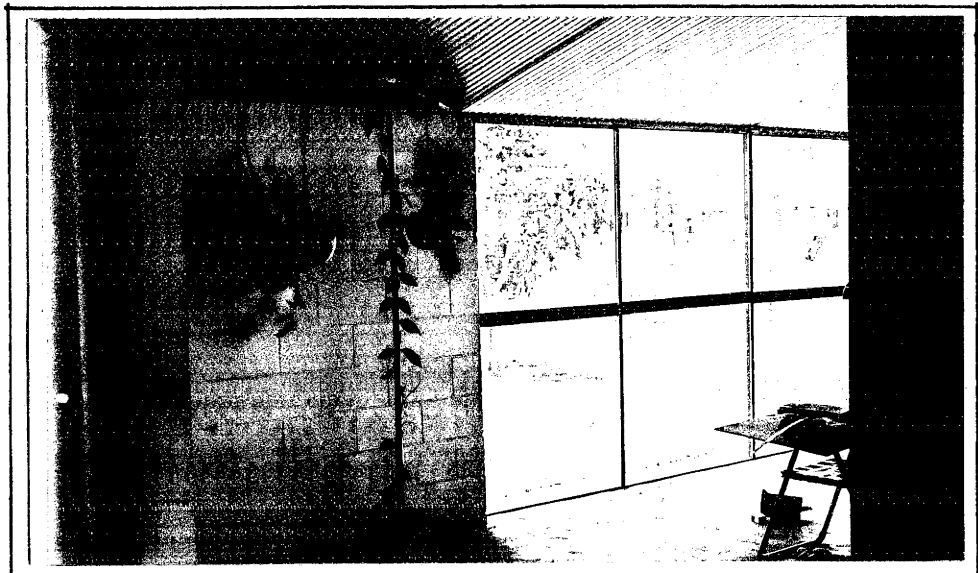


FIGURE 60

Figure 60 illustrates the peripheral verandah, which is flyscreened and used as living space during "normal" weather conditions.

The one feature which was lost in homes as they became more like fortresses than homes, was outdoor living space, sheltered from driving rains. Verandahs tended to create critical pressure points on a structure which needed to be eliminated. It was realized however that if this outdoor area could be integrated more successfully into the structural system then it may serve a two fold function of protecting openings, which could subsequently be enlarged.

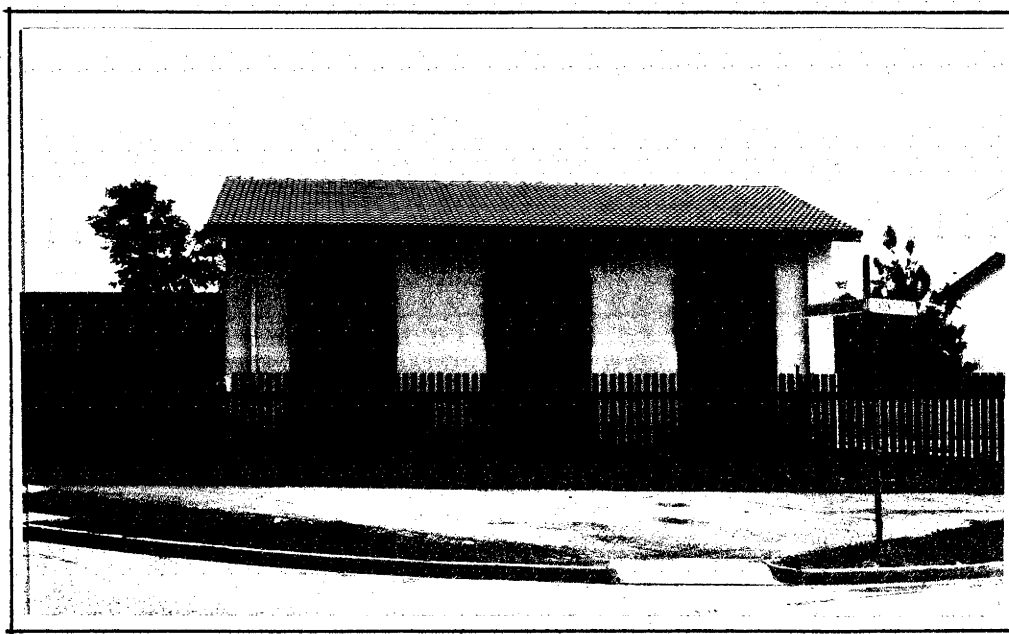


FIGURE 61

The house in Figure 61 illustrates a design solution in which the verandah is supported by and tied down by heavy precast panels making a welcome extension to the homes, especially when screened as illustrated, and an effective device to protect openings from flying debris and solar radiation.

The result - a more substantial and practically suitable home utilizing a locally manufactured precast concrete panel to introduce a cost saving. A similar practice was common along the west face of ground level homes, with the provision of a carport.

7. 3. 9. THE EFFICIENT – ECONOMIC UTILIZATION OF
LOCAL RESOURCES AND APPROPRIATE TECHNOLOGY

The high cost of construction, in conjunction with an over reaction-ary code, was initially blamed for the minimum sized, thermally inadequate homes that were constructed. However as home builders have realized the shortcomings of these "southern designs" and the reduced areas essential to maintain economy, some individuals have begun to rationalize, cost and building methods. Thus a new set of priorities have emerged, emphasizing open shaded space, suited to tropical living, attainable, by reducing the number of components and finishes.

The need for expensive finishes both internally and externally have been questioned. As a result of a new "clean" architecture has resulted. Concrete block walls are laid fair face on both sides, reinforced as required and waterproofed using silicon paints. Exposed ridge beam and rafter roof construction, allows interesting internal proportions, alleviating the need for finishes normally applied over blockwork and on ceilings. Timber ply panelling is becoming popular as an internal screen wall, providing a colour and texture contrast to the concrete making it far more acceptable as a naked finish. The higher ceiling increases the spaciousness without an actual increase in area.

The range of local building resources is extremely limited. However many, inspired by a desire to establish independence in the building industry have, made excellent contributions to local domestic design with the imaginative and appropriate use of the few locally produced materials and even fewer local resources.

The Figures overleaf illustrate these more forward thinking ideas.

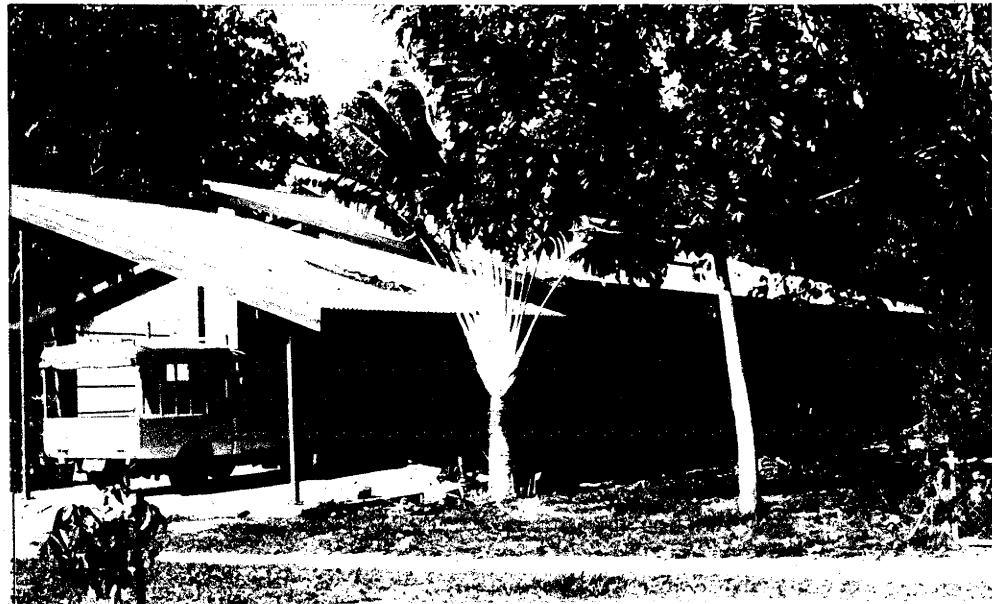


FIGURE 62

Figure 62 illustrates a 16 sq house which has been constructed with some labouring assistance from the home owner for \$42,000. This economy was attainable by eliminating ceiling, leaving rafters exposed, verandah by extending eaves 5 ft beyond the building line, and constructing the home of exposed single leaf concrete blockwork treated with a silicon based paint. Several of the large timber sections remaining on the site after the cyclone have been re-used in the new house. The full length skylight along the central axis of the home expels hot air and promotes air movement through the home. The extensive eaves and abundant vegetation virtually eliminate solar penetration.

The role of precast panels and components have been reviewed by some owner builders. Customarily, precast moulds are adapted to suit existing "southern designs" which still require, separate roof systems, internal walls, ceilings, expensive finishes, external shading etc, without the advantage of flexibility afforded by other materials. Consequently an unsatisfactory home is produced and systems, along with their obvious cost advantages are being rejected by many.

Certainly, in a city as isolated and devoid of natural building resources as Darwin, precast concrete, sandwich panels and "kit homes" are an inevitability.

To ensure real cost benefits and the provision of homes which adopt the principles of shading, air movement, large area and privacy, essential for a congenial and healthy existence in the tropics. Pre-constructed components and panels which integrate both internal and external screening, engineering requirements, overhangs or other shading devices, roof slope - eliminating truss and ceiling, have been developed.

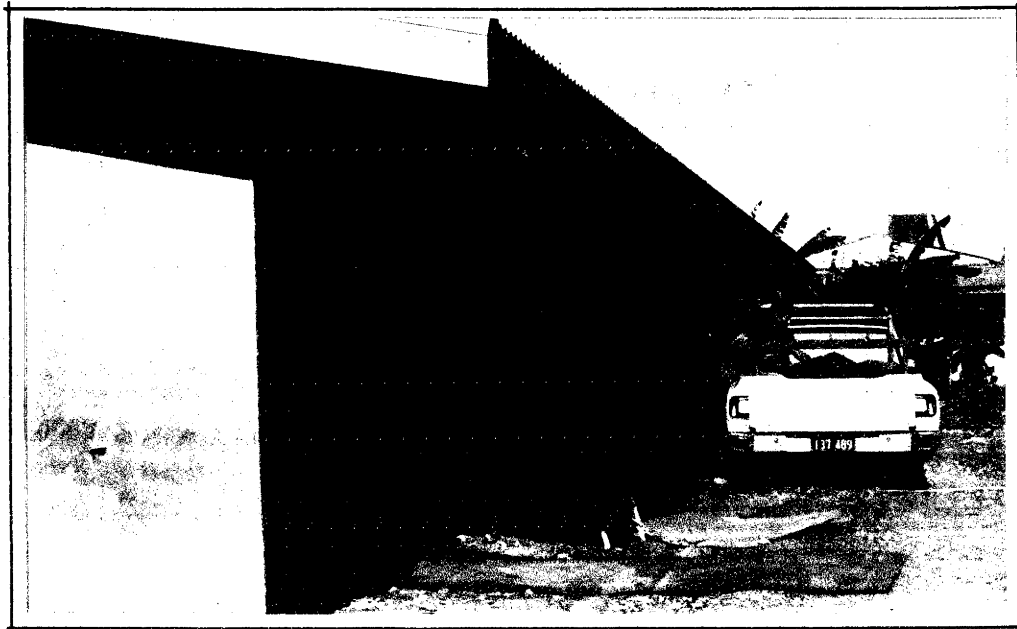


FIGURE 63

Figure 63 illustrates a prototype which incorporates all the advantages in precast components as just outlined. It has been estimated that this home can be completed for about \$33,000-\$36,000, making it very competitive with existing low cost brick and tile homes, which possess few climatic advantages.

This precast concrete component eliminates the need for additional roof trusses, rafters, internal walls and verandah posts.

All functions are integrated into this precast panel, standardized throughout the house. Purlin sections need to be increased and the roof diagonally braced between panels. Painting on the concrete is sufficient as an internal finish. The penalty for such economy is restricted flexibility in internal spaces, although in this case the restriction coincides with many already established climatic determinants.

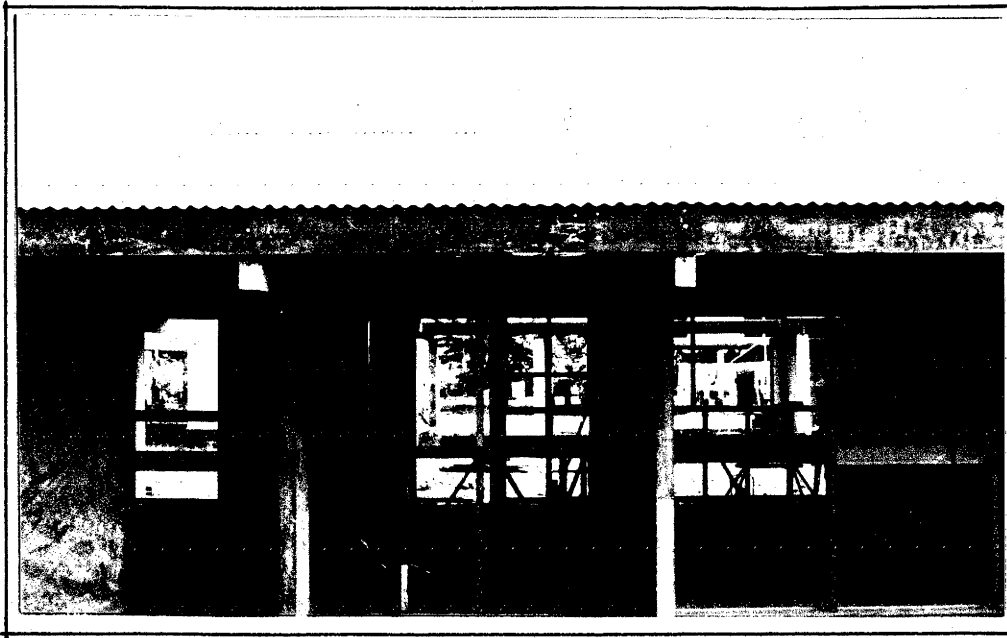


FIGURE 64

A view along the north-south axis. The thermal capacity of the massive components will in this home serve to absorb heat from the internal spaces, rather than radiate heat from outside.

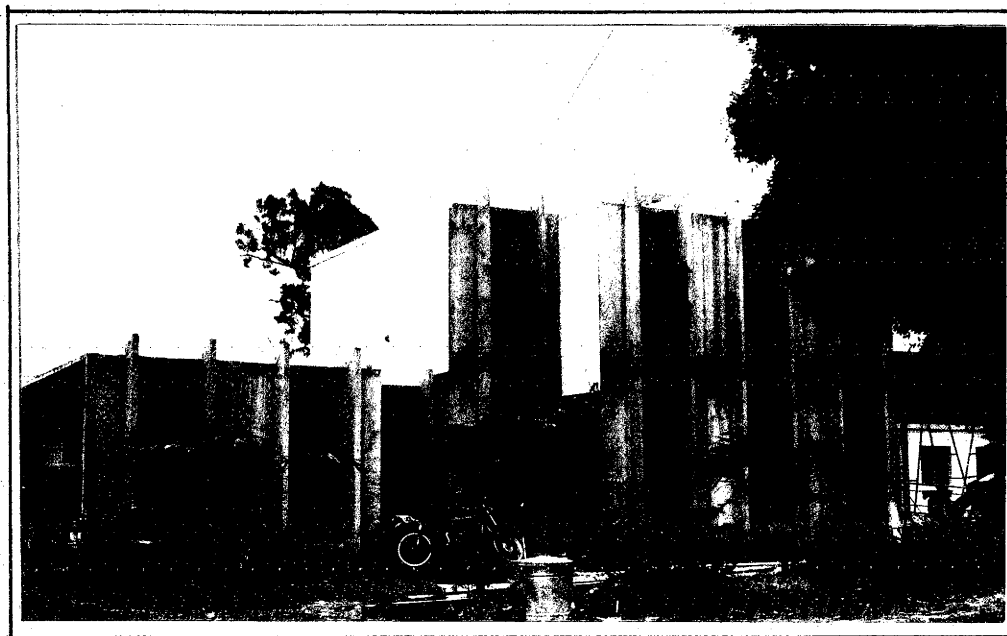


FIGURE 65

A double storey house constructed from 11 Melcast Melocco reinforced concrete units. This locally produced precast system integrates the structural requirements, the roof, the floor and the external walls into the one \$1,800 unit. With this arrangement cross ventilation is achieved through all rooms and sun penetration is minimized. The protruding ribs on either side of the hopper window banks, assist in reducing sun penetration. These ribs also cast a shadow across the roof at most times of the day which assists in reducing the heat load. Note that two units have been used as a verandah on the east face. The sleeping areas are elevated to benefit from prevailing breezes and the living and service areas are at ground level.

These units have been extremely popular with owner builders who were seeking a system which can allow them to by-pass the major contractor and enable them to finish their home without the pressure of time. They have been used very imaginatively to suit a diverse range of needs. Between 3 and 16 units have been installed into single dwellings, with very satisfactory results. This fact, in conjunction with the ease of manufacture locally, make this unit worthy of attention from the housing dictators. Although the high thermal capacity of the concrete is in contrast to the ideal of light weight construction, cross ventilation is easily achieved and a simple roof thrown over the entire structure can form a parasol roof with all the subsequent comforts. The separate roof, which many have built over their Melocco home, has protected the mastic joints from moisture. The jointing system still requires some attention in this regard. The structural rib protruding 300 mm from the main rectangular section, elevates the floor from the ground thus avoiding the problems of moisture and vermin attack.

In reviewing areas of cost saving, several very successful attempts have been made at reviving the old Pise method of construction, using perhaps Darwin's only natural building resource. Indications at this stage, are such that considerable economy can be achieved if time penalties can be tolerated and ones own labour used. Soil mixes and ramming techniques have been perfected, achieving satisfactory stability in the structure and incorporating adequate tie down members. An extended market could now achieve additional cost reductions with economy in formwork and a corresponding increase in flexibility.

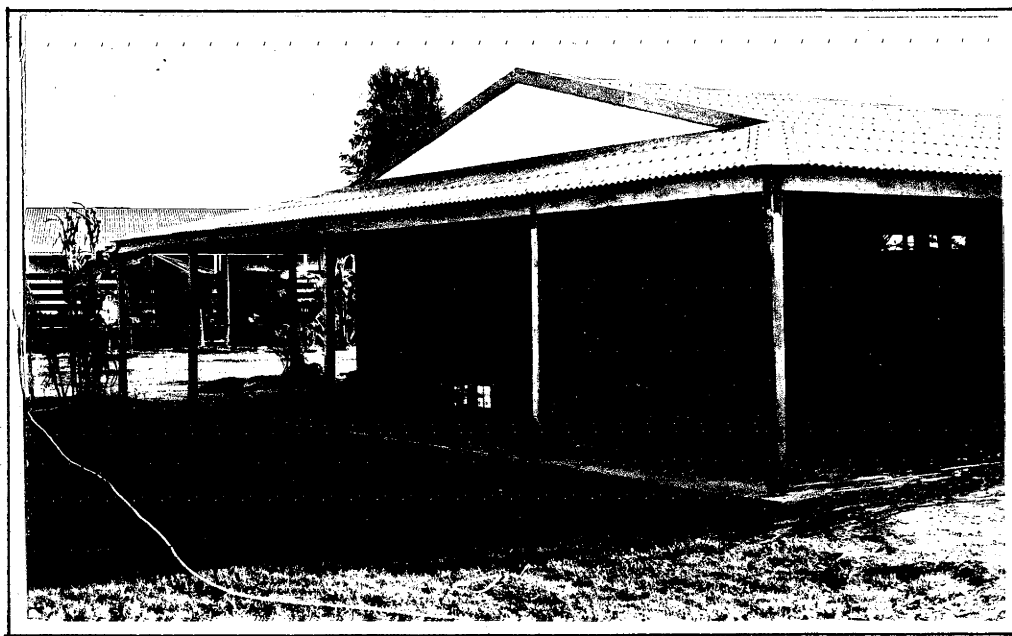


FIGURE 66

A pisé house constructed in an Australian vernacular style to ensure shading of all walls. The high thermal capacity of this construction system, can cause discomfort internally if walls are not shaded. Note the heavy concrete bond beam which ties the pisé panels together and anchors the tensile members which are integrated into the wall panels and footings. A concrete apron also encircles the house to protect the earth walls from white ant attack. Shading is further improved by encouraging vines to grow around the perimeter of the verandah. This is a common practice in Darwin, especially where system homes, constructed of high thermal capacity wall components have been used.

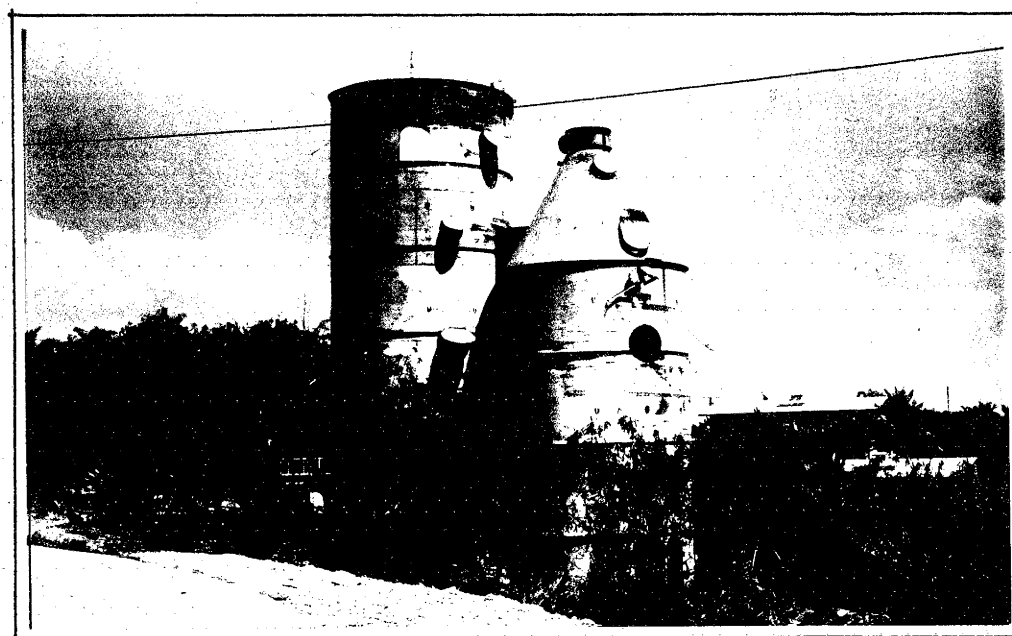


FIGURE 67

Another local resource - discarded uranium processing silos. This novel home is not advocated as an appropriate system for Darwin, but does display the resourcefulness of the local Architects and is indeed an engineering success. Its aesthetic success is not agreed upon, although one must not assess this masterpiece until its completion?

7.4 MEANING IN DARWIN CONTEXT

7.4.1 IMPACT UPON DARWIN DOMESTIC ARCHITECTURE

The fact that is most strikingly evident from the research undertaken, and the analysis of the architectural domestic fabric is the diversity of human domicile needs.

Housing has been through many phases since the end of 1974.

Initially it represented an understandable over reaction to the devastation resulting from a major natural disaster.

This event no longer remains as vivid in the minds of the Darwin population as it was in 1975. This is due partly to the fact that the majority of the population today are unfamiliar with consequences of a disaster because of their recent arrival, and because the evidence of the devastation has been substantially removed. The long term effect of this event is an upgraded standard of construction and more obviously an architectural monument to the event. The fortresses which testify Tracy's visit are likely to remain with Darwin for many years.

The second important fact, that the emergent architecture represents is the very vital symbolic function at the individual level of the home. Housing in Darwin pre cyclone was symbolic of a Public Service city, set in a humid, tropical climate. The symbolism now, is that of the constituent population, as individuals from a broad range of environmental backgrounds. This diversity of meaning, as expressed in the built form is juxtaposed on lots, subject to the same zoning classification and similar in area. One wonders whether this uniformity should persist in future town planning.

Darwin is no longer the city supporting only the singular frontier administrative role, for which it was established.

The investment into homes in itself is a clear indication of permanency. Residential areas not only accommodate houses built to support the nuclear family on a two year work mission, but a population whose aspirations and associations with Darwin differ dramatically. The age composition of the population is still fairly uniform although this situation is likely to alter over time. This will create a demand for alternative living arrangements and alternative residential zonings.

7.4.2 THE POSITIVE OUTCOMES

Now that the building industry has stabilized, a more realistic assessment of the reconstruction can be made. Future trends can and should draw from the experience of many prototypes which have emerged in housing as a result of the need to reconstruct. Darwin can not as readily tolerate the monotony in the built environment which characterized the pre cyclone residential areas. The visual interest afforded by the existing fabric would accentuate the lack of identity, creating potential slums by comparison. The wider range of materials and construction techniques now available must clearly prevent this backward step. This diversity is the one most positive outcome of the cyclone which created the need for reconstruction and the opportunity for individual enterprise to affect the options available.

The other positive outcome is the upgraded building code which now dictates the structural standard. Contrary to expectation, this has increased building freedom by stimulating investigation into structural alternatives with very successful results.

This is evident from the structural forms and components illustrated in SECTION 7.2 and 7.3.

The heightened awareness of building procedures and structural systems on the part of the lay population is indeed a positive outcome of the reconstruction. This awareness is hopefully the most reliable guarantee against future building "rip offs"!

7.4.3 AN ASSESSMENT OF THE RECONSTRUCTION OPERATION

The Darwin Area Building Manual stipulates a standard, which if adhered to, will guarantee the structural adequacy in the event of a future cyclone with destructive characteristics similar to Tracy.

This is indeed an important assurance to the owners and occupants of houses in Darwin. The evidence from the survey carried out indicates success in regard to the strength of buildings. Only a few situations were sited where weakness in the chain of structural integrity may cause significant failure.

Strength however is not the only measure of successful compliance with a code. Whether or not optimum decisions have been taken to balance construction costs and risks is also significant. Over capitalization is very clearly a major problem. If one is to assess the success, in these terms, then the operation was a definite failure. In almost all instances of inspection, conducted as an integral part of the survey, some links in the structural chain were excessively over designed, if one takes the weakest link as the measure.

Fortunately, as tie-down principles have become more clearly understood these excesses are being eliminated.

It is my belief that considerable attention should continue to be given to this aspect of building as a vital measure in stabilizing excessive building costs characteristic of the industry in Darwin.

A less desirable outcome of the reconstruction is the number of houses which aggravate the already extreme environmental conditions, because of their inappropriateness to the setting in climatic terms. This situation can only be easily modified by the extensive installation of air conditioning, which in the face of foreseeable limited energy supplies, is an unwelcome prospect.

This problem does not only exist with the "fortresses" constructed early in the reconstruction period. Many decisions were made in the process of house selection, with air conditioning in mind. The running and installation costs have since proven to be prohibitive, leaving many owners with homes below the expected standard. Typical examples are the selection of dark coloured finishes, sealed, small windows and designs not conducive to breeze penetration and air movement without mechanical aide.

7.4.4 FUTURE PROSPECTS

There are amidst the many over reactionary designs some very satisfactory achievements resulting from initiatives taken by the owner builder. These are particularly evident with the ground level designs. Real attributes are inherent in this type of living arrangement, especially desirable, as economics have diminished the adequacy of the elevated arrangement. Privacy is increased, vegetative protection is more effective and access is simplified. This decreases the stress for mothers with young families and the hostess who is accustomed to entertaining down stairs.

The authorities who are responsible for mass produced low cost housing appear already to be into full production again. Unfortunately few of the principles demonstrated as advantageous for economic, or functional reasons, have been adopted, by these authorities.

Because of the additional freight costs which reinforce already inflated costs in the building industry, the need for cost reduction is paramount in Darwin. This problem has occupied designers in Darwin for years with the result - standardized housing drastically reduced in area and modified from southern designs.

The only satisfactory way of alleviating this problem is to concentrate on local needs and to utilize components which can be produced locally.

The alternatives which satisfy these demands are extremely limited. However some initiatives in the private sector stimulate hope for an architecture, truly appropriate to tropical living and attainable within restraints set by isolation and a monsoonal climate. Because of these conditions the home buyer will continue to be manipulated by southern influences, and vulnerable to delays and excessive prices, unless a concerted effort is made to establish some independence in the industry. The component which can be produced locally, and economically, is the precast concrete panel or module.

These components are traditionally modified to meet "standard" house designs, instead of allowing a standardized component, offering flexibility to influence the design.

The popularity of the precast Melocco unit, and the considerable results achieved, clearly indicate the need for this type of system. Other successful standard units and construction techniques have been outlined in SECTION 7.3.9.

There are some inherent constructional problems associated with the Melocco building system. Waterproofing the joints has proven to be difficult with inflexibility within the constructed home a likely problem which has yet to arise.

However as a component produced locally, they do offer the greatest potential for imaginative, simple and appropriate design.

For this reason a sketch is included to illustrate a concept, for the utilization of these components, primarily inspired by a desire to optimize their benefits and minimize the inherent construction difficulties.

This design is developed from concepts which several private individuals in Darwin had conceived. It is to these people that all credit must go for their part in displaying to me the potential of these units.

This introverted design basically;

- optimizes cross ventilation.
- reduces exposure to neighbours.
- provides large open living areas internally, achieved economically by brick paving between a periphery of precast units.
- utilized a precast unit which integrates, ceiling, floor, walls and upgraded structural requirements.
- screens driving rain allowing windows to remain open.

- by-passes the problem of water proofing joints by eliminating most of them.
- allows flexibility in the internal spaces, with the use of framed internal walls, screens or movable storage units.
- minimized maintenance by utilizing hard finishes
- eliminates the need for expensive internal finishes by providing interest in the spaces created.
- reduces cost by simplifying roof and minimizing its size.
- reduces heat load by shading the basic building components.

Only 5 units are required to form the basic shell of this home.

The main living area is achieved by the arrangement which creates a court yard in the centre. With this area covered as illustrated in the design overleaf the options internally are numerous. Alternative arrangements of units, utilizing this basic concept would multiply the options, allowing a house of any area to be constructed.

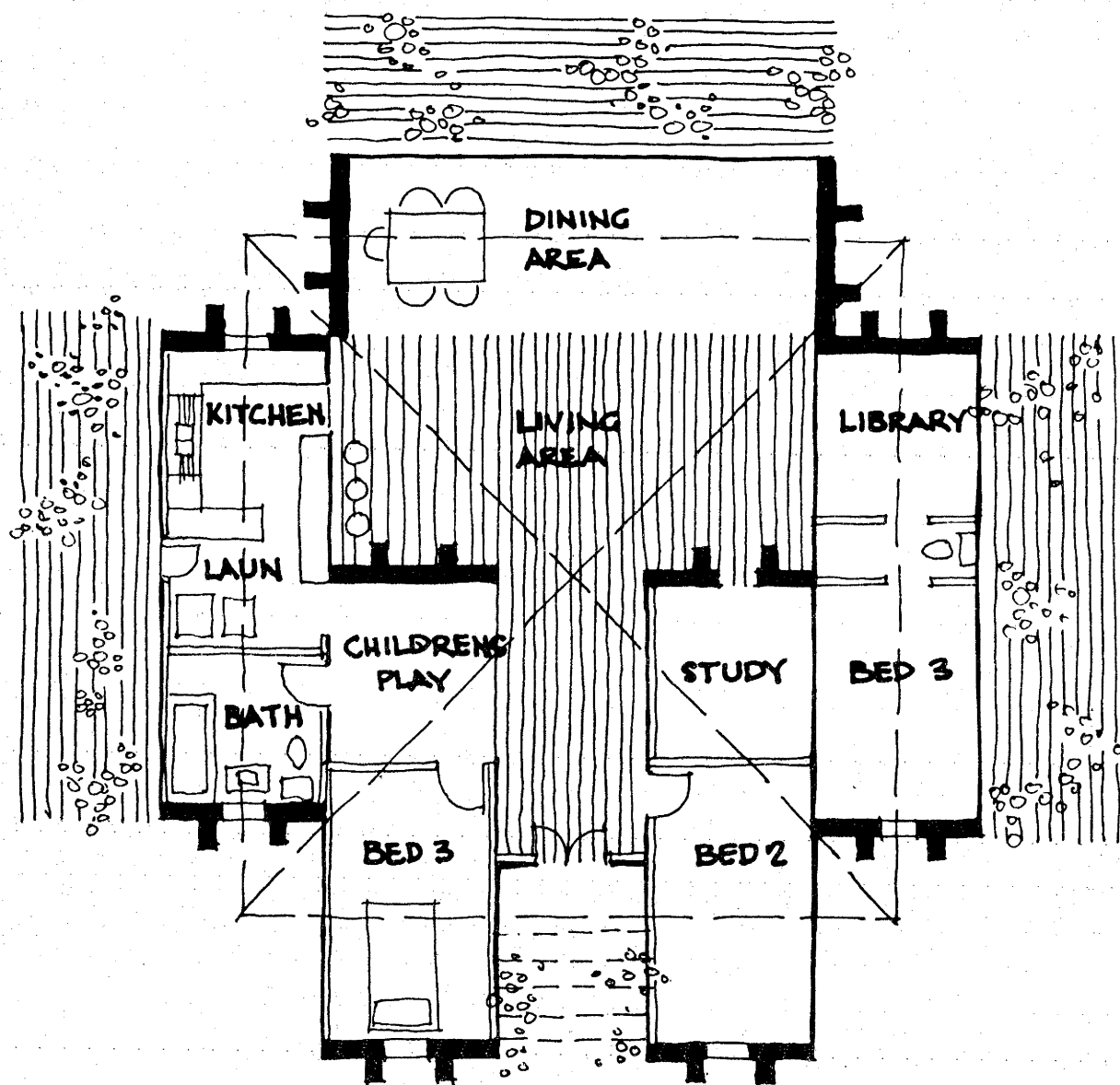
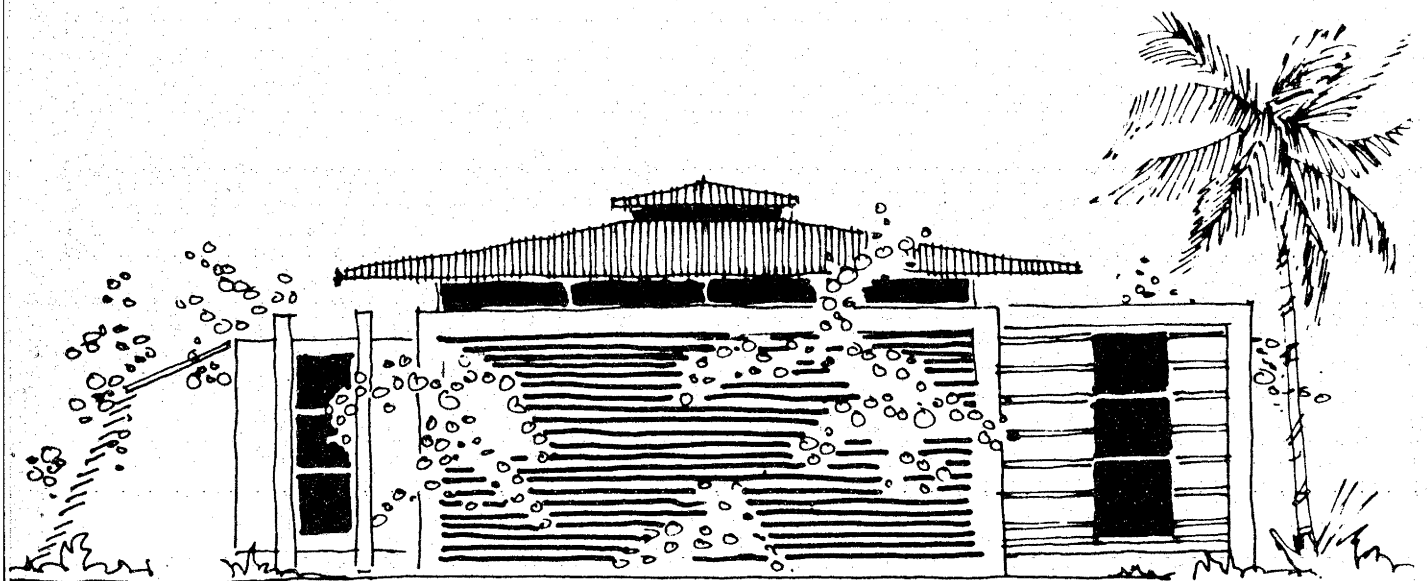


FIGURE 68. CONCEPT PLAN — USING A 5 MELOCCO UNIT CONCRETE SHELL.



ENTRANCE ELEVATION.



SIDE ELEVATION

FIGURE 68 (b) — PROPOSED ELEVATIONS.

8.0. CONCLUSION

CONCLUSION

The study, which is documented in this report has in effect attempted two things.

Firstly, a specific architectural event in a specific location - that being the re-construction of Darwin since 1974 - has been used as a case study for sociological and technical investigation, of interest to the architect.

Secondly, the findings of the investigations have laid the foundation for recommendations at a more practical level in view of the architectural problems which exist.

The study was initiated to further understand:

- (a) the meaning of an architecture quite distinctive in its setting, as the expression of:
 - the human experience of deprivation created in the wake of extensive destruction, caused by cyclone Tracy
 - environmental symbols, which are entwined into the psychological make up of each individual.
- (b) the composition of this distinctive architecture, with a view to assessing it in terms of its structural success and habitability within its extreme natural environment.

The latter investigation revealed many areas of success, providing the inspiration to extract from the findings, architectural results which demonstrated the successful resolution of conflicting requirements with the potential for future development.

The context, within which the architectural expression has emerged, was established to allow the extent of the architectural expression to be realised. This involved understanding the environmental determinants of a hot humid tropical region, and the architectural forms which had evolved within these determinants. This built fabric formed the precedents to events which were to follow, and the basic material which was to be modified when the opportunity arose.

The specific event of devastation, created determinants which set the limitations on the expression being investigated. These were technical in nature, as a result of structural inadequacy, clearly demonstrated by the extensive structural failure and social in nature with the disruption of the normal systems of supply, demand and the social order and control mechanisms.

With these restrictions determined the analysis could proceed in a meaningful manner.

The message emerging from the built forms in the sociological sense is the need for diversity in the manufactured environment, preferably diversified by the people for whom the environment is created. An architectural laissez faire is not advocated. The opportunity for each individual to mould his environment of some degree certainly is. Utilitarian and psychological requirements differ markedly if the case study of this report is any real indication. Without this contribution at a personal level, the environment suffers a derogation, in direct relationship to diminishing commitment by the inhabitants within their environment.

Conclusions cannot easily be formulated for events which are not of a recurrent nature. This is the case with the study of the architectural fabric, as an expression of human reaction to a major natural disaster. The impact of the event can however be identified, and the positive influences encouraged. The successful results identified in this report can hopefully assist in drawing attention to a trend, of vital importance to the successful achievement of a congenial tropical living arrangement.

The tangible record of this event is a reminder to the persons involved in environmental decision making of the vital need for a human input, and moreover an example of the successful resolution of complex needs in the technical sense.

The one most significant fact revealed by the re-construction operation is the need to reduce the vulnerability of the Darwin home buyer to the negative effects of:

- (i) a monopolised system of supply
- (ii) inappropriate housing influences from the south
- (iii) excessive costs generated by isolation and the need to mitigate cyclonic hazard, through the utilisation of reviewed construction techniques.

The analysis of the housing fabric clearly reveals the detrimental effects that these factors have had upon a large section of the homes re-constructed.

The more positive outcomes of the re-construction operation have been the reviewal of basic architectural principles, by the more innovative, allowing a more appropriate form, independent of external influences to emerge.

This involves:

- (i) the utilisation of locally produced building components
- (ii) the resolution at the first principle level of conflicting architectural functions.

These are the positive outcomes of the re-construction of Darwin which must be encouraged.

The active response of Darwinites - new and old - to the opportunity to rebuild is a clear indication of Darwin's permanency and likelihood of further large scale development. This fact alone adds vitality to the need for architects, working at all levels, to maintain a close communication with the complex needs of the uses of their buildings (and not just the clients) in fulfilling their primary role of environmental modification of greatest benefit to everyone and everything subject to that modification.

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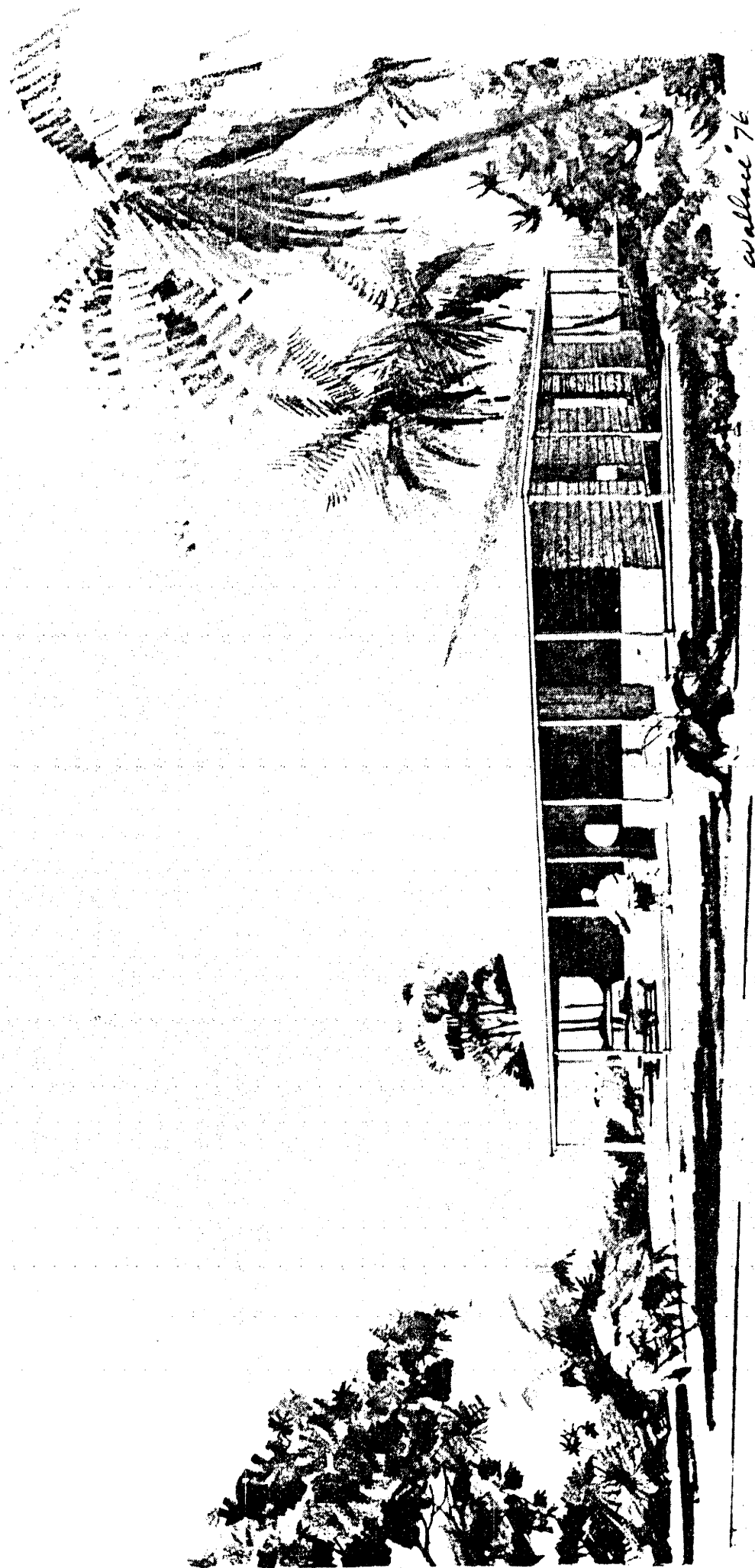
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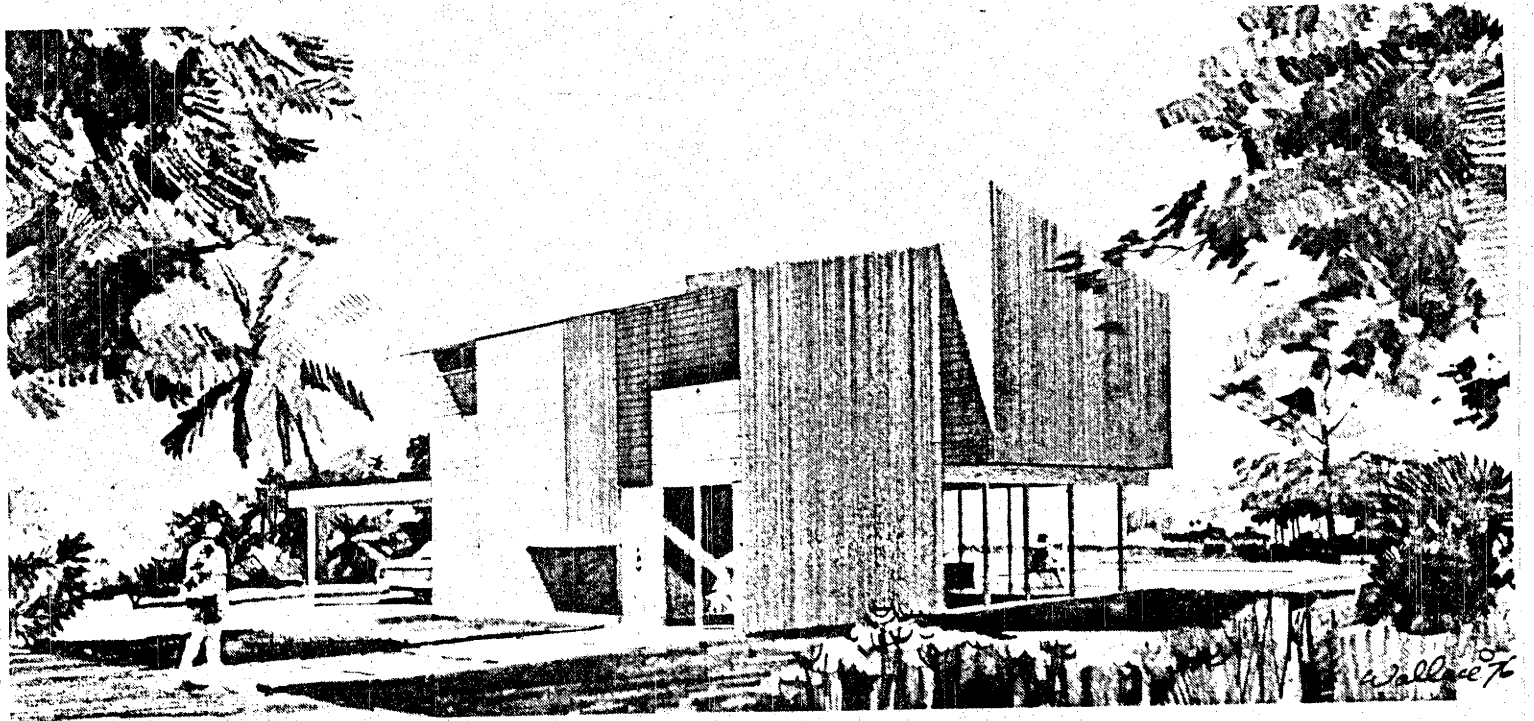
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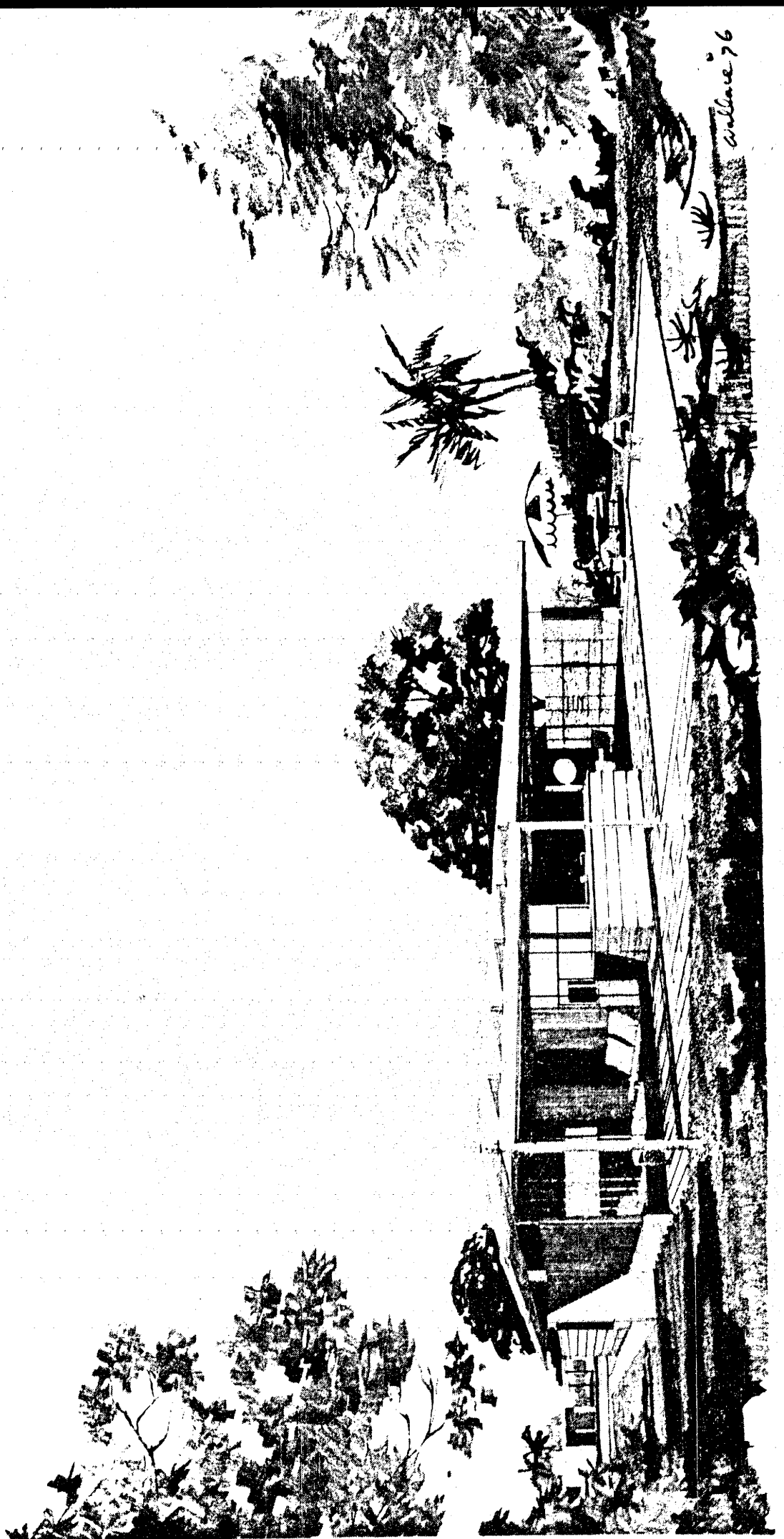
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APPENDIX A.



walrus 76





Wallace 76

APPENDIX B

D.R.C. HOUSING ADVISORY SERVICE

Activities from 15 March 1976 to present:

Red Graph;

Consultations with
callers on:-

Technical problems with owner
builders

Contract negotiations

drafting services

financial advice

Introductions to building
contractors & sub-contractors

House purchase

Dangerous properties & works

D to C and D.A.B.M. queries

Site and amenity requirements

Surge zone

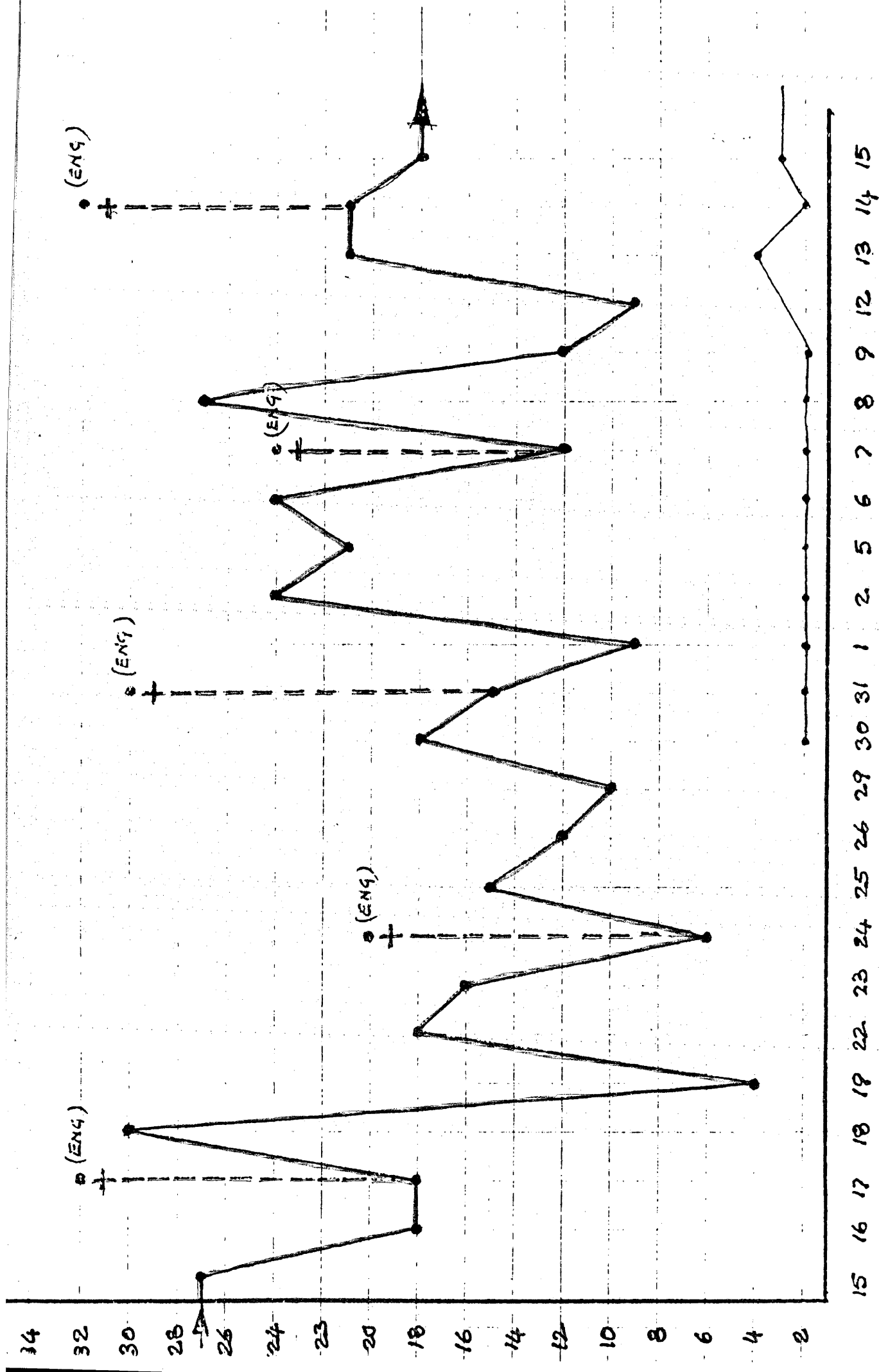
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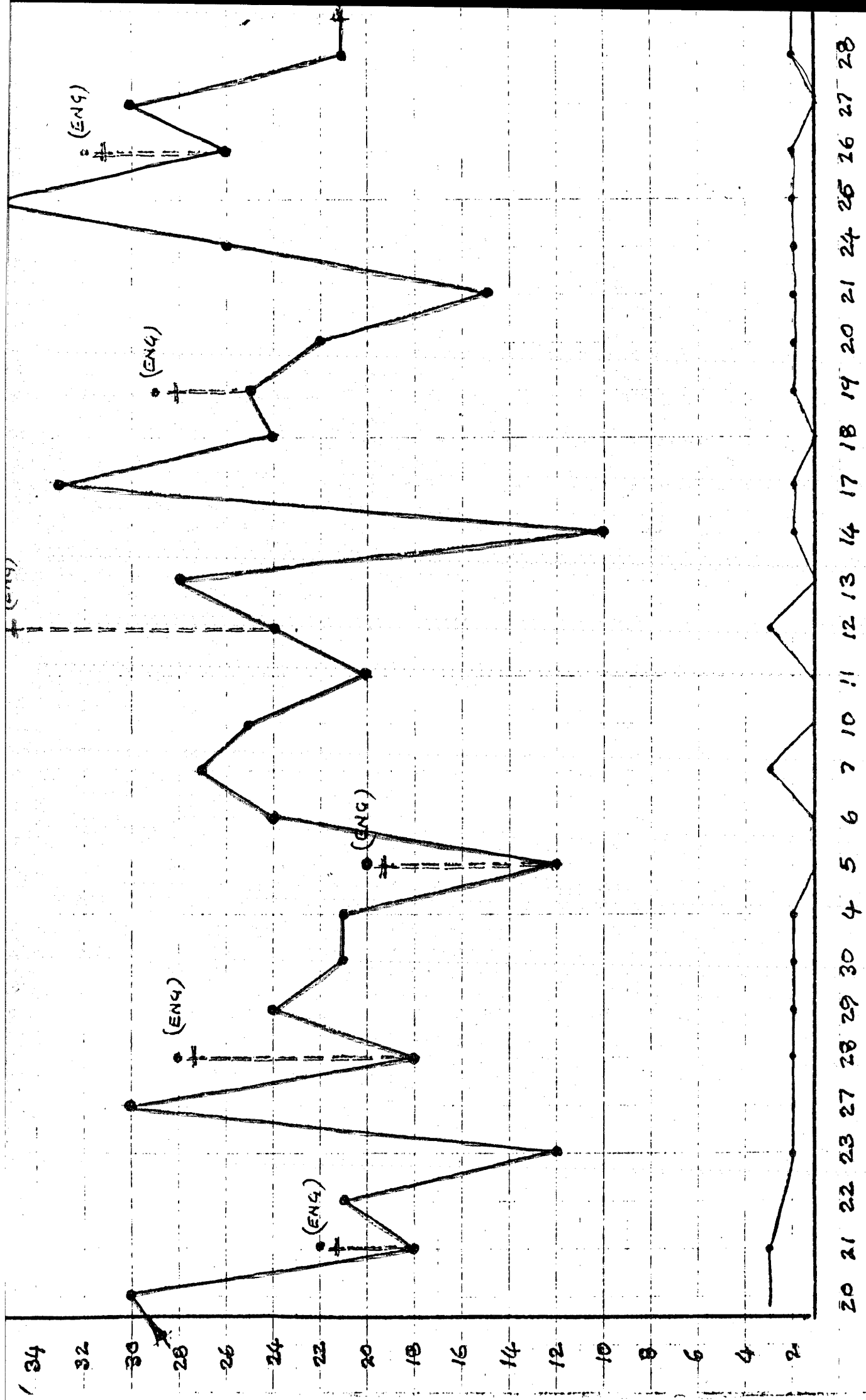
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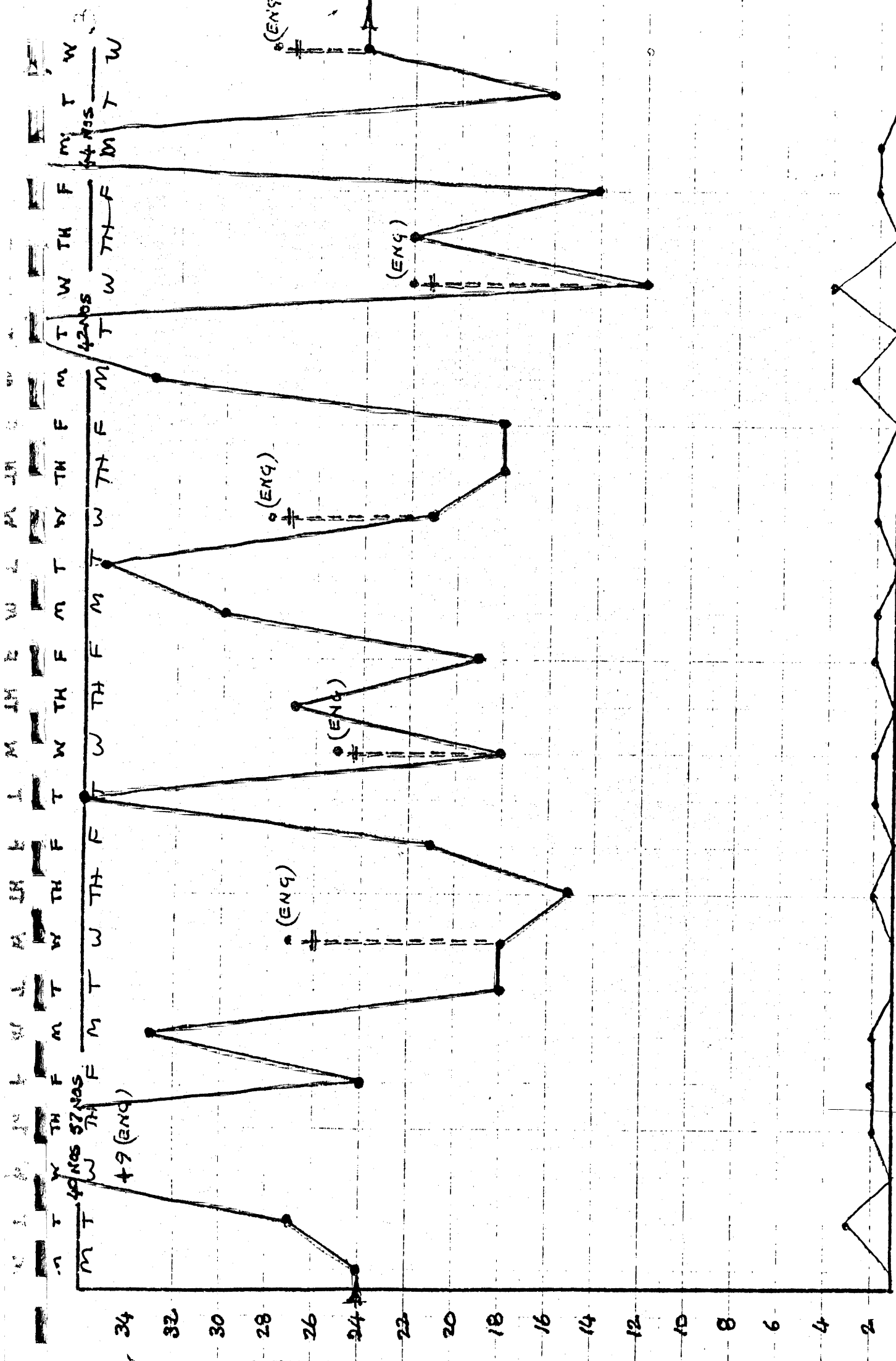
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Wooden shipbuilding in Tasmania

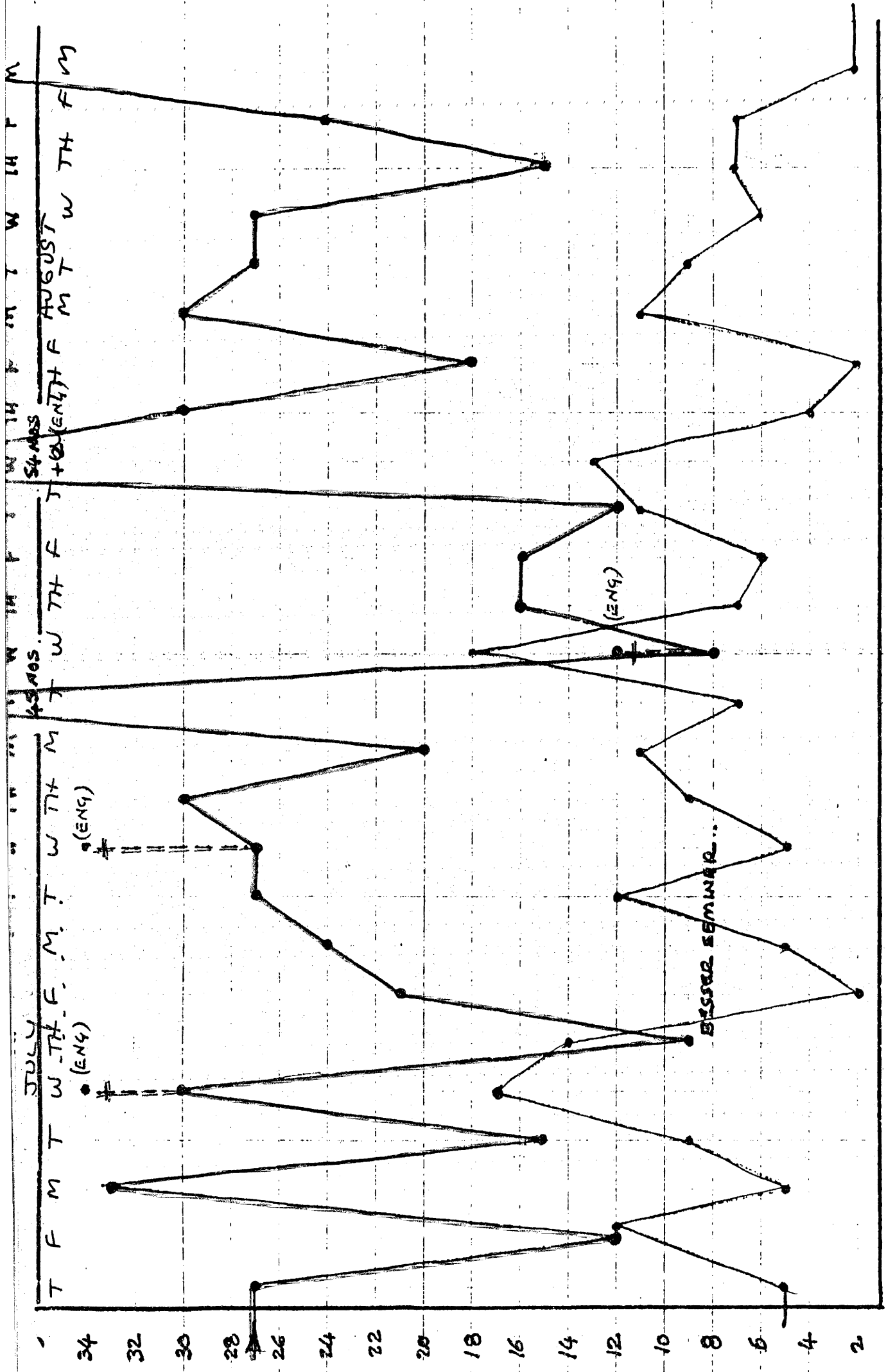
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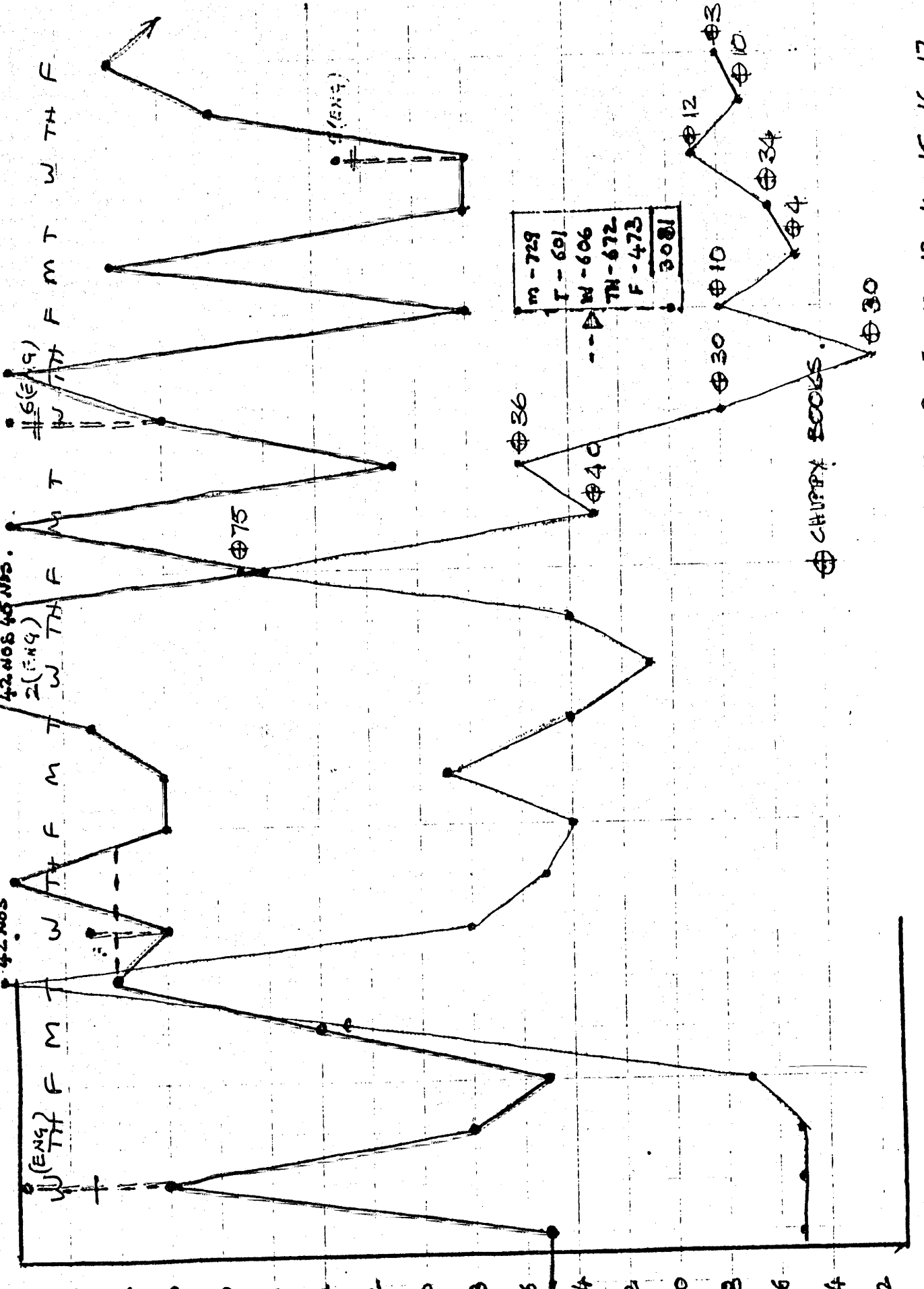
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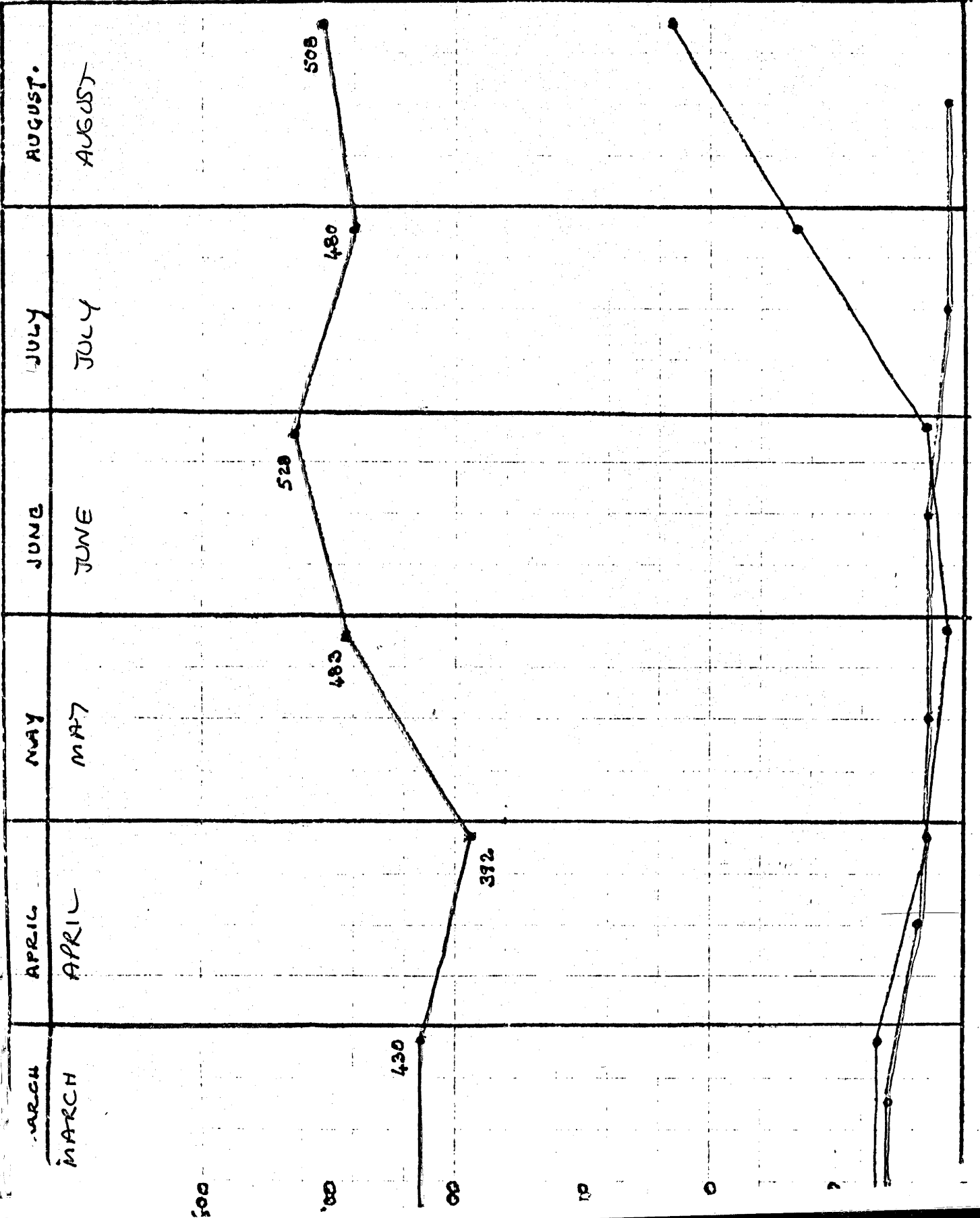
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GENERAL CONSULTANT SERVICES

SALES OF PUBLICATIONS

ENGINEERING SERVICES

APPENDIX C

1.

2.	3.	4.	5.
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6.	7.	8.
4	8	6

9.	10.	11.
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House Type.	elevated	1.
	ground level	2.
	split	3.
Materials	masonry.....	1.
	framed	2.
	combination.....	3.
	other	4.
Roof	tile	1.
	sheet.....	2.
	other.....	3.
Debris Protect.	none	1.
	sml windows.....	2.
	screens.....	3.
	vegetation.....	4.
	recessed openings.....	5.
Orientation	optimum	1.
	middle	2.
	no consid	3.
Sun penetration	High.....	1.
	medium.....	2.
	low	3.
Cross vent.	high.....	1.
	med	2.
	low	3.
Thermal	high.....	1.
	med	2.
	low	3.
Display	elaborate.....	1.
	average.....	2.
	plain	3.

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QUESTIONNAIRE

418.6

1. In several words or short sentences, describe what you believe to be the most important characteristics for a home in Darwin.

.....

2. When you began to consider construction at your home, what pre-cyclone structural elements were on your present site?

1. nothing
2. concrete slab on ground
3. concrete slab on ground with some habitable superstructure
4. piers and floorboards only
5. piers and floorboards with some habitable superstructure

1.
2.
3.
4.
5.

3. Before Cyclone Tracy was this site

1. Vacant
2. Developed with Gov't elevated house
3. Developed with Housing Comm. house
4. Developed with Privately constructed house
5. Housing temporary accomodation

1.
2.
3.
4.
5.

4. Did you live on this site before cyclone Tracy

1. Yes
2. No

1.
2.

(If your answer to Question 4 is NO - answer Questions 5 & 6)

(If your answer to Question 4 is YES - answer Questions 7 & 11)

5. Have you previously lived in a humid tropical climate?

1. Yes.
2. No.

1.
2.

Please indicate location and approximate length of stay.

.....

6. What was the primary reason for purchasing a site in your present location?

.....

7. How long had you lived in this home before the cyclone?

1. less than 6 months.
2. between 6 months and 12 months.
3. between 1 year and 2 years.
4. between 2 years and 10 years.
5. more than 10 years.

1.	
2.	
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8. After the cyclone did you (the main breadwinner) leave Darwin?

1. Yes
2. No

1.	
2.	

9. Did your family leave Darwin after the cyclone?

1. Yes
2. No

1.	
2.	

10. If your answer to ques. 8 is Yes, how long were you absent from Darwin?

1. less than 3 months.
2. between 3 and 6 months.
3. between 6 months and 2 years.
4. more than 2 years.

1.	
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11. How long were your family absent?

1. less than 3 months.
2. between 3 and 6 months.
3. between 6 months and 2 years
4. more than 2 years.

1.	
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12. When faced with the prospect of construction, what factors did you consider to be most important?

.....
.....

13. Which services did you consult for advice before construction?
(Please indicate more than one answer if appropriate.)

1. Architect/Engineer.
2. Builder.
3. D.R.C. Advisory service for technical advice.
4. D.R.C. Advisory service for standard plans.
5. Written reports by D.R.C. or other.....
6. Material Suppliers.
7. Local suburban building co-operatives.
8. Neighbours.
9. Operation Self Help D.R.C.
10. Other. Please specify.....

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14. Which of these do you believe were of most value in assisting you? (indicate using numbers as in ques. 13.)

15. Which of these do you believe were of least value in assisting you? (as above)

Please comment on the above if you care to. (continue overleaf)

.....

16. From which sources did you receive finance for construction?

1. Insurance Company.
2. Home Finance Trustee.
3. Reconstruction Loan.
4. Repatriation and Compensation.
5. Building Society.
6. Finance Company.
7. Savings.
8. other. Please specify.....

1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

17. What percentage of the value of your existing home is presently covered by insurance?

1. less than 30%
2. between 30% and 50%
3. between 50% and 75%
4. more than 75%

1.	
2.	
3.	
4.	

18. Who/what primarily determined the design of your house?
 (Please indicate more than one answer if appropriate)

1. Architect.
2. Builder.
3. Project home. e.g. System Build, Lockwood, etc.
 please specify.....
4. Yourself.
5. Advisory board plans
6. " " " with your alterations.
7. other

1.	
2.	
3.	
4.	
5.	
6.	
7.	

25. Does the cost indicated in 24, include a cyclone shelter?

1. Yes

2. No

1.	
2.	

26. Do you have a Certificate of Compliance for your home?

1. Yes

2. No

1.	
2.	

27. What is the approx area of outdoor covered living space?

.....

28. What is the approx area of internal living space?

.....

29. Is your home air conditioned?

1. not at all

2. partly Please specify.....

3. throughout

1.	
2.	
3.	

30. Is your home insulated?

1. not at all

2. roof only

3. roof, east & west walls

4. throughout

1.	
2.	
3.	
4.	

31. What is the occupation of the main breadwinner?

.....

32. What was your pre-cyclone building experience?

1. nil

2. minor home repairs or equivalent

3. major home repairs or equivalent

4. trade assistance experience

5. Tradesman Please specify.....

6. other Please specify.....

1.	
2.	
3.	
4.	
5.	
6.	

33. If your father was not born in Australia, in which country was he born?

Thank you for your co-operation and time. This information can greatly assist me in my research.

Please feel free to include any further comments you may like to express, or sketches to illustrate your home or points you are making. I am happy to have you use the back of questionnaire sheets for this purpose.

INTENTION OF QUESTIONS

1. A general question, designed to stimulate thought about housing and establish what is perceived as important, with a view to investigating the relative success of the resulting forms constructed. May also reveal the extent of lay understanding of "shelter" principles in the tropics.
2. A major economic factor in reconstruction would be existing material. Many, in fact, purchased sites holding some remains, to reduce costs. This also reduced building options. This questionnaire shall only be distributed to sites where damage exceeded 60% of house value on 25.12.74. Thus there is little likelihood of more substantial structure being intact.
3. This question is included, to determine whether or not the upgraded standard house designs existed as an option, which could subsequently be adopted or rejected.
4. A belief (partly supported by observations in similar situations at disaster response), suggests that a major motivation in reconstruction is to create one's home and supporting community exactly "as was", in order that social functions can be rehabilitated.

In contrast to this belief is the "recognition of the disaster as a juncture in human experience, providing a form of social absolution permitting people to make a clean break with the past".

The question is designed to determine how many people left Darwin and how many established themselves in Darwin, as a result of the cyclone.

5. These questions are designed to determine the occupant's experience with tropical living.

6. It is intended that this question may indicate to some extent perceived permanency and also elicit some interesting prejudices.
7. It is assumed that period of occupancy and commitment to home bear some association, which this question, in conjunction with built form may clarify. Alternatively this may be misleading as those with a long domicile association may well have been of such an age as to make reconstruction unjustified. Response to this will vary significantly, according to suburb as is evident by study of historical suburban events and age of suburb.
10. Social research has clearly indicated various levels of deprivation associated with evacuation and time absent from home - those most affected psychologically, presumably being those who did not return. These questions are designed to assess whether or not time away caused a loss in morale, increased exposure to ideas or delayed reconstruction and whether subsequent building activity was affected.
11. Observations indicate that time may be a factor influencing the switch between the two phenomena explained in Question 4. It would be anticipated that extended time away allows for rationalization of essential cyclone proofing, avoiding over reaction and the opportunity to consider alternatives (reinforced by exposure to ideas in south or elsewhere).
12. This question is basically designed to stimulate the respondent's memory about the problems being encountered - having made the decision to build and attempt to establish life in Darwin and to determine what factors inhibit the attainment of the characteristics considered desirable in a house as expressed in Question 1.
3. Designed to assess which services are perceived as being most accessible and reliable.

- . & I5. This question should allow respondents to indicate their delusions and impressions with various assisting authorities, and building industry advisors.
- I6. This question is purely designed to establish the actual financial freedom each respondent possessed and establish the real effectiveness of the schemes in operation.
- I7. Underinsurance proved to be the cause of a major expense to the Government. This question is included to assess the likely independence financially of home owners in the event of a similar disaster. Alternatively, has the expenditure into structural upgrading been perceived as an adequate insurance policy.
- I8. This is included to determine who influenced the "shape" of existing suburbs and the extent of individual contributions.
- I9. Further to I8 one would anticipate that the act of building allows more individual are usually tailored to standard detail and known practice when draughting is contracted to "specialists".
20. This is significant, as building manuals were amended, reducing cost, counterbalanced by "normal" inflationary increases. Thus priorities altered overtime. A lack of knowledge in the early stages may also have caused over design in hazard initigation, altering the attention given to house functions.
- 2I. Follow on from 20. An indicator of the frustrations experienced through delay or lost morale.

22. Delays and frustrations tend to cause compromise. To understand what latter home builders may have attempted to avoid in the course of action they adopted, it is necessary to understand the sources of delay.

23. I am interested in finding out the investment made into

- (a) comfort - "house a machine to live in"
- (b) protection - "a device against extreme loading"
- (c) display

in an attempt to understand the priority of these three things and the way in which they differ over time and with characteristic groups (if any).

The question is designed to assess investment into (b) protection. The other two considerations are recorded on the cover sheet as questionnaire is distributed. Assigning a monetary value to elements of display would be meaningless as most decorative applications are done by "Greek relatives" under their unique system of exchange.

24. Designed to assess the real cost penalty of structural upgrading and how it altered over time.

& 26. As above. These ensure a certain level of investment into protection.

& 28. Changes in life style with the introduction of Television and a changing family structure had rendered many pre-cyclone house, less than adequate over time. Reduction in specification also reduced certain areas of the home. The manner in which individuals have reconstructed their homes must reflect the extent of pre-cyclone inadequacy.

29. Air-conditioning has naturally had a significant effect upon altering the nature of tropical houses. This information is necessary to determine how many apparently inappropriate designs are made tolerable with the use of air-conditioning.

30. To assess investment into the comfort function of home.

31, 32, These questions are designed to determine what the experience of people actively
& 33. involved in reconstruction really is, and how these factors influence home needs
and knowledge of housing principles.

APPENDIX D

INTERVIEW SCHEDULE

I. Assess success of climatic modifications.

How well are principles understood.

How effectively are devices used.

2. Assess success of structure to resist;

(i) uplift

(ii) lateral forces

(iii) distortion

Anticipated level of damage in reoccurrence of similar disaster.

3. Materials selected - internal and external.

Reason for selection.

Are needs (i) aesthetic
(ii) practical
(iii) psychological

4. When did construction begin and reason for delay if any.

5. Evolvement of Design:

(i) who was responsible

(ii) main design criteria

(iii) alternatives considered

(iv) process of elimination

(v) extent of alteration from pre-cyclone home

6. Advantages/disadvantages over previous living arrangement.

7. Costs - in energy and material components. - Market value today.

8. Effect of change at suburban level on home environment.

(i) life style

(ii) breeze

(iii) commitment to home

9. Perceived permanency in present house - of previous.

10. Perception of the likelihood of cyclone recurrence.

II. Satisfaction - procedures they would adopt and changes they would make to design in retrospect.