"using low-cost indigenous building materials is quite sound, provided they were fixed satisfactorily."

Some Steps Towards the Development of Low-Cost Typhoon Resistant Housing in the Philippines

by

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With Assistance From The Typhoon Assessment Group for Typhoon Damaged Houses Building Research Service

ABSTRACT

Due to the high occurrence of typhoons in the Philippines, it is important that all housing be typhoon-resistant. Following the passage of typhoon "Herming" in the Philippines, an extensive investigation of damage to low-cost housing was undertaken. The principal aim of the activity was to isolate systematic problems in the structural action of low-cost housing and to make specific recommendations with respect to low-cost improvements to the buildings. Three problems were highlighted and appropriate recommendations have been made. An education programme will be mounted to publicize the recommendations.

The paper outlines the structural damage caused by the typhoon and examines the recommendations made based on the preliminary data from the damage survey.

INTRODUCTION

A United Nations funded Regional Network was established in Asia in 1983 to facilitate information interchange on the development of satisfactory low-cost housing within the area. The UNDP/UNIDO Regional Network in Asia for Low-Cost Building Materials Technology and Construction Systems has recently held two seminar/workshops that have focused on the problems associated with the development of low-cost typhoon-resistant housing within the region.

The first, held in December 1986, established a dialogue between the network countries that highlighted the scale of their typhoon-related problems and made progress towards a solution. Within the network countries alone, the damage figures are staggering. On an annual average, over 1,000 people die and more than half a million are rendered homeless. These figures do not include the Bangladesh typhoon of 1979 in which over 300,000 people died. While some of the deaths and the damage can be attributed to water effects, poor structural response of buildings subjected to large wind loads is a major cause of community hardship during typhoons.

The second seminar/workshop held in July 1987 specifically addressed the need to supplement knowledge of the engineering properties of many materials used in low-cost housing by con-

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ducting structural damage assessments following the passage of typhoons (Boughton, 1987). By examining the performance of buildings that sustained damage, and those that were free of damage. failure envelopes could be drawn for many different building materials and components.

Within four weeks of the completion of the Seminar/Workshop on Typhoon Damage Assessment, a severe typhoon had crossed over Northern Samar, Southern Luzon and Northern Mindoro in the Philippines. To consolidate the theory established in the training sessions at the seminar/workshop, a structural damage investigation was mounted.

The complete findings from that investigation will be available towards the end of 1987, but the preliminary findings have enabled the commencement of an education programme for owner/builders of low-cost houses. This programme aims to improve the structural response of low-cost houses to the typhoons that have rendered thousands of families homeless each year in the Philippines in the past.

PROVISION OF HOUSING IN THE PHILIPPINES

Most of the housing in the Philippines is privately owned, though there are a number of government assisted housing development programmes. The government, through its Housing and Urban Development Coordinating Council, makes land available to housing authorities and prospective home owners and the National Housing Authority has developed housing in both urban and rural centers for long term purchase or rental. In many cases, this housing is for the upper- or middle-level income earners, but a number of small standard house systems have been investigated for low-income earners. Many government funded scientific research bodies are actively involved in research into new housing materials or construction methods.

In spite of these initiatives, there is still a shortfall in housing throughout the nation. As a result of the housing deficit, squatter areas abound in cities. Here, individuals build their own houses mainly from reclaimed materials, relying on government agencies to provide infrastructure services such as water, drainage, refuse removal and power and postal services. There is not sufficient manpower available to exercise any sort of building supervision or regulation in these areas.

In the rural areas, prospective home owners generally build their own houses using a wide variety of materials ranging from concrete hollow blocks with corrugated steel roof to bamboo framed thatched houses. Again, the shortage of trained building inspectors and difficulties with access to many settlements has precluded the implementation of systematic building regulation.

The Philippines has the dubious distinction of having the largest number of typhoons cross into its meteorological area of any country in the world. On the average, over 19 per year are monitored by the meteorologists based in Manila.

The large number of typhoons experienced by most areas of the country means that even houses with a projected lifetime of five years have a high probability of experiencing a moderate or severe typhoon. Most of the typhoon activity occurs within the Visayas group in the central Philippines or the northernmost regions including the largest island of Luzon.

To prevent already acute housing shortages from becoming more serious after the passage of typhoons, housing should be constructed in a manner that will minimize damage caused by wind.

DAMAGE TO STRUCTURES CAUSED BY TYPHOON HERMING

Typhoon Herming was the seventh typhoon to be monitored by the Philippines in 1987. It developed as an active disturbance south of the Marianas Islands, approximately 2,500 km east of the Philippines on August 7, 1987, and rapidly developed into a tropical depression. On the 8th, 9th and 10th, it moved slowly northwards and intensified, and on the 11th, it changed direction to move westwards. At landfall over Northern Samar, its central pressure was estimated at 935 hPa, and its central wind speed at more than 200 kph.

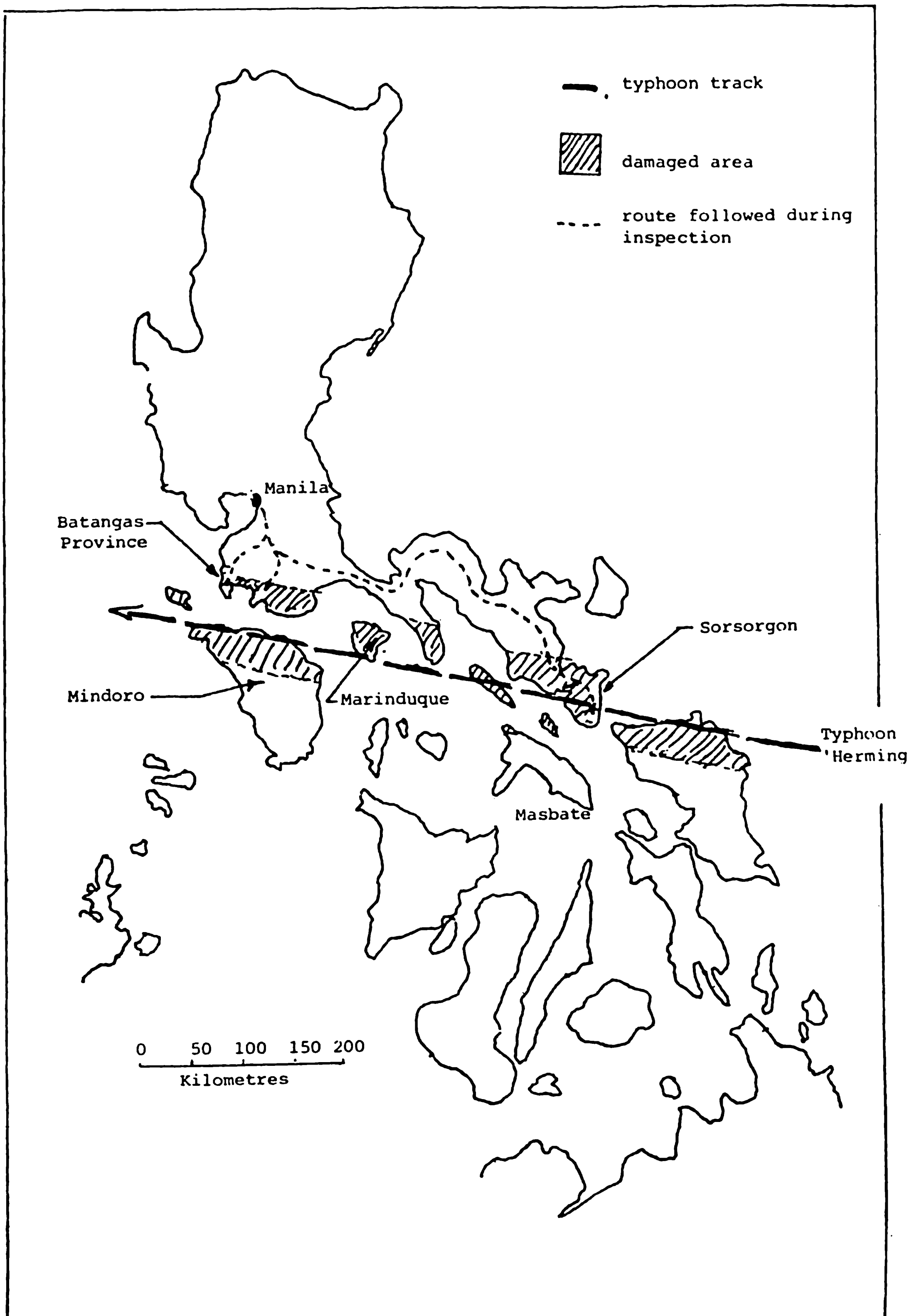

Figure 1. Typhoon Herming – Path and Damaged Areas

Some reduction in wind speed and a slight increase in central pressure may have occurred as it crossed the Philippine archipelago. Typhoon Herming was the most intense to make landfall in the Philippines so far this year, and the most severe in the affected areas since 1981.

Damage was widely spread among the peninsulas and islands that were in the direct path of the typhoon. Due to logistical constraints, the assessment team was restricted to the mainland of Luzon, but still managed to inspect structures in three separate provinces. Figure 1 shows the estimated path of the typhoon, the severely damaged regions and the areas in which the damage was assessed.

Over 100 structures were inspected. Some of these were simple structures such as road signs, which were used to find wind speeds. Each structure was documented with respect to its wind environment and the structural materials and system used. Damage was also carefully studied to determine the first elements that failed in each building. To facilitate the interpretation of the damage, only buildings with simple damage were chosen. Many with more spectacular damage were bypassed.

The structures that were assessed could be categorized as follows:

houses	63
schools	18
signs	8
shelters	5
large buildings	6

Of the 81 smaller buildings examined, 60 percent had roofs clad with a thatch material, and over 70 percent incorporated bamboo or a bamboo derivative somewhere into the structural system. It is primarily on the performance of the structures that had indigenous material components that the remainder of this paper concentrates.

The damage assessment undertaken had a number of objectives which included the following:

(i) provision of field practice for Philippine architects and engineers in assessment of structures following typhoon damage;

(ii) isolation of those building components and systems that exhibited consistently poor structural performance;

(iii) isolation of those building components and systems that exhibited consistently good structural performance; and

(iv) evaluation of failure loads for indigenous building materials and components.

The first three of these were short-term objectives and produced tangible results within the ten-day assessment period. The last one will require many months of analysis to produce tangible benefits.

Structural inadequacies in all types of building materials were observed. Structural performance was not a property of the materials used, rather it was determined by the attention to detail in making connections. Three common problems encountered were:

(i) deterioration of timber;

(ii) inadequate fastening of light weight roofing; and

(iii) poor performance of bracing or inadequate bracing.

Timber Deterioration

In many cases, large-scale structural damage to a building was caused by failure of a single connection weakened by timber deterioration. The most common elements to fail in that manner were timber columns or piles that were buried in soil. The activity of borers or termites in some cases had caused total loss of all timber below ground level. It was nearly impossible to tell whether the timber had been treated, but currently available methods do not have much success in penetrating the heartwood of tropical hardwoods, so attack through the end grain is highly likely.

Other locations where deterioration had occurred included the important connection between the roof structure and the top of the wall. Moisture accumulation in the region of that connection allowed deterioration to proceed at an accelerated rate. Figure 2 shows a photograph of a timber roof structure member significantly weakened by timber deterioration at the connection with the wall top plate. It was identified as the primary cause of a chain of failures that resulted in the loss of a complete school building.

Figure 2. Photograph of Weakened Timber at Roof Structure Anchorage Point

The failure of roof anchorages caused the roof structure to become disconnected from the remainder of the building. Frequently the roof loss was followed by collapse of wall panels that were no longer supported at the top.

Such large-scale failures can be prevented in the future by adequate protection of the timber, or by the use of naturally durable timber species. Where properly treated timber is not available, important structural connections can be protected by painting with insect repellents or poison such as a kreosote and sump oil mixture or dieldrin. Also, leaving important structural connections open allows ventilation around the joint which will in turn prevent moisture build up in that crucial area. It also allows the connection and the joining members to be periodically inspected. Signs of deterioration can be detected at an early stage and an appropriate remedy undertaken.

Fastening of Lightweight Roofing

Most of the roofing seen during the course of the assessment was lightweight. Traditional housing utilized locally grown thatch materials tied to split bamboo supports. Western style housing often utilized galvanised profiled sheeting fastened with rivets and straps. Both systems had their problems.

Among the thatch materials, the most commonly used in coastal areas was nipa palm thatch which was bound into tiles by wrapping the leaves over split bamboo or nipa palm stalks. The tiles were approximately one meter long and had a coverage of between 0.1 to 0.2 square meter.

The performance of the nipa tiles themselves was very dependent on the structural and aerodynamic form of the house. Where windows on the windward wall had been left or blown open, the nipa tiles had suffered more damage than those on houses which had remained sealed.

However, some patterns in the failure were quite obvious. The nipa tiles had been fastened to the roof structure in many different ways:

- The most common was nailing with one nail through the nipa tile into rafters at every crossing point.
- Some fastenings utilized ties with nylon fishing line at every crossing point in conjunction with nailing. One loop of fishing line was the most common form of this connection, but others included abaca twine, rattan, and plastic strip.
- In some cases, ties had been used on two crossing points on each tile, with the others being held by nails alone.

In many cases, nailing was not used in conjunction with these materials. Figure 3 shows a detail of failure where a nipa tile had been secured only with nails. The cracks in the split bamboo are quite obvious. It was probable that the bamboo split at the time of nailing, but the damage was concealed by the nipa thatch. Upon uplift, the nipa tile would have lifted over the nail head with little resistance.

In contrast with this type of failure, the performance of the roof was much better where the bamboo splits were tied to the roof structure at every crossing point. On one house, the owner had run out of nylon fishing line prior to tying the whole roof, and the area which had not been tied had been removed by uplift forces but the tied area had remained untouched.

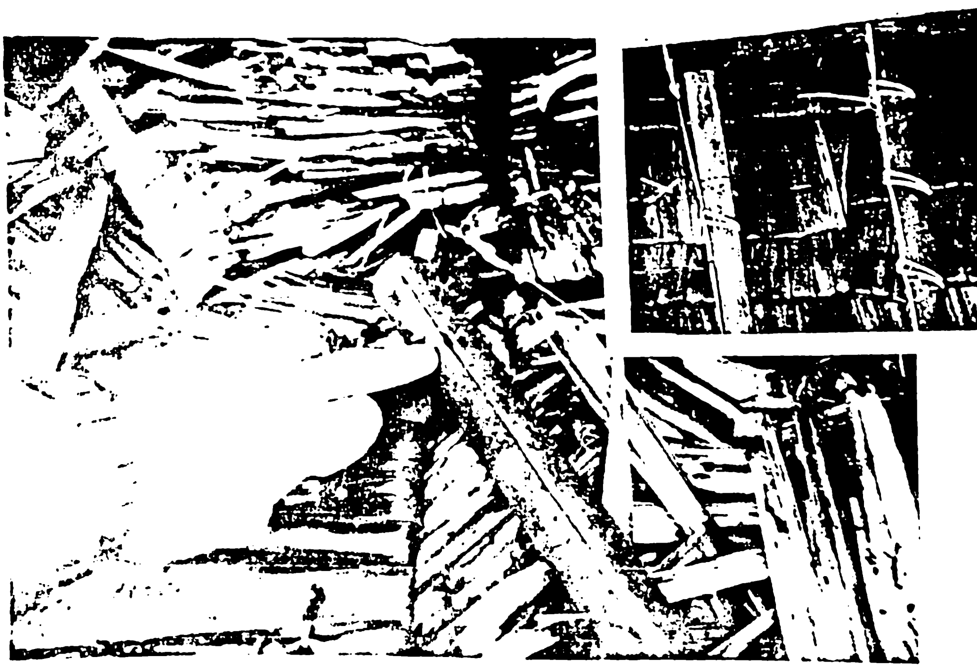

Figure 3. Nailing of Split Bamboo Pieces
(Inset shows splits tied with rattan)

Failures were observed on roofs in which only two points on each tile had been tied. In these cases, the tiles had all remained fastened to the rafters at the tied joints, but had been separated from the roof structure at all of the nailed connections. The tied rafters had been overloaded and broken, allowing their separation from the roof structure. Almost all of the houses in which partial tying of the nipa tiles had been used, were damaged in this way.

While the performance of the nipa thatch was highly variable, anahaw thatch performed much better. Anahaw is also a palm thatch, but in this case, whole leaves are tied into the roof structure as shown in Figure 4.

Figure 4. Anahaw Thatch

The anahaw thatch had performed consistently better than the nipa thatch primarily due to the fact that it was virtually impossible to fix without tying. Conventional fixing techniques used split bamboo pieces on both the inside and outside of the thatch with nylon or rattan ties connecting the two. This attests to the success of ties in securing split bamboo members in a structure.

The most commonly used western style roofing was galvanized corrugated steel sheeting and it was fixed by rivetting a light gauge steel strap to the roofing and then nailing the strap to purlins. In many cases, flapping of the roof had caused fatigue failures in the light gauge straps.

Resistance of Housing to Lateral Loads

Many of the houses constructed of indigenous materials utilized bamboo wall cladding. The cladding included:

- split bamboo lengths tied or nailed to the wall frame to give a semi-permeable wall.
- woven bamboo sawali frequently sandwiched between the frame on the inside and cover strips on the outside.
- crushed bamboo in which mats of bamboo formed by crushing single stalks were placed in two layers and sandwiched between the frame and cover strips.

No bracing was observed in the walls of any of the houses that used these systems. As a result, racking had occurred with all of the systems. With the split bamboo lengths, the racking was so severe that the house was frequently a total loss as is shown in Figure 5. Houses with sawali and crushed bamboo seemed to be stiffer, and the resulting racking deflection was often small, leaving the house quite serviceable.

The installation of a small number of simple diagonal braces in the walls of these houses would have in many cases prevented any racking damage from occurring and in all cases would have significantly reduced the movement so that the houses could still be safely occupied.

External diagonal braces were used on a number of houses. These braces ran from eaves level to the ground as shown in Figure 6. The purpose of this brace was to secure the house against lateral movement; however, the braces had proved largely ineffective.

The braces were rarely tied at the bottom which meant that they could carry no tension, and their slenderness prevented them from carrying much compression. Their value appears to be psychological.

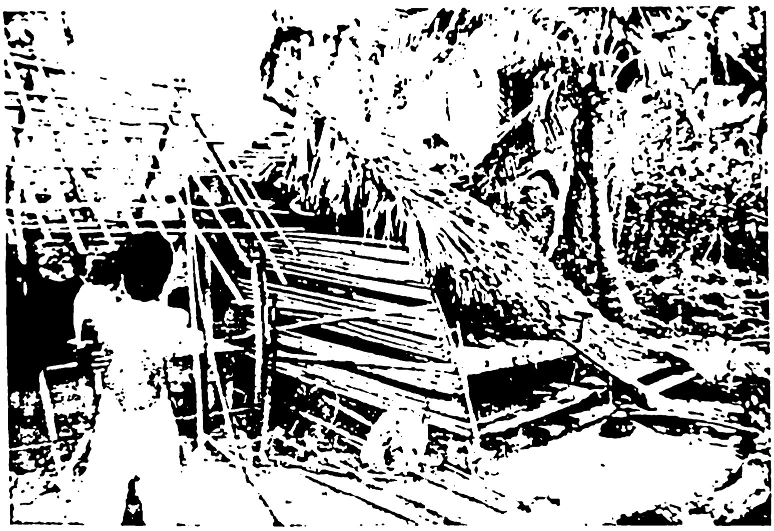

Figure 5. Racking Failure of an Unbraced House

Figure 6. External Bamboo Bracing (Arrowed)

IMMEDIATE STEPS TOWARDS IMPROVEMENT OF LOW-COST HOUSING

In all of the areas inspected, the lightness of many houses meant that they could be readily reconstructed. However, the reconstruction frequently followed the same structural form as the building that had been damaged.

This clearly indicates the important role education has in the establishment of sound building practices using low-cost indigenous materials. Sufficient cases in which indigenous materials had remained intact were seen to convince the assessment team that as building materials, they were quite sound, provided they were fixed satisfactorily.

The systematic observation of the structural performance of many building systems has enabled some preliminary recommendations to be prepared. These relate primarily to the three items (timber, roofing, bracing) discussed in the previous section. A small comics-type leaflet is currently under preparation. It will have captions in Tagalog and Bicolano, the languages of the areas in which the assessment was performed. It will later be translated into the Samar dialect. As these will be inexpensive leaflets they can be widely distributed at the commencement of the next typhoon season.

Each of the recommendations made will be clearly illustrated and the cost of each is very small. Among the recommendations will be:

- use of old sump oil to treat timber in important structural connections (cost: free)
- use of nylon fishing line to tie down nipa thatch at every crossing point (cost: P2.00 for a whole house — equivalent to the cost of two nipa tiles)
- tying of diagonal bracing into wall frames (cost: P5.00 for bamboo, P3.00 for bush timber)

The leaflets will be distributed to barangay captains who have leadership roles in the villages and will also be included in comics to be placed in village comics libraries.

LONGER TERM STEPS TOWARDS IMPROVEMENT OF LOW-COST HOUSING

Eventually, it is hoped that engineering properties can be derived for many indigenous building materials. Current laboratory testing programmes and the result of analyses performed on the damaged buildings should enable failure loads to be determined for bamboo framing connections, nipa thatch and concrete hollow block walls. These figures will enable the engineering design of reliable low-cost housing to be constructed using proven, readily available indigenous materials and construction techniques that have been established over a long period of time but adapted for low-cost modern materials such as nylon fishing line.

These designs could also be published using comics-type leaflets.

CONCLUSIONS

The provision of low-cost housing that is typhoon-resistant is possible using owner/builder construction methods and currently available materials. These measures will not increase the cost of the house by more than a few pesos yet have the potential to significantly reduce the level of damage sustained in a typhoon.

Forming education programmes for the dissemination of the information currently available remains a significant challenge. Present plans utilize clear, comics-style leaflets in an appropriate language and will be timed to reach the village when the awareness of the need to act is at its highest.

However, the problem is so vast, that in spite of the activities of many research agencies, much work remains to be performed on the development of low-cost typhoon-resistant housing. This includes adequate documentation, analysis and improvement of the many structural systems currently in use for low-cost housing throughout the country.

ACKNOWLEDGEMENTS

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Street	Location	Type	Walls	Roof	Damage	Features
1	Pt Santiago	house	timber	steel	nil	o/battens and rope, roof fastener
2	Pt Santiago	house	timber	steel	nil	rope over roof fastener
3	Pt Santiago	house	timber	steel	nil	o/battens and rope roof fastener
4	Pt Santiago	school	CHB	steel	roof loss /cracks	truss anchorage to CHB
5	Calatagan	house	CHB timber	nipa	roof loss	timber deterioration
6	Calatagan	house	CHB timber	steel	roof lift	truss anchorage to CHB
7	Calatagan	house	timber	steel	eaves damage	corrosion of roofing
8	Calatagan	house	timber	nipa	little	logs and steel on roof to stop uplift
9	Calatagan	house	timber	nipa	nil	chicken wire netting over
10	Calatagan	house	timber	nipa	nil	bamboo slats over
11	Calatagan	house	nipa	nipa	racking	roof ok — windows closed
12	Calatagan	house	nipa	nipa	roof damage	racking ok — windows open
13	Calatagan	house	nipa	nipa	impact	nipa tied with fishing line
14	Calatagan	house	timber	steel	roof/wall	truss anchorage — deterioration
15	Calatagan	house	nipa	nipa	roof	6th months nipa — nailed
16	Calatagan	house	nipa	nipa	roof	heavy weights on roof
17	Calatagan	house	timber	steel	racking/total	reconstruction from salv matls
18	Calatagan	house	sawali	nipa	roof damage	nipa nailed
19	Calatagan	house	timber	nipa	roof damage	nipa nailed/ lattice over
20	Calatagan	house	nipa	nipa	roof damage	nipa nailed
21	Calumbuyan	school	timber / ply	steel	total collapse	panel failure timber det
22	Calumbuyan	house	CHB	nipa	little	nipa/bamboo nailed verandah
23	Calatagan	house	timber/ nipa	nipa	little	nipa tied with nylon line
24	Calatagan	house	CHB	nipa	none	fishing net over roof

Street	Location	Type	Walls	Roof	Damage	Features
25	Balayan	sign			none	
26	Nasugbu	house	nipa	nipa	racking/total	no bracing
27	Tagaytay	house	CHB	steel	roof damage	truss anchorage — previous damage
28	Tagaytay	house	plywood	steel	wall panel	panels sucked out
29	Tagaytay	house	brick	steel	roof loss	truss anchorage
30	Tagaytay	house	plywood	steel	some roof loss	makeshift repairs, weights on roof
31	Victoria Village	house	timber	nipa	wall and roof	nipa nailed
32	Victoria Village	house	timber	steel	little	new timber walling
33	Victoria Village	house	timber	nipa	wall/roof	nipa nailed
34	Victoria Village	school	timber	nipa	roof/total	roof fixed with rattan
35	Victoria Village	school	timber	nipa	roof	repairs with rattan
36	Victoria Village	house	timber	nipa	total	reconstruction as before
37	Victoria Village	house	timber	nipa	lateral	o/battens on nipa, undermining
38	Victoria Village	chapel	CHB/ timber	steel	roof loss	top plate anchorage to CHB
39	Victoria Village	house	timber	nipa	nipa and split loss	splits nailed to battens
40	N of Wharf	house	plywood	nipa	new house	diagonal external brace
41	N of Wharf	house	plywood	nipa	roof	splits pulled over nails
42	N of Wharf	house	CHB	nipa	block fail	no r/f except corners
43	N of Wharf	house	timber	nipa	total loss	reconstruction
44	Legazpi City	school	CHB	steel	roof loss	batten fastener — timber det
45	Legazpi City	sign			bent	bent post
46	Legazpi City	sign			nil	doubtful aerodynamics
47	Legazpi City	house	CHB	nipa	some nipa dam	splits failed where nailed
48	Legazpi City	house	bamboo	nipa	lateral	no bracing

Street	Location	Type	Walls	Roof	Damage	Features
49	Legazpi City	house	sawali bamboo	anahaw	little	slight roof damage nylon twine
50	Legazpi City	house	CHB	steel	total roof	bent r/f
51	Legazpi City	indst	CHB	steel	partial roof	purlin to rafter
52	Legazpi City	house	bamboo	nipa	racking	no bracing
52*	Sorsogon	indst	CHB	steel	roof loss	truss anchorage — timber nailing
53	Sorsogon	school	plywood	steel	roof loss walls	wall panels out batten fastener
54	Sorsogon	school	CHB	steel	nil	J bolts roofing
55	Sorsogon	school	CHB	steel	nil	U bolts roofing
56	Buhatuan	school	timber	steel	roof lifted	Purlin to rafter connection
57	Buhatuan	school	CHB	steel	nil	
58	Casiguran	house	timber CHB	steel	nil	U straps at eaves — single strap
59	Juban	house	abaca	abaca	roof racking	thatch tied with abaca
60	Juban	house	abaca	abaca	little	thatch tied with plastic ties
61	Bulusan	shelter	nil	anahaw	racking	lack of bracing
62	Batang	house	nipa	anahaw	slight roof	topographic effects
63	Batang	house	sawali	anahaw	little	exposed side open
64	Bulan Rd	sign			little	
65	Matnog	school	CHB	steel	roof loss walls	purlin/rafter connection
66	Matnog	house	plywood	steel	total/panel	timber det
67	Matnog	house	sawali	nipa	racking/panel	
68	Matnog	comm	concr	tiles	tile loss	
69	Matnog	house	plywood	nipa	lateral	failure of piles timber det
70	near Sta. Magdalena	house	bamboo	nipa	lateral	no bracing
71	Bulan	house	timber	nipa	small roof	nipa thatch nailed
72	Bulan	comm	timber	steel	lateral	failure of pile — timber det
73	Bulan	house	plywood	nipa	lateral	no bracing
74	Bulan	house	plywood	nipa	lateral	no bracing

Street	Location	Type	Walls	Roof	Damage	Features
75	Bulan	house	timber	anahaw	lateral	diagonal external bamboo
76	Bulan	house	coco palm	anahaw	panel	lashings at joints held
77	10 km S Sorsogon	sign			nil	
78	Sorsogon	school	timber	nipa	roof damage	truss anchorage timber det
79	Sorsogon	school	CHB	nipa	roof damage	truss anchorage coco lumber det
80	Sorsogon	school	CHB	steel	roof & walls	bamboo r/f CHB
81	Bacon	house	bamboo	nipa	roof damage	lashed joints
82	Bacon	house	CHB	nipa	roof damage	nailed nipa
83	Bacon	shelter	nil	nipa	lateral	no bracing
84	Bacon	shelter	bamboo	nipa	roof damage	open structure – nailed nipa
85	Bacon	shelter	nil	anahaw	nil	open structure
86	Bacon	house	bamboo	anahaw	nil	secure nailing – bent over
87	Bacon	shelter	CHB	nipa	roof loss	old nipa
88	Bacon	house	bamboo	nipa	roof loss	nailed nipa racking
89	Bacon	school	CHB	steel	roof loss	corrosion
90	Sorsogon	gym	concr	steel	roof loss	fastener and purlin failure
91	Sorsogon	sign			damaged	
92	Sorsogon	sign			damaged	
93	Sorsogon	sign			damaged	
94	Capuy	house	timber	nipa	roof damaged	old nipa
95	Capuy	poles			leaning over	
96	Capuy	school	timber	steel	roof damage/ walls	connection wall/roof
97	Capuy	school	CHB	steel	racking/ roof	fatigue in roof straps
98	La Union	school	CHB	steel	racking	exposed location
99	Kumakad	house	sawali	anahaw	nil	sawali & crushed bamboo
100	Legazpi City	house	sawali	nipa	nil	tied nipa

STATISTICS

By materials

	Walls		Roof	
Houses	bamboo	6	nipa	39
	timber	23	steel	15
	plywood	8	abaca	2
	nipa (incl. abaca)	12	anahaw	7
	CHB	7		
	sawali	6		
	brick	1		
	TOTAL	63		63
Schools	timber	5	steel	18
	CHB	11		
	plywood	2		
	TOTAL	18		18
Others	signs	8		
	shelters	4		
	church	1		
	poles	1		
	commercial	5		
	TOTAL	19		

By materials and damage

All buildings and roof performance

roofing	damaged	not damaged	total	% damaged
steel	26	13	39	67
nipa	25	17	42	60
anahaw	1	8	9	11
abaca	1	1	2	50
tiles	1	0	1	100