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Studies of the Third Miyakojima Typhoon

-Its Characteristics and the Damage to Structures-

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Abstract

An expedition was made to Okinawa for the study of the Third Miyakojima Typhoon, which brought about serious damage there in September 1968. The meteorological characteristics and the damage to buildings were examined in comparison with those of the Second Miyakojima Typhoon, which struck the same region in 1966. The results are described in this paper following the checking rules which were advised to UNESCO by the AD HOC Working Group on Missions to Areas Damaged by Severe Wind Storms.

1. Introduction

From 23rd to 24th September 1968, severe wind storms caused by the Third Miyakojima Typhoon (6816, Della) devastated many communities in Okinawa. The damage was severe and widespread over buildings, services, crops, trees, ships and telephone lines.

The Miyakojima Islands suffered, more than any other islands, from the destructive force of the wind, where a maximum wind speed of 54.3 m/sec and a maximum peak gust of 79.8m/sec were observed and as many as 807 houses were completely destroyed. These wind records and the number of destroyed houses are the largest ones in Miyakojima Isl. second to those caused by the Second Miyakojima Typhoon (6618, Cora) which passed over the region just two years before.

It is quite unusual for two intense typhoons to pass over the same region within a few years even in this area of the West Pacific and so it is quite interesting to study and compare the meteorological situations and damage. Fortunately the present authors had already made a survey of the Second Miyakojima Typhoon in 1966 with regard to the meteorologcal characteristics and the damage to buildings, and some interesting informations about the structure of the typhoon and the distribution of damaged houses were obtained. Thus, the present authors joined into a party again for the expedition to the Okinawa area to study the typhoon and typhoon damage.

The expedition was made to the four islands of Okinawa, i.e. Miyakojima Isl., Kumejima Isl., Ishigakijima Isl. and Okinawajima Isl., from 1st to 10th October 1968.

In December 1968, after the expedition, the AD HOC Working Group on Missions to Areas Damaged by Severe Wind Storms advised UNESCO as to the desirability and feasibility of sending missions to areas damaged by severe wind storms. The Working Group suggested to UNESCO, in its "Report and Recommendation", a check-list of information to be obtained and points to be studied by missions.

Hereafter this check-list will be a guide for the study of storm damage, and the adoption of the same rule in damage surveys will be helpful for future studies of wind resistant structures. Therefore the present authors have tried in this paper to follow the checking rule as faithfully as possible.

2. The Third Miyakojima Typhoon

Life history

The track and the change of central pressure of the Third Miyakojima Typhoon (Typhoon 6816, Della) are shown in Fig. 1.

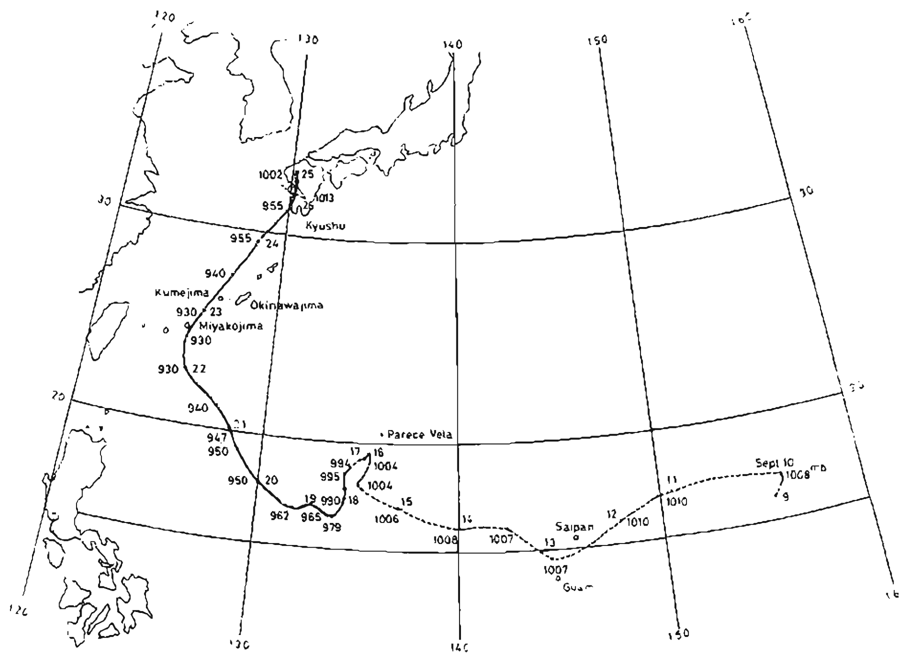


Fig. 1 The track of the Third Miyakojima Typhoon.

This typhoon was first detected on Sept. 9, 1968 to the east of Saipan Isl. with an intensity of tropical depression. Moving slowly northwestwards, it developed into typhoon intensity (central pressure of about 988 mb) at a distance of about 1200km to the southeast of Miyakojima Isl. on Sept. 18, and it hit Miyakojima Isl. with its maximum intensity (central pressure of about 930 mb) in the middle of the night of 22nd, and Kumejima Isl. in the afternoon of 23rd. After that, turning its track to the north and filling the central pressure, the typhoon landed on the south coast of Kyushu Isl. in the middle of the night of 24th, and this typhoon was filled up over the north-western part of Kyushu on 25th.

The detailed movement of the typhoon near Miyakojima Isl. and Kumejima Isl. is shown in Fig. 2, which is drawn by the use of the results obtained from direct positioning by aircraft reconnaissance, radar observations and the analysis of surface observations. The method of analysis is the same as the one used in the case of the Second Miyakojima Typhoon by the present authors[1]. As shown

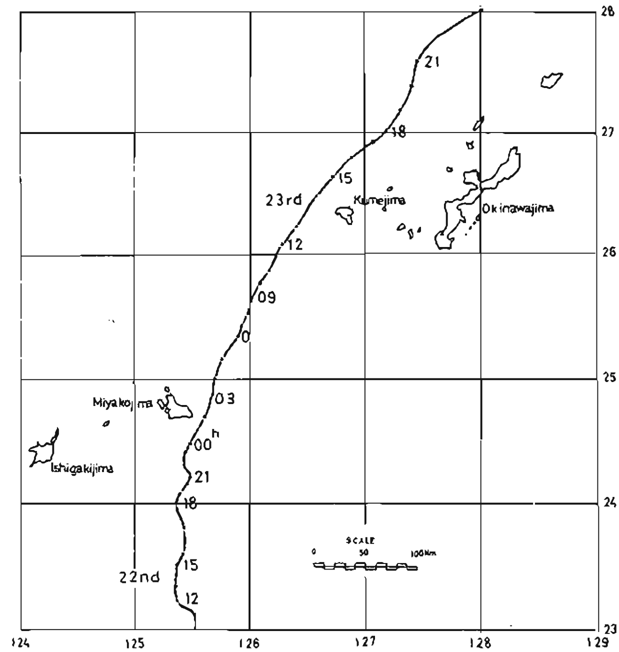


Fig. 2 The detailed track of the Third Miyakojima Typhoon near the Ryukyu Islands.

in this figure, a part of Miyakojima Isl. was within the typhoon eye around 0200JST. Kumejima Isl. was also in the typhoon eye for one or two hours in the afternoon of 23rd.

Characteristics

This typhoon recorded a maximum wind speed of 54.3m/sec and a maximum peak gust of 79.8m/sec at the Miyako Weather Station. These are the second largest next to those recorded on the occasion of the Second Miyakojima Typhoon. The minimum pressure of 943 mb recorded at the Miyako Weather Station is the fourth minimum there. But the typhoon itself is not so severe, and it has an intensity equivalent to the typhoons which appear two or three times over the West Pacific every year. The extreme values observed at the Miyako and Kumejima Weather Stations are listed in Table 1. In this table, the records of the Second Miyakojima Typhoon are also shown for comparison.

Meteorological environment during the passage of the typhoon

Fig. 3 shows the time changes of hourly rainfall, wind speed and atmospheric pressure at the Miyako Weather Station on 22nd and 23rd. The barogram and the anemogram are reproduced in Appendix A. Wind speed exceeded 20m/sec at 1400JST of 22nd, when the typhoon was located at a distance of about 150km to

Table 1 Weather records of Typhoon 6816 (Della).

	Typhoon 6816				Typhoon 6618	
	Miyakojima		Kumejima		Miyakojima	
		Time JST		Time JST		Time JST
Min. sea-level pressure, mb	942.5	230138	947.9	231435	928.9	051001
Max. wind, m/sec	54.3 NE	230006	43.7 SE	231250	60.8 NE	050731
Max. peak gust, m/sec	79.8 NE	222354	62.4 SE	231310	85.3 NE	050631
Change of wind direction.	Backing		Veering		Veering	
Duration of wind above 10m/sec		220100-231700		230215-232243		0410-0616
Total precip., mm	289.1	221053-231603	146.0	230152-232125	291.6	040440-060730
Max. daily precip., mm	150.0	230000-232400	146.0	230000-232400	236.4	0424-0524
Max. hourly precip., mm	40.0	222249-222349	22.5	231530-231630	30.2	042000-042100
Max. 10-min. precip., mm	10.0	230340-230350	9.0	231601-231611	8.7	050820-0830

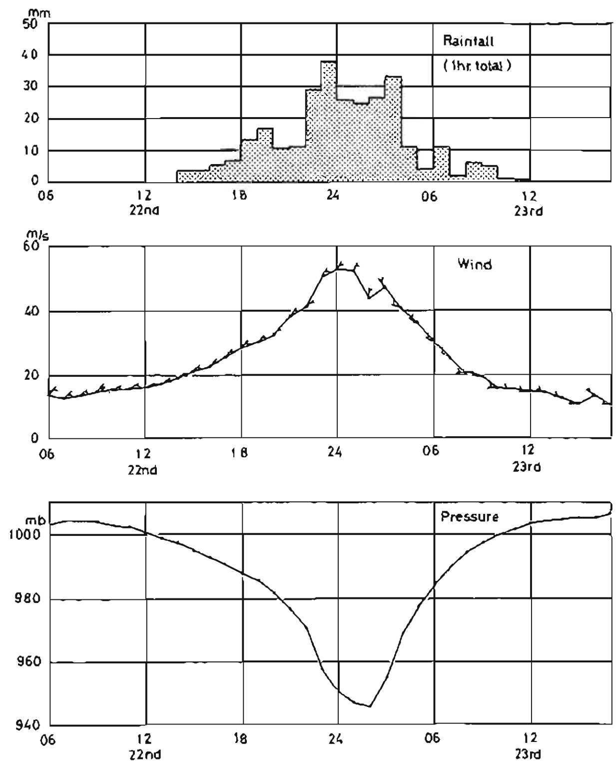


Fig. 3 Hourly changes of rainfall, wind and surface pressure at the Miyako Weather Station. during the passage of the typhoon.

the south of Miyakojima Isl. From 2000JST of that day, when the front part of the maximum wind zone passed the island, the rainfall became so severe that an intensity of 32mm/hr was recorded during the period from 2300 to 2400JST. The maximum wind speed of 54.3m/sec (NE) was observed at 0006JST of 23rd. The typhoon center was at its nearest position from the weather station during the period from 0100 to 0200JST, meanwhile the minimum atmospheric pressure of 942.5 mb was observed at 0138JST of 23rd. During this period wind and rainfall were relatively weak. The second peak of wind and rainfall were seen for 2 hours from 0200JST, when the rear part of the maximum wind zone passed over.

Radar observation shows that the eastern part of Miyakojima Isl. entered the typhoon eye (Photo. 3). This can well explain the meteorological situation obtained by field expedition within Miyakojima Isl. (Fig. 4). The detailed results of the field expedition are shown in Appendix B. As is clear from these data the western edge of the typhoon eye has passed the western part of the island, where no significance of eye phenomena was observed.

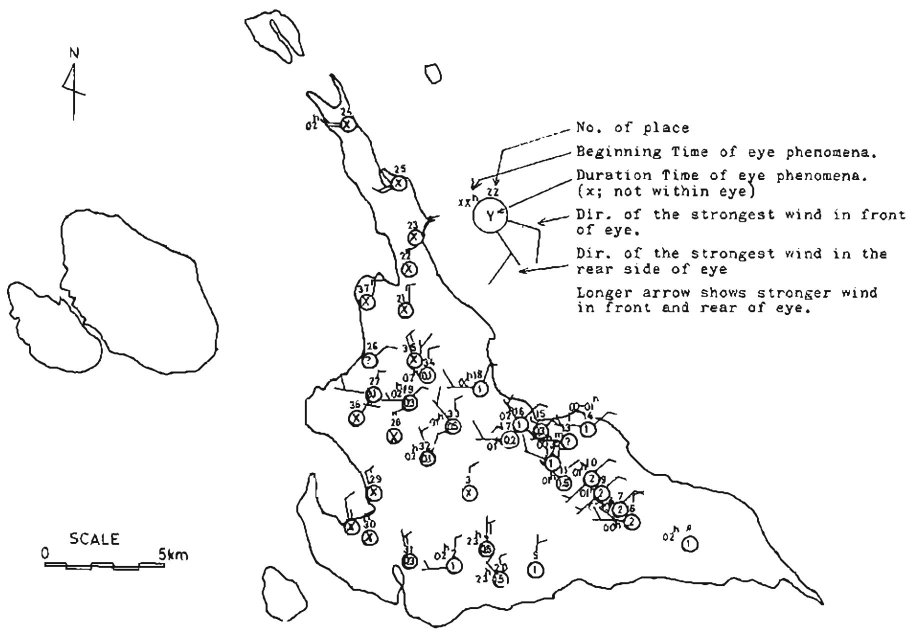


Fig. 4 The meteorological situation obtained by field expedition in Miyakojima Isl.

Fig. 5 shows the time change of three-hourly rainfalls, wind speed and atmospheric pressure at the Kumejima Weather Station on 23rd. Here, a maximum wind speed of 43.7m/sec (SE) and a maximum peak gust of 62.4m/sec (SE) were observed about 1300JST of 23rd. The typhoon was nearest to the Kumejima Weather Station when it was about 40km to the northwest at 1400 to 1500 JST, and a minimum atmospheric pressure of 947.9 mb was observed at 1435JST of 23rd. Around this time the whole island was within the eye of the typhoon and eye phenomena were seen all over the island, as seen in the results of the field expedition shown in Fig. 6 and Appendix B. The central pressure of the typhoon was not so filled

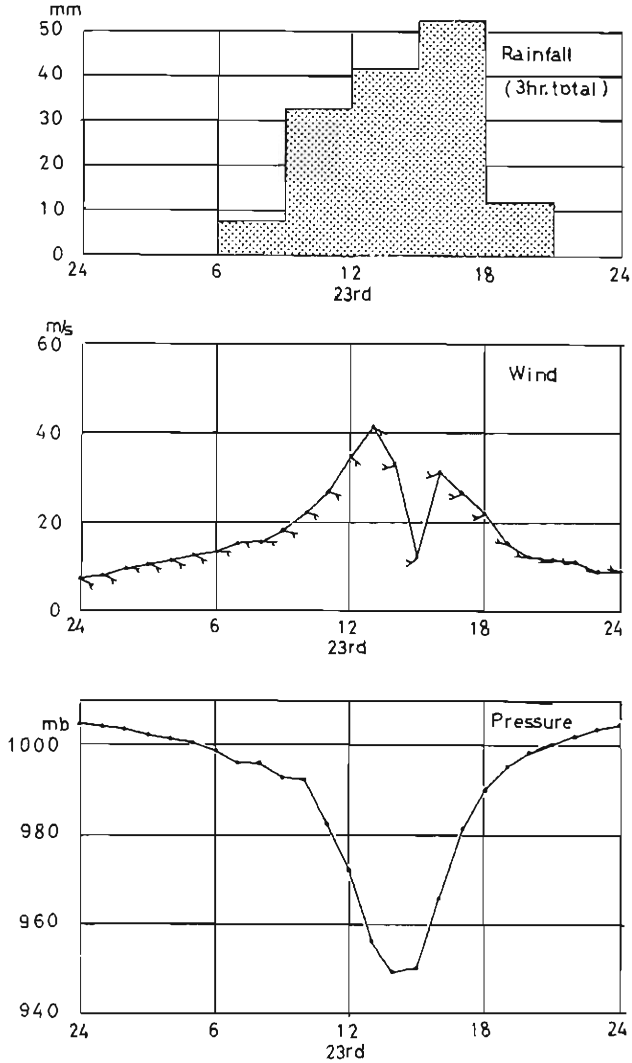


Fig. 5 Hourly changes of rainfall, wind and surface pressure at the Kumejima Weather Station.

as at the time of passage near Miyakojima Isl., but the wind over Kumejima Isl. was not so strong as over Miyakojima Isl. This might be caused by the difference in the ground topography of the two islands, i.e. the former is mountainous and the latter is flat all over the island. However, there exists another possible explanation of this maximum wind speed difference, which is that the difference was caused by the variation in the diameter of the eye, i.e. the diameter became larger near Kumejima Isl. as shown in the next paragraph. If the total circulation is conserved in the eye, the maximum wind speed at the edge of the eye is inversely proportional to the diameter.

The hourly data from the meteorological stations in Okinawa during the passage of the typhoon are shown in Appendix C.

Typhoon eye

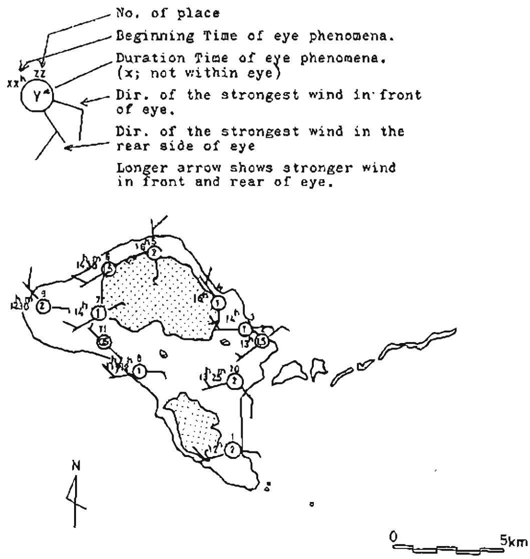


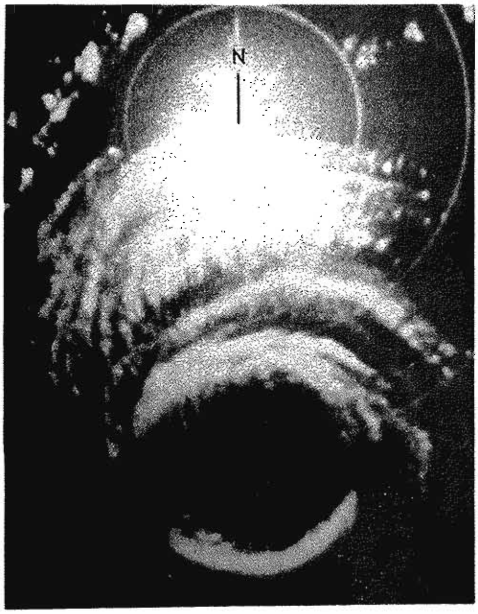
Fig. 6 The meteorological situation obtained by field expedition in Miyakojima Isl.

The eye of the Third Miyakojima Typhoon had a size of about 60 to 100km in diameter, which was clearly detected on the radar-scopes of the Miyako Weather Station and the Ryukyu Meteorological Agency at Naha. At 0700JST, Sept. 22nd, the radar of the Miyako Weather Station first caught the typhoon eye, when its diameter was about 90km. After that, the diameter decreased to about 60 km as the typhoon approached Miyakojima Isl. It became 105km, when the radar of the Ryukyu Meteorological Agency at Naha first caught the eye at 0500JST of 23rd between Miyakojima Isl. and Kumejima Isl., and the size did not change so much during the passage near Kumejima Isl. The cause of change of eye size is not clear.

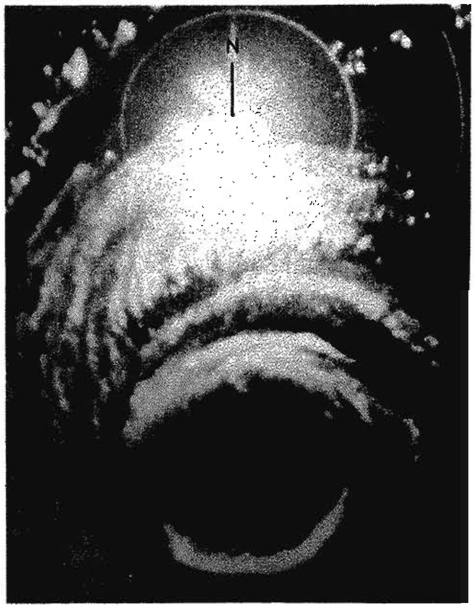
The size of the eye on the radarscope on Miyakojima is about 60km and the western edge of the radar eye has passed the western part of the island and its borderline almost coincides with the western end of the region where no eye phonemenon was reported, as shown in Fig. 4. As the radar eye edge is known to be almost the same as the maximum wind zone and/or the eye edge by aircraft reconnaissance in the case of the Second Miyakojima Typhoon[1]) the radar-eye, maximum wind zone, eye observed on the surface and the eye seen from the air are almost identical in size.

Photo. 1 shows the features of the typhoon eye at 1400JST of 22nd, when the center of typhoon was at a distance of 150km to the south of Miyakijima Isl. It can be seen that some line echoes extend from the eye wall inwards. These line echoes have a certain angle to the eye wall, and move in an anticlockwise direction. These line structures of the eye wall can well be seen in the next photograph (Photo. 2). The southwestern part of the eye consists of lump echoes on lines whose ends extend inside from the eye wall into the eye as shown in Photo 1.

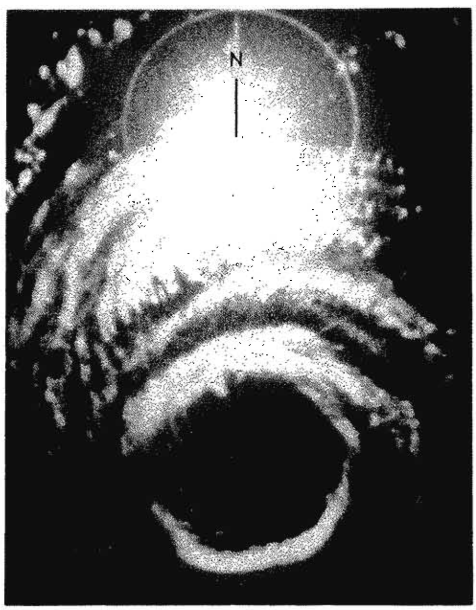
Photo. 3 is the radar picture at 0100JST on 23rd, when the typhoon was at its nearest point to Miyakojima Isl. The existence of distinct cloud echoes within the eye is supported by the fact that rainfall was reported within the eye as shown in Appendix A and B. A remarkable radar echo like swirl can be found within the eye. These characteristics of the typhoon eye will be discussed in



(a)



(b)



(c)

Photo. 1 The feature of typhoon eye seen on the radar scope of the Miyako Weather Station around 1400JST of 22nd. Every 2-minute change from (a) to (c).

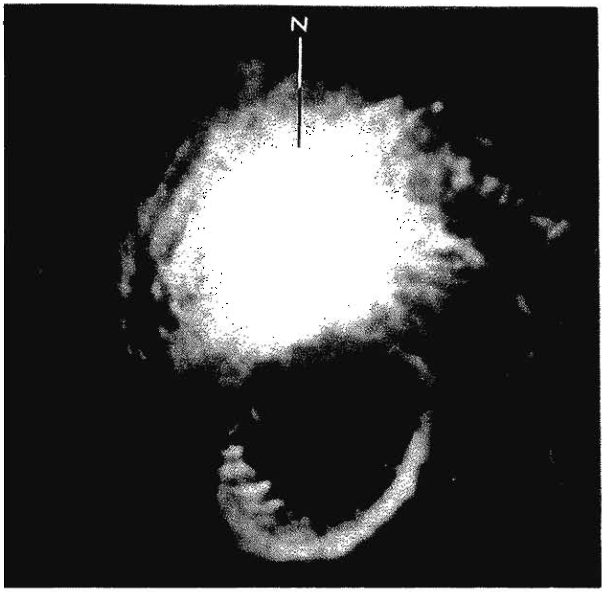


Photo. 2 The feature of typhoon eye around 2200JST of 22nd.

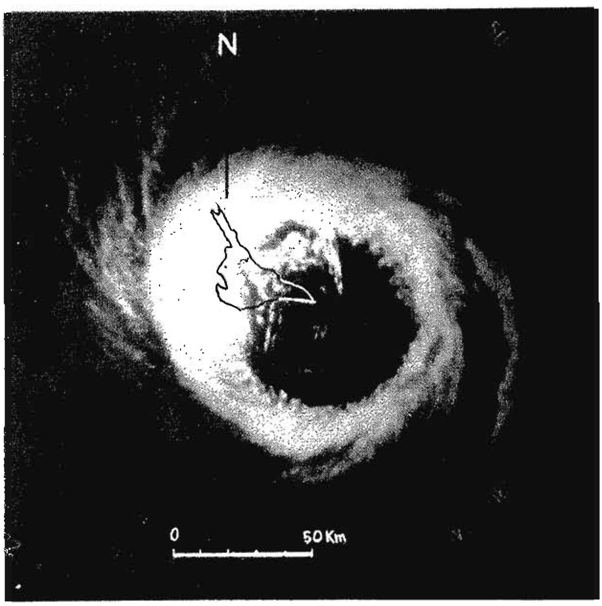


Photo. 3 The feature of typhoon eye around 0100JST of 23rd.

another paper.

Climatological properties in Okinawa

Okinawa is located at the southwestern end of Japan and is one of the areas which typhoons of mature stage frequently hit. The number of strong wind days at the Miyako Weather Station is shown in Table 2. It is only in the typhoon season from July to October when strong winds higher than 30m/sec are observed.

Table 2 The number of strong wind days in Miyakojima Isl.

	month / m/sec	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of strong wind days	10.0-14.9	16.0	14.6	13.7	12.1	9.0	10.6	6.6	7.4	7.8	17.1	16.5	16.4	147.9
	15.0-28.9	2.2	2.2	1.0	1.3	0.3	0.7	1.7	3.6	1.0	2.5	4.0	3.3	23.8
	above 29.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.4	0.2	0.1	0.0	1.1
Number of typhoon within 300km from Miyakojima Isl. on average	1938-1964	—	—	—	0.1	0.1	0.5	1.2	1.1	0.9	0.5	0.3	0.1	4.8

The number of typhoons, which came within a range of 300km from Miyakojima Isl., amounted to 132 in the period from 1938 to 1964, which means 4.8 typhoons per year on the average. The occurrence probability of annual maximum wind speed at Miyakojima Isl. is estimated from the wind records during the past 30 years. The result is shown in Fig 7.

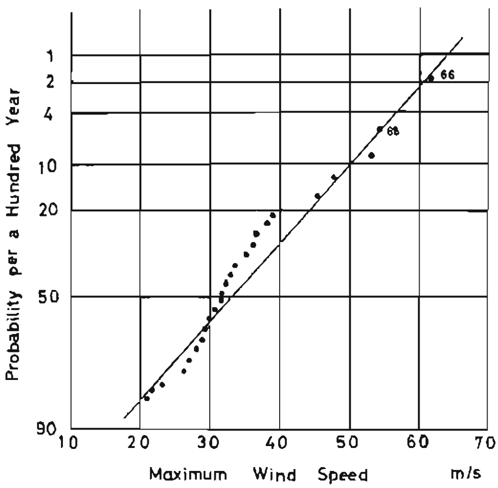


Fig. 7 Occurrence probability of annual maximum wind speed at Miyakojima Isl.

The climatological data from weather stations in Okinawa is shown in Table 3 and their extreme values are shown in Table 4.

Meteorological instruments

The meteorological instruments used in Okinawa are the same as the ones in Japan. The peak gust is observed by a propeller type anemometer (Koshinvane supplied by Koshin Electric Engineering Co.). The wind speed is averaged over 10 min. before the time of measurement and is measured by a three-cup anemometer with cups 10cm in diameter.

3. General Information

Topography and terrain features of the damaged area

In the wind resistant structure design the topography and terrain features are

Table 3. Climatological data of weather stations in Okinawa.

	Naha	Miyakojima	Ishigakijima
Position Lat. N	26°14′	24°47′	24°20′
Long. E	127°41′	125°17′	124°10′
Elevation Height, m	36	39	6
Annual Mean Temp., °C	22.1	23.2	23.6
Annual Mean Max. Temp., °C	25.0	26.0	26.7
Annual Mean Min. Temp., °C	19.8	20.9	21.1
Annual Mean R. H., %	80	79	80
Annual Mean Wind Speed, m/s	5.8	6.4	4.9
Annual Most Frequent Wind Dir.	NE	NNE	NNE
Annual Total Precip., mm	2178.4	2338.2	2195.5
Mean Cloud Amount	7.1	7.4	7.2

Table 4. Extreme values of meteorological elements.

	Elements	Period	Ranking				
			1	2	3	4	5
Naha	Min. sea-level pressure, mb	(1931-1960)	936.6	940.3	949.0	955.4	956.3
	Max. wind, m/sec	(1891-1961)	ENE 49.5	SW 47.0	NNE 46.4	N 45.2	WNW 44.8
	Max. peak gust, m/sec	(1928-1961)	S 73.6	NNE 68.3	NNE 64.5	S 61.4	N 58.2
	Max. daily precip., mm	(1890-1961)	468.9	427.0	351.8	342.7	287.3
	Max. hourly precip., mm	(1900-1961)	92.6	86.3	79.4	76.1	74.8
	Max. 10-min. precip., mm	(1941-1961)	23.3	23.3	22.4	21.9	20.2
Miyakojima	Min. sea-level pressure, mb	(1938-1968)	908.4	928.9	934.4	942.5	952.1
	Max. wind, m/sec	(1938-1968)	NE 60.8	NE 54.3	SW 53.0	W 47.5	NNE 45.2
	Max. peak gust, m/sec	(1938-1968)	NNE 85.3	N 79.8	SSE 70.0	W 64.8	ESE 60.3
	Max. daily precip., mm	(1938-1961)	401.9	340.4	331.7	250.6	235.2
	Max. hourly precip., mm	(1938-1961)	106.0	100.2	91.2	83.8	83.5
	Max. 10-min. precip., mm	(1938-1961)	31.2	26.4	26.0	25.9	23.2
Ishigakijima	Min. sea-level pressure, mb	(1898-1967)	923.8	926.6	937.3	942.0	946.9
	Max. wind, m/sec	(1900-1966)	S 50.3	SSW 48.6	S 47.6	SE 46.5	E 45.4
	Max. peak gust, m/sec	(1941-1966)	ESE 57.2	S 50.0	N 47.2	SSE 46.5	WNW 44.9

(continued to Page 56)

Table 4. (Continued)

	Elements	Period	Ranking 1	2	3	4	5
Ishigaki-jima	Max. daily precip., mm	(1898-1966)	378.9	349.5	291.6	270.4	269.1
	Max. hourly precip., mm	(1898-1966)	111.8	96.3	95.4	92.5	91.8
	Max. 10-min. precip., mm	(1898-1966)	38.2	32.3	31.0	29.0	28.0

taken into account as factors which affect the vertical wind speed profile, and as the modifying factor of the wind speed distribution. The latter effect is important but has not yet been studied in detail, though the damage distribution caused by this effect has been described in many reports of wind damage surveys.

In this context the topographical maps of Miyakojima Isl. and Kumejima Isl. are shown in Fig. 8. These two islands show quite different features of topography ; Miyakojima Isl. is a flat coral island and the highest point is only 108m above sea level, while on the other hand in Kumejima Isl. mountains about 300m high occupy the largest part of the island. Houses or buildings are scattered all over the island in Miyakojima Isl., but in Kumejima Isl. they are confined to flat narrow areas near the coast.

Statistics of damage

Table 5 shows the statistics of the damage to personnel, houses and public buildings in Okinawa with reference to areas, population and the number of households.

Personnel damages were quite few compared to the severity of damage to materials, which shows successful refuge activities. The total number of houses damaged was 4,518, summing up the 1,055 completely destroyed and the 3,463 badly damaged. This damage was entirely due to wind, not to the effect of rain or flood. The areas which suffered severe damage were as a matter of course near the path of the typhoon. They were Miyakojima Isl., Kumejima Isl., Tonakijima Isl., Agunijima Isl., Iejima Isl. and the middle and northern areas of Okinawajima Isl.

The cost of the damage caused by the Third Miyakojima Typhoon is shown in Table 6. The estimated cost of the damage is as much as $7,519,764, which is as large as about 6 % of the 1968 general budget of the Government of the Ryukyus.

In spite of the same extent of severeness of wind storms, the damage caused by the Third Miyakojima Typhoon was less serious than in the case of the Second Miyakojima Typhoon. This is clearly seen, for example, in the rates of completely destroyed houses of 17.6 and 5.8% in Miyakojima Isl. for the Second and Third Miyakojima Typhoon, respectively. The difference is considered to be because many of the houses that were destroyed in 1966 were reconstructed into reinforced concrete structures or repaired and made stronger.

Fig. 8 Topographical maps of Miyako-jima Isl. and Kumejima Isl.

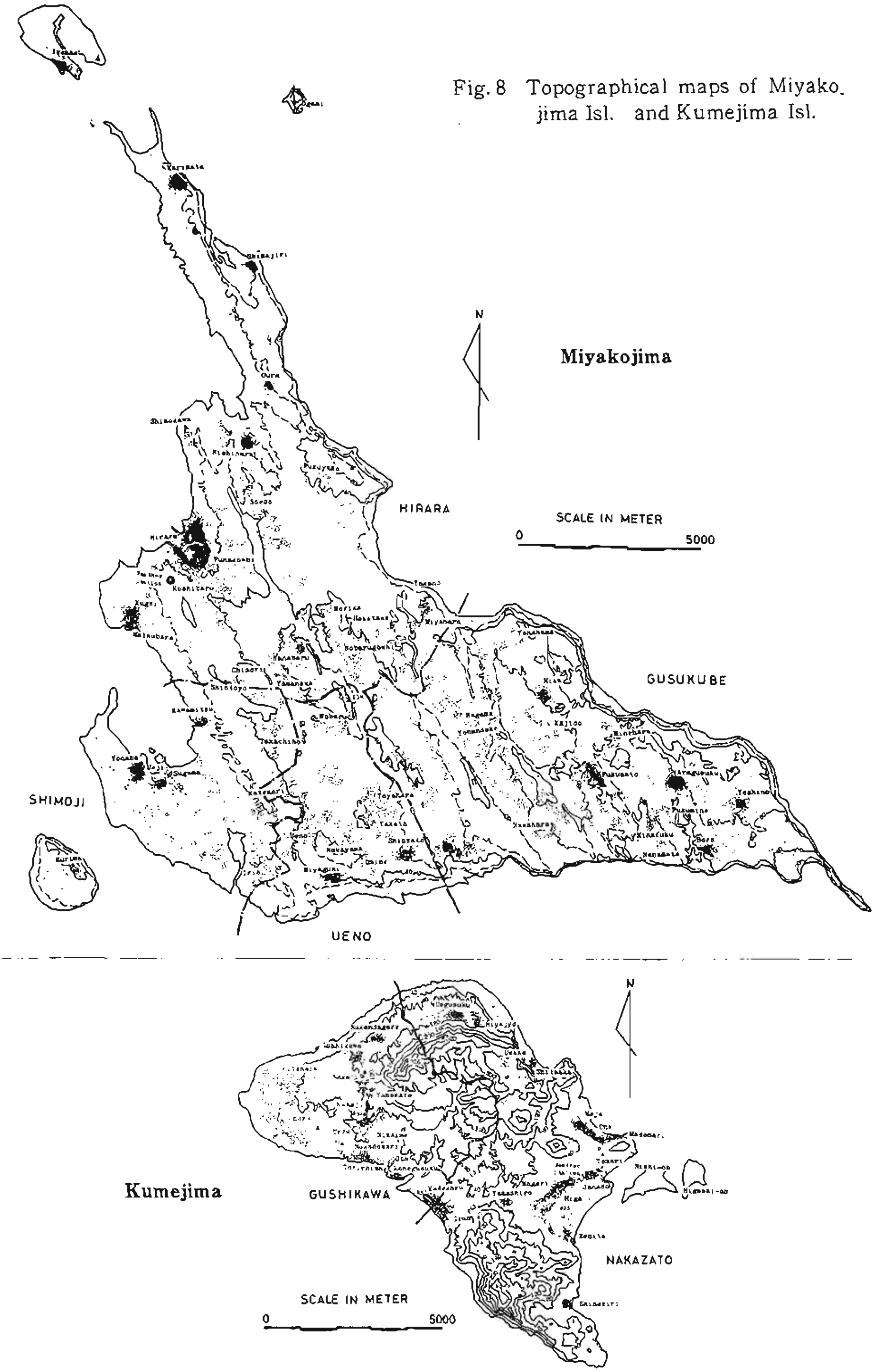


Table 5. Statistics of damage caused by the Third Miyakojima Typhoon (tabulated Police Office).

Region	Area+ km²	Population+	Number of households+	Number of personnel damage			
				Dead	Missed	Injured	
						serious	slight
							Okinawajima
Northern District							
1 Kunigami	196.03	9364	1806				
2 Ogimi	63.91	5966	1348				
3 Higashi	67.35	2879	575				
4 Haneji	62.94	8173	1834				
5 Yagaji	5.86	3590	519				
6 Nakijin	41.50	13869	2661				
7 Kamimotobu	11.16	4936	994				
8 Motobu	44.81	16421	3144				
9 Yabu	20.37	4497	878				
10 Nago	46.49	20521	4336	1			
11 Onna	52.05	8459	1550				
12 Kushi	92.48	6179	1213				
13 Ginoza	29.88	4040	811				
14 Kin	39.53	9209	2147				
15 Ie	23.98	7259	1425				
16 Iheya	33.23	3268	570				
17 Izena	11.44	3912	809				1
Total	842.98	132542	26620	1			1
Central District							
18 Ishikawa	19.14	16681	3395				
19 Misato	23.85	23727	4581				
20 Yonagusuku	24.83	16728	2915				
21 Katsuren	13.63	13325	2206	1		1	
22 Gushikawa	32.82	38662	7304				
23 Koza	24.29	62536	15708				
24 Yomitan	37.09	22089	3906				
25 Kadena	15.95	15069	3052				1
26 Chatan	13.15	10235	2011				
27 Kitanakagusuku	11.92	8780	1737				
28 Nakagusuku	16.00	10495	1902				
29 Ginowan	18.48	37433	8526				
30 Nishihara	18.52	9810	1845				
31 Urasoe	18.12	33782	7642				
Total	287.79	319352	66730	1		1	1

from the damage statistics under date of September 26 published by the Ryukyu

Damage to houses							Number of offcial building damage	
Completely destroyed		Badly damaged	Ratio %		Flooding			
houses	resident		Rc*	Rd*	over floor	under floor	completely destroyed	badly damaged
Islands								
1	1		0.1	0.1				
		1		0.1		8		
		1		0.2		13		
		1				141		
		4		0.4				
		3		0.1	2			
1	3	5		0.1	53			
		1		0.1				
*	*							
		5		0.4				
5	30	19	0.9	4.2				
4	8	9	0.5	1.6				1
11	42	49		0.2	55	162		1
		2						
1	1							
					7	7		
1	1	2			7	7		

(continued to Page 60 and 61)

Table 5. (Continued)

Region	Area† km²	Population†	Number of households†	Number of personnel damage: Dead	Missed	Injured: serious	Injured: slight
Southern District							
32 Naha	35.68	275987	65299				
33 Tomigusuku	18.15	11522	2052				
34 Itoman	45.34	35809	7092				
35 Kochinda	15.02	9896	1788				
36 Gushichan	12.57	7020	1253				
37 Tamagusuku	16.67	9964	1828				
38 Chinen	10.41	6172	1065				
39 Sashiki	10.90	8487	1606				
40 Yonabaru	4.89	9285	1851				
41 Osato	12.12	7027	1337				
42 Haebara	11.17	9992	1880				
43 Nakazato	42.83	△ 8781	△ 1490				
44 Gushikawa	27.82	△ 6800	△ 1162				3
45 Tokashiki	26.44	1038	252				
46 Zamami	19.57	1408	329				
47 Aguni	9.79	2010	528				
48 Tonaki	5.81	1168	273				
49 Minami-Daito	25.91	3077	675				
50 Kita-Daito	20.05	955	167				
Total	371.14	416398	91927				3
							Sakijima
Miyakojima							
51 Hirara	72.29	32666	△ 6838	3			
52 Gusukube	60.92	△ 14232	△ 2591				3
53 Shimoji	25.65	5222	△ 943				3
54 Ueno	23.03	△ 4738	△ 850				
55 Irabu	38.53	12251	2085				
56 Tarama	29.60	2603	553				
Total	250.02	71712	13860	3			6
Yaeyama							
57 Ishigaki	235.36	42490	8679				1
58 Taketomi	372.42	6342	1400				
59 Yonaguni	29.78	3627	715				
Total	637.56	52459	10794				1
All Ryukyus	2388.22	992463	209931	5		1	12

† Area, population and number of households are quoted from "Okinawa Nenkan,
R_c=rate of completely destroyed houses R_d=rate of damaged houses
△ These are numbers announced by the individual administrative community
* unknown.

Damage to houses							Number of offcial building damage	
Completely destroyed		Badly damaged	Ratio %		Flooding		completely destroyed	badly damaged
houses	resident		Rct	Rdt	over floor	under floor		
△ 105	△ 512	△ 149	7.0	17.0				
△ 51	△ 200	△ 165	4.4	18.6			3	
2	6		0.6	0.6				
71	230	55	13.4	23.9				2
7	28	8	2.6	5.5				1
							3	3
236	976	377	0.3	0.7			6	6
Islands								
△ 272	*	△ 1782	4.0	30.0	17	24	6	5
△ 200	*	△ 695	7.7	34.5	1	6	1	
△ 210	△ 716	△ 266	22.3	50.5	△ 7	△ 5		4
△ 100	*	△ 246	11.8	40.7		1	2	1
25	*	46	1.2	3.4				1
807	716	3035	5.8	27.7	25	36	9	11
1055	1735	3463	0.5	2.2	87	205	15	18

1968 Edition" published by the Okinawa Times.

offices.

Table 6 Estimated cost of damage caused by the Third Miyakojima Typhoon (quoted from the publication of the Government of the Ryukyus)

Item	Okinawa		Miyakojima		Kumejima		Total	
	Quant.	Est. Cost	Quant.	Est. Cost	Quant.	Est. Cost	Quant.	Est. Cost
		$		$		$		$
Houses	298	103180	2888	848080	472	157740	3658	1109000
completely destroyed	140	70000	596	298000	171	85500	907	453500
badly damaged	158	33180	2292	550080	301	72240	2751	655500
Crops	76407 t	2019954	67397 t	913694	27950 t	521069	171754 t	3454717
Live-stocks		200		41779		1750		43729
Stalls	15	1445	4151	1573509	692	295500	4858	1870454
Trees	370m³	4251	6840m³	92688	5590m³	9434	12800m³	106373
Fishing facilities		176781		164212		3700		344693
Vehicles			20	1472			20	1472
Ships		5000		14400		1600		21000
Roads		3740		84780		6900		95420
Agricultural facilities						162		162
Wharfs		32340		10200		2100		44640
Ports		24000		5300				29300
Airports						4578		4578
Power lines		5150		39047		8964		53161
Communication lines		52875		7900		350		61125
Official buildings				50525		500		51025
Schools		12908		178276		21884		213068
Factories				15847				15847
Total		2441824		4041709		1036231		7519764

The words concerning damage, such as "completely destroyed" or "badly damaged", will be used in this paper following the definitions below :—

Definition of terms

Completely destroyed : damaged to the extent that the expense of repairs is more than 70 % of the total construction cost.

Badly damaged : damaged to the extent that the expense of repairs is more than 30 % of the total construction cost.

Rate of completely destroyed houses : ratio of the number of completely destroyed houses to the total number of households.

Rate of badly damaged houses : ratio of the number of badly damaged houses to the total number of households.

Rate of damaged houses : sum of the two rates defined above.

Distribution of the damage

Fig. 9 illustrates the distribution of completely destroyed houses in Miyakojima Isl. It will be seen from this figure that the distrbution pattern is complicated. The characteristic features of damage in this island can be summarized as follows in comparison with the case of the Second Miyakojima Typhoon.

Shimoji-cho : This is the region of the severest damage in Miyakojima Isl. The direction of the severest wind in this region was NNW. This wind comes

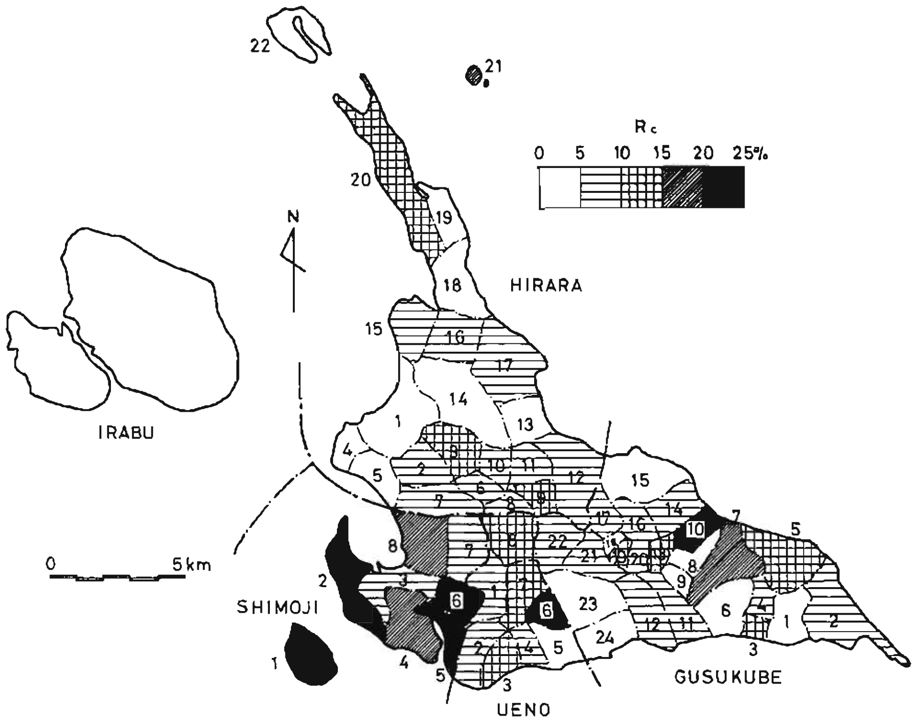


Fig. 9 The distribution of completely destroyed houses in Miyakojima Isl.

from the sea and the flat feature of this county weakens the intensity of the wind very slightly because of small ground roughness.

In the case of the Second Miyakojima Typhoon, damage in this county was not so severe as in others. This is because the severe wind came from the east and the east wind has a long overground fetch.

Ueno-mura : This region suffered severe damage by both the Second and Third Miyakojima Typhoons. The severest winds caused by these two typhoons were from E or S and NNW, respectively. But this county is generally flat and located at the highest spot of Miyakojima Isl., which causes severe wind in all directions.

Gusukube-cho : This is a rugged county having many ups and downs of 20 m or so. These ups and downs appear to affect the wind speed distribution delicately and correspondingly the damage done by the Second and Third Miyakojima Typhoon.

Hirara city : Various types of topography are contained in this region, and the extent of damage seems to be affected correspondingly by these different types. The southern part of this region near Ueno-mura is a part of the highest area of Miyakojima Isl. and the damage is as severe as in Ueno-mura. In the north peninsula the damage is also severe, which is considered to be caused from its good seaward exposure and the modifying effect of the topography as shown in the next section. The city area of Hirara is closely settled but the damage was very minor compared to that in other regions, for which the detailed descriptions will be given in the next section.

Fig. 10 is a similar damage distribution map of Kumejima Isl., in which the

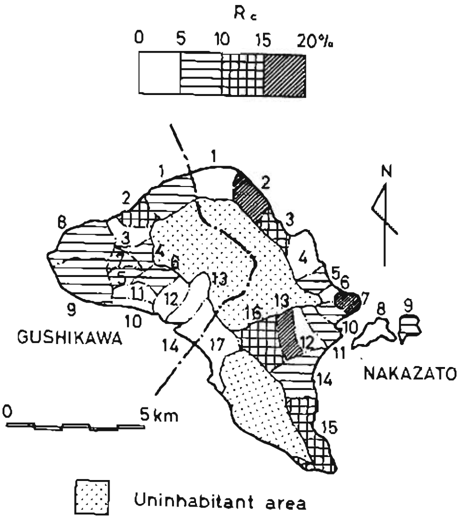


Fig. 10 The distribution of completely destroyed houses in Kumejima Isl.

distribution of damage is more complicated than in Miyakojima Isl. This is considered to be mainly due to its mountainous topography. This consideration is partly supported by the fact that, as shown in Fig. 6, the directions of the severest wind judged by the residents differ variously in individual counties in the island.

Most seriously damaged counties are located in the following regions: (i) the region near the coast which projects into the sea, (ii) the region in a mountain gap.

Hiyajo (county No. 2), Ueaka (3), Madomari (7) and Shimajiri (15) in Gushikawa are counties in the former region, where the rates of completely destroyed houses were more than 10%, which was larger than in nearby counties. The severest wind in these counties came from the direction parallel to the coast and it is considered that the mountains near the coast increased the wind speed over the region. The counties in the western area of Nakazato also appear to suffer the damage in a similar situation.

Magari (13) and Yamashiro (16) are located in or near the mountain gap between the northern and the southern mountains. These counties were seriously damaged by the force of the wind which blew through this mountain gap from east to west.

4. Detailed Distribution of Damage and Its Relation to Environmental Conditions

The environmental conditions, such as topography, seem to cause a large difference in the extent of wind damage. Two examples of the effects of environmental conditions are shown in the following. One is related to an effect of topography and the other to an effect of artificial environment.

Damage distribution in the city

Hirara City of Miyakojima is the most highly populated city that suffered the disturbance of the typhoons. The wind damage ratio in highly populated cities has been reported to be clearly smaller than that in rural districts. This was also true in Hirara City in the case of the Third Miyakojima Typhoon which brought about damage to houses of 2.3% complete destruction, which is also smaller than in other parts of Miyakojima Isl. This is also much less than the rate in the case of the Second Miyakojima Typhoon. The main reason of this decrement might be the effect of wind resistant work completed after the Second Miyakojima Typhoon.

This phenomenon of less serious damage in the city is said to be due to the decrease of wind speed over the built-up area caused by larger surface roughness and also due to the wind-shelter effect of buildings or structures near each other. The first point is proved to be reasonable after examining the damage distribution in detail as follows :—

Fig. 11 shows the distribution of completely damaged houses in Hirara City. The directions of the severest wind observed at the Miyako Weather Station, which is in the suburbs of Hirara City, were E and NE for the Second and Third Miyakojima Typhoon, respectively. Examining the relations between the wind direction and damage distribution, it will be found that the damage is less

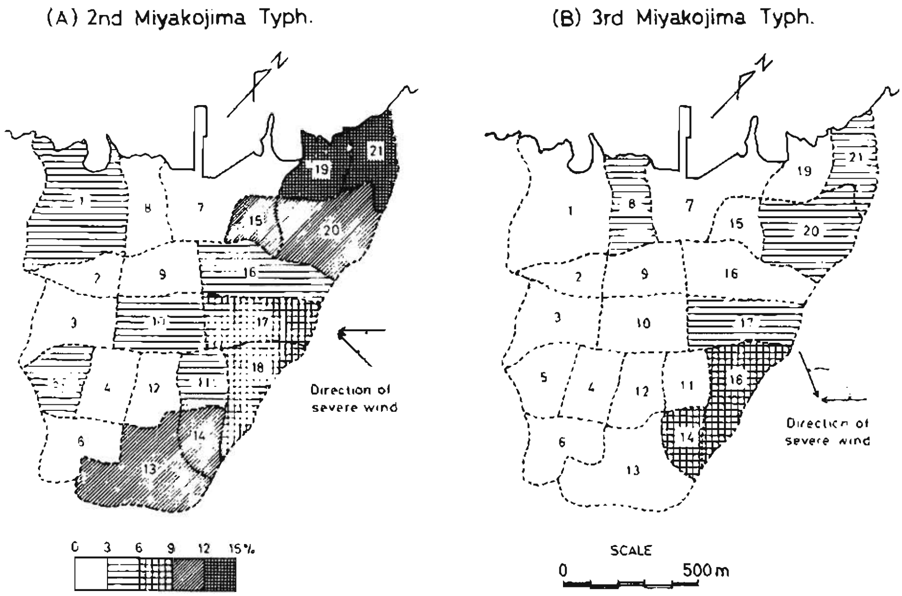


Fig. 11 Distribution of completely destroyed houses in Hirara City. Severe wind directions in the figure correspond to winds more than 40m/s.

severe in the central and leeward parts of the city and more serious in the windward parts of the city area. This is because the extent of wind speed decrement is smaller over the windward outskirts than the leeward.

This example of Hirara City is considered to be a typical damage pattern in highly populated cities, and shows that the damage in large cities can be decreased down to the extent of that in the central part of Hirara City by changing the environmental conditions in the outskirts. Appropriate arrangements of trees appeared to be satisfactory for this purpose in Maja or Janado, Kumejima, where the damage rate (5% or so) was smaller than in nearby areas. But it will take a long time until the trees grow into effective wind-shelter belts, so the half-way method must be adopted for the time being to make artificial wind shades or wind breaks.

Distribution of damaged houses in Karimata

Fig. 12 shows the topography of Karimata, which is located at the tip of the north peninsula of Miyakojima. An east-west section of this area is also shown

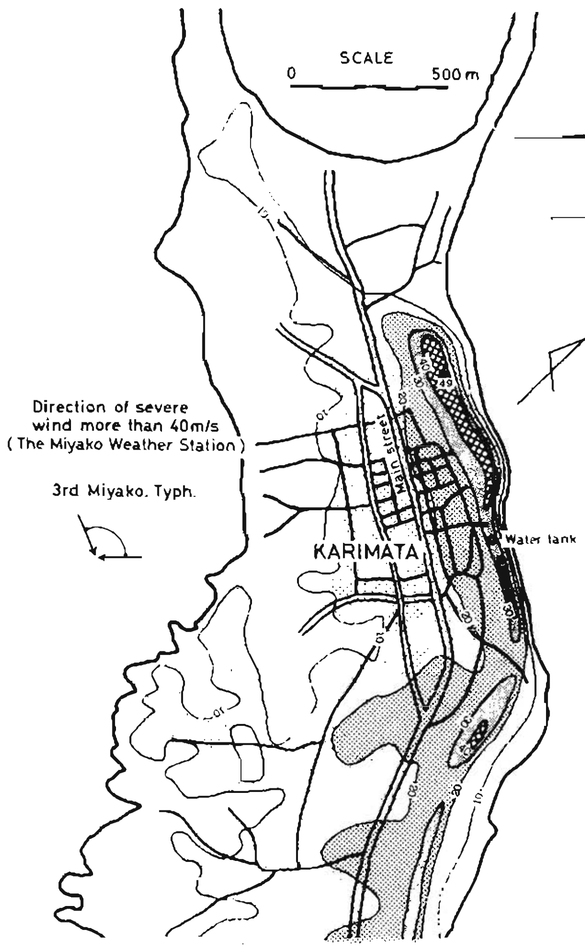


Fig. 12 Topography of Karimata.

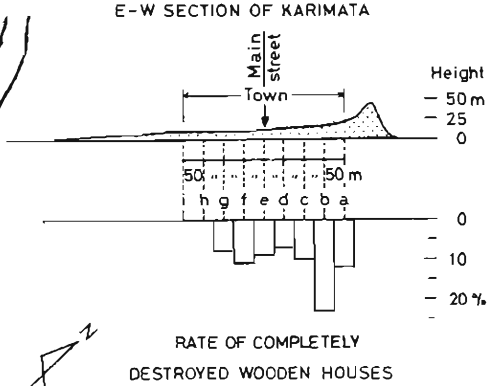


Fig. 13 East-west section of Karimata and the rate of completely destroyed wooden houses. Rates in the figure are calculated as follows : (1) towns are divided into 9 strips (a-i) of 50m wide parallel to the main street as shown in Fig. 14, (2) completely destroyed houses in a strip are divided by the total number of wooden houses in the strip, because the completely destroyed houses were all wooden and reinforced concrete houses suffered fairly slight damage.

in Fig. 13. There is a sharp narrow range of about 50m high running from north to south at the eastern end of the county. In the case of the Third Miyako-jima Typhoon the most serious wind was from NW in this area.

Fig. 14 shows the locations of completely destroyed wooden houses in Karimata. From reports, received from local residents, wind was severer in the east part of the main street. This seems to be supported by the distribution of completely destroyed houses as seen in Fig. 13. This will be explained by the fact that the wind speed was increased at the east end of the main street by the effect of the range where stream lines concentrated to the sideway of the range. The damage rates are shown in Fig. 13 in relation to the terrain section.

5. Structural Design

The performance of individual structures will be referred to in the next sections. In order to examine their performance it is necessary to have some information about the structural design methods generally adopted in Okinawa.

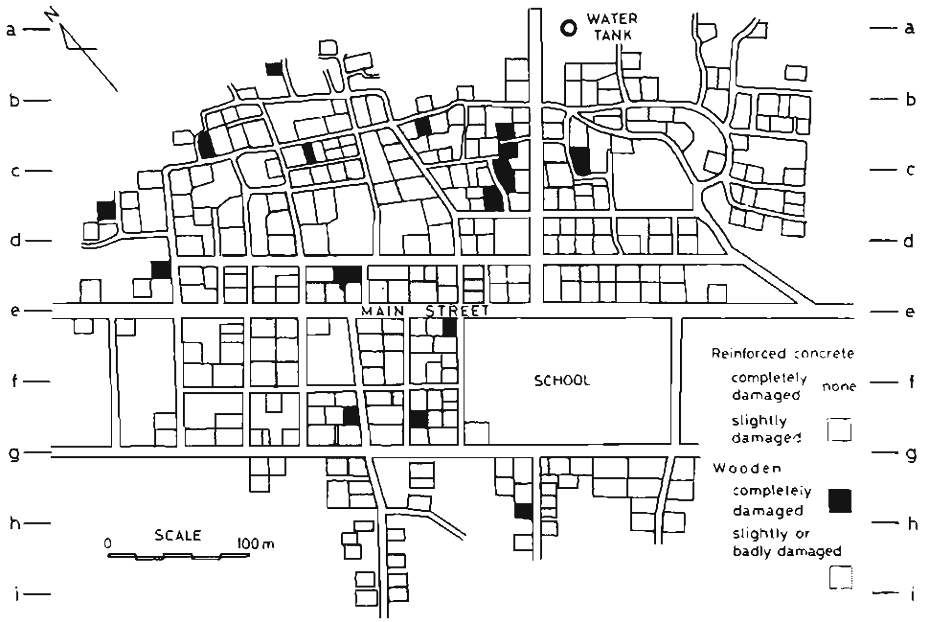


Fig. 14 Locations of completely destroyed houses in Karimata.

For this purpose the Building Code and the current methods of construction in Okinawa is reviewed in this section.

Buildings in Okinawa are constructed to be able to bear a wind load regulated by the Building Code which is given in Appendix D. According to this code the design wind speed at 10m high above the ground is about 270kg/m², which is as large as one and a half times the value in South-West Japan.

Concerning the method of construction, there is no peculiarity to be described here. But a brief comment on wooden houses which suffered serious damage is considered to be necessary.

Wooden houses are most popular in Okinawa. Most of them are hip-roofed ones with tile roofings. The structure of the tile roofings are divided into two types ; clay-tile roofings and cement-tile roofings. These are illustrated in Fig. 15, picked out from the report[2] by the present authors. As cement-tile roofings have no bed board under the tiles, the wind pressure acts directly on the tiles. Wooden houses have stud wall framing finished on both sides by boards, which is reinforced against horizontal load by bracing.

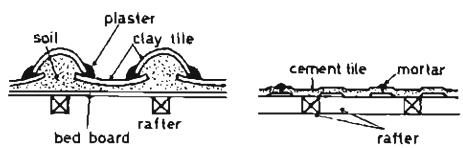


Fig. 15 The structure of the tile roofing : clay-tile roofing (left). cement-tile roofing (right).

6. Performance of Individual Structures

The proposal of the AD HOC Working Group, mentioned before, recommends detailed inspections of the performance of individual structures. In the present expedition, most of the severely damaged spots were cleared away before our inspection. So the following examples are confined to the performance of parts of the structures.

Window damage at the radar mast of the Miyako Weather Station

A small room 3 m × 5m of the rader mast has 16 sheets of glass (47cm × 57cm × 0.68cm) in both the north and south sides. 8 sheets of glass on the north side window were broken by the wind. These glass sheets were all steel-mesh reinforced. It is reasonable to infer that they were not broken by debris at this height but that they were broken by something else. The strength of this type of glass is the same as of ordinary sheet glass. But as the bending strength of these broken glass sheets is estimated to be $500kg/cm^2$, a wind pressure of more than $2,000kg/m^3$ is calculated to be necessary to break the sheets. It is hard to consider that such a large wind pressure acted on the glass, so these glasses were therefore broken by something else such as vibration.

Damage to wooden window sash

Photo. 4 shows the damage to a wooden school building. Wooden window sashes were completely removed from the windward side of the reinforced concrete wall. This is because of the weak connection between the sashes and the

Photo. 4 Damage to a wooden school building : removal of wooden sashes from windows.

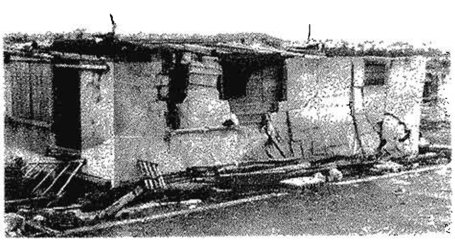


Photo. 5 Damage to a masonry building : complete removal of the roof.

Photo. 6 Damage to light-gauge steel shutter : complete removal of shutter from the opening.

walls. Similar damage was often seen to have occurred to reinforced masonry houses as shown in Photo. 5. This damage can be prevented by careful construction work.

Damage to light-gauge-steel shutters

Photo. 6 shows the damage to an opening of a school building. This damage was inspected in detail by the Construction Section of the Government of the Ryukyus.

According to the inspection, the causes of damage were found to be as follows:—

i) Lack of adequate connection between walls or beams and shutters

ii) Deficiency in the strength of several parts of the shutter against wind.

Damage to reinforced concrete buildings

Photo. 7 is a parapet of a new building completed five days before the occurrence of the Third Miyakojima Typhoon. A part of the parapet was blown

(a) (b)

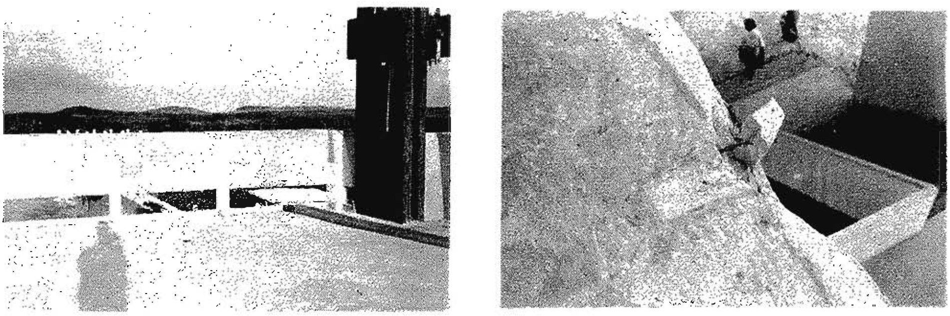


Photo. 7 The same parapet of reinforced conrcete as shown here (a) was blown off to the ground because of weak anchorage to the roof (b).

off from the roof to the ground because of the weak anchorage of the parapet to the roof.

Damage to roofs of wooden houses

The features of the roof damage to wooden houses appeared to differ seriously according to the type of roofings. In the case of clay-tile roofings which generally have bed boards, the removal of roof tiles from eaves, ridges verges or corners is observed, but it is not so crucial for the total collapse of the houses. On the other hand, in the case of cement-tile roofings without bed boards the damage is extensive over the roof and often it leads the houses to total collapse (Photo. 8).

Damage to steel structures

Damage to steel structures occurred to sugar factories and a paraboloid reflector antenna for radio communication in Miyakojima Isl. In sugar factories, sheet zinc was removed from walls and roofs (Photo. 9) and the latter antenna was transformed in the plane of the reflector to the leeward by the

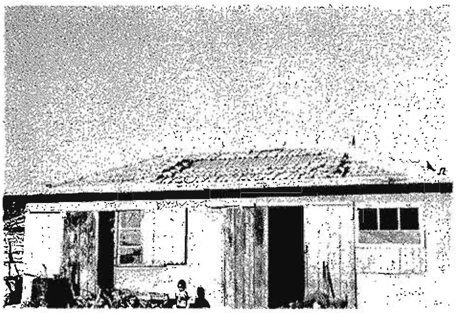


Photo. 8 Damage to a cement-tile roofing : tiles were removed extensively from the roof (damaged part are repaired by sheet-zincs).

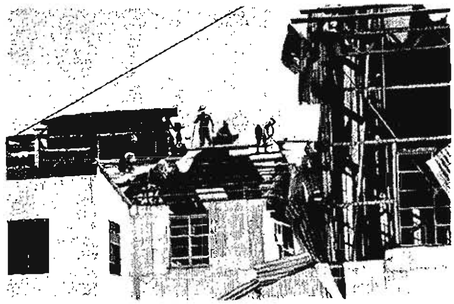


Photo. 9 Damage to sugar factories : removal of sheet-zincs.

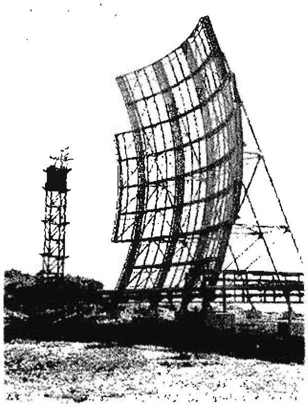


Photo. 10
A paraboloid reflector antenna (16m×16m) transformed slightly in the plane of the reflector.

force of sidesway wind (Photo. 10).

Other large steel structures, such as a lattice tower of more than 100m height, suffered fairly slight damage in the typhoon.

7. Concluding Remarks

The Third Miyakojima Typhoon was one of ordinary intensity in the northwest Pacific area, but the maximum peak gust of 79.8/sec observed in Miyakojima Isl. was one of the extreme values in Okinawa.

Severest wind damage was caused by this typhoon in Miyakojima and Kumejima Isls. The damage to houses in Miyakojima Isl. was of 5.8 % complete destruction but less serious than that caused by the Second Miyakojima Typhoon in 1966, which is considered to be because many of the houses that were destroyed in 1966 were reconstructed into reinforced concrete structures or repaired and made stronger.

The damage distribution appeared to be remarkably affected by the topography and features of the terrain, which was observed clearly and in complex aspects in the mountainous island of Kumejima, and was also observed even in the flat island of Miyakojima.

Acknowledgement

This study is part of the project for the study of the disasters caused by the Third Miyakojima Typhoon headed by Prof. H. Ishizaki and was sponsored by a Grant in Aid for Fundamental Scientific Research from the Ministry of Education of Japan.

The authors desire to convey their thanks to the many residents of the region affected by the disturbance, for their assistance in supplying information ; also to the Government of the Ryukyus and local administration offices in Miyakojima and Kumejima Isls for their cooperation in supplying information, and to the Ryukyu Meteorological Agency who afforded facilities for the expedition and cooperated in supplying meteorological information.

The authors are indebted to Mr. Y. Gushi, the Chief of the Ryukyu Meteorological Agency and Mr. T. Maeshiro, the Mayor of Hirara City for their kind arrangements for our expedition to Okinawa under the administration of the United States, and also to Mr. K. Kawahira, a graduate student of Kyoto University, for his assistance in the course of the expedition to Okinawa and with data analysis.

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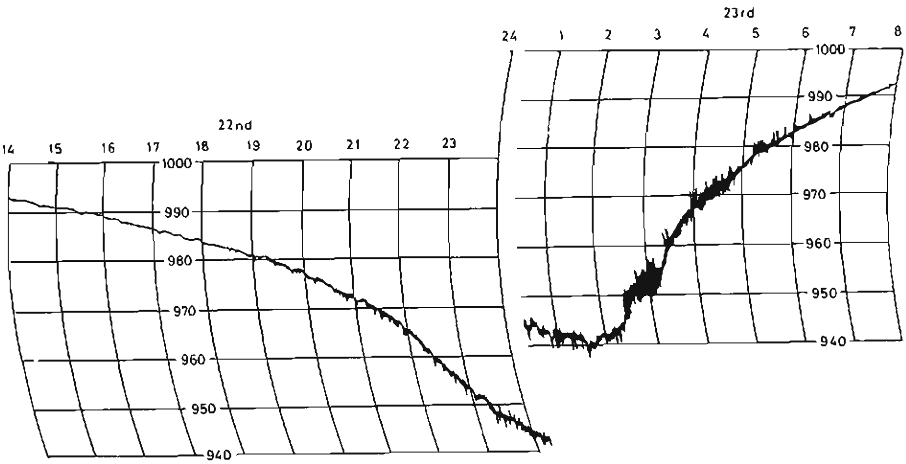
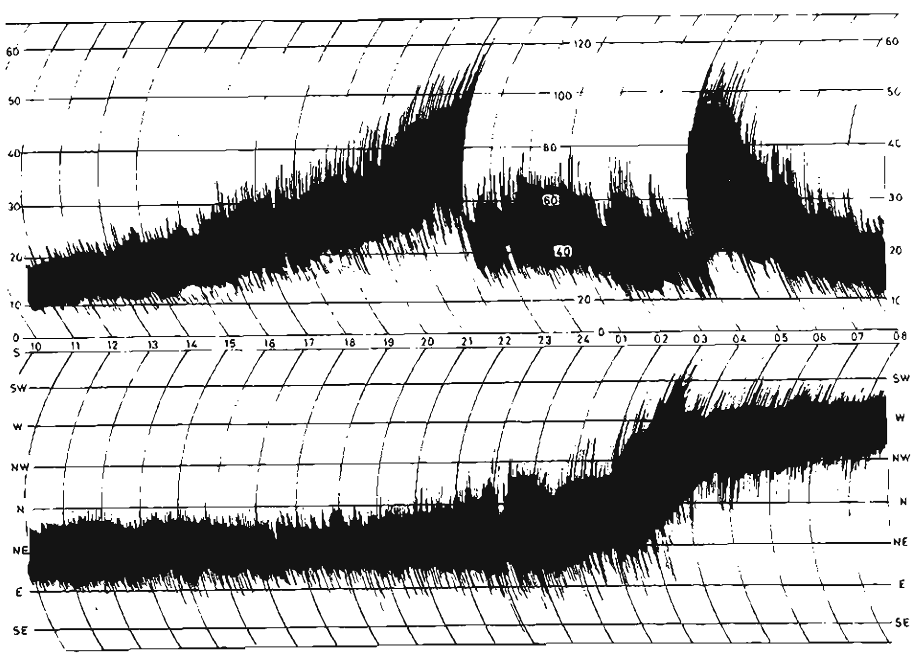
2) Ishizaki, H., Katsura, J. and Murota, T. : The Damage to Structures Caused by the Second Miyakojima Typhoon, Bulletin of the Disaster Prevention Research Institute, Kyoto Univ., Vol. 18, Part 1, July 1968, pp. 1-14.

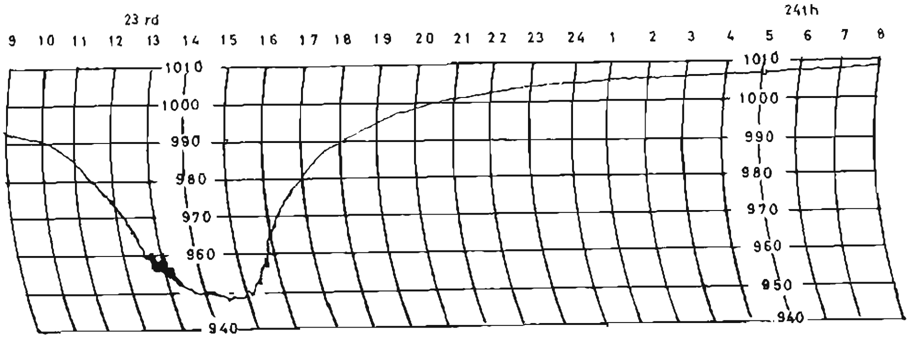
Appendix A



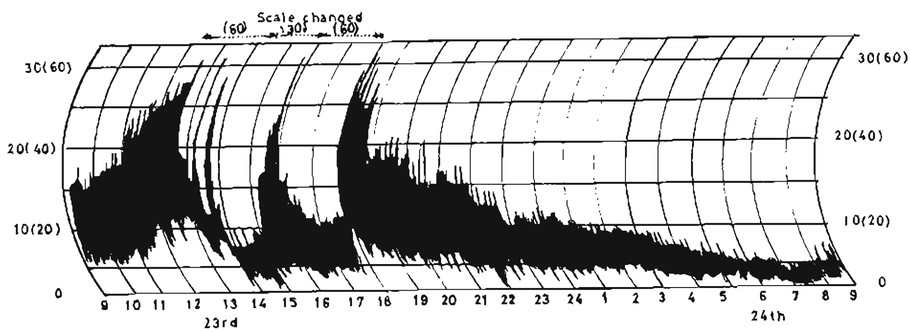
A-1 Barogram at the Miyako Weather Station.



A-2 Anemogram at the Miyako Weather Station.



A-3 Barogram at the Kumejima Weather Station.



A-4 Anemogram at the Kumejima Weather Station.

Appendix B

B-1 The meteorological situation obtained by field expedition in Miyakojima Isl.

No. of Place	Front of typhoon eye			Within typhoon eye			Rear of typhoon eye			Remarks
	Beginning time of strong wind	Time of the strongest wind	Wind dir. of the strongest wind	Beginning time of eye phenomena	Duration time of eye	Meteorological situation	Time of the strongest wind	Wind dir. of the strongest wind	End time of strong wind	
1 Ueji	—	02^h-03^h	N-NW	No significance of eye phenomena.			—	—	—	—
2 Ueno	—	—	N	02^h	1 hour	drizzle light wind	—	WSW	—	—
3 Nobaru	—	23^h	N	No significance of eye phenomena.			—	—	—	—
4 Toyohara	—	—	N	23^h	0.5	drizzle	01^h	N	—	—
5 Uruka	—	—	—	—	1	drizzle light wind	03^h	N	—	—
6 Fukuzato A	—	—	N	0^h	2	no rain open sky	—	W	4^h	Wind is stronger in the rear side of eye.
7 Fukuzato B	—	—	NE	0^h30^m	2	no rain open sky	03^h	NW	8^h	Wind is stronger in the rear side of eye.
8 Fukumine	—	01^h-02^h	—	02^h	1	—	—	—	—	Wind is stronger in the rear side of eye.
9 Kajido A	—	—	NE	01^h	2	drizzle light wind	—	SW	—	—
10 Kajido B	—	—	NE	01^h	2	drizzle	—	SW	—	—
11 Keyaki	—	—	N-NE	01^h	1-2	no rain	03^h	NW	—	Wind is stonger in the rear side of eye.
12 Nagama	—	—	N-NE	03^h20^m	1	drizzle light win	—	NW-W	07^h	Wind is stronger in the rear side of eye.
13 Ozebara	—	—	N	0^h30^m	—	drizzle	03^h	W	—	Wind is stronger in the rear side of eye.
14 Yonahama	—	—	NE	00^h-01^h	1 hour	no rain no wind	—	W	—	Wind is almost const. in front and rear of eye.
15 Shimobara	—	21^h	NE	—	0.3	drizzle	—	—	04^h	—
16 Yamakita	—	—	NE	02^h	1	drizzle light wind	—	NW	—	Wind is almost const. in front and rear of eye.

B-1 (continued)

17 Miyahara	—	—	NE	01^h	0.2	drizzle	—	W	—	Wind is stronger in the rear side of eye.
18 Onogoshi	—	—	NE-NNE	00^h	1	drizzle	01^h30^m	W	—	Wind is stronger in the rear side of eye.
19 Television tower	—	01^h-01^h30^m	NE	02^h	0.2-0.3	drizzle	—	W	—	Wind is stronger in the rear side of eye.
20 Shinzato	—	—	N	23^h	1.5	drizzle	02^h	NW	—	Wind is stronger in the rear side of eye.
21 Nishihara	18^h	01^h-02^h	N	No significance of eye phenomena.			—	—	04^h	Thunder
22 Oura	—	01^h-02^h	N	〃		〃	—	—	04^h	—
23 Nanseien	19^h	02^h-03^h	NE	〃		〃	—	—	04^h	—
24 Karimata	23^h-00^h	02^h	W	〃		〃	—	—	04^h-05^h	—
25 Shimajiri	23^h	02^h-03^h	SW	〃		〃	—	—	—	—
26 Nishikawa	—	23^h30^m	NE	00^h-01^h	?	light wind	01^h-02^h	—	—	Wind is stronger in front of eye.
27 Nishizato	18^h	22^h-01^h	NNE	1^h20^m	0.1	drizzle light wind	01^h30^m	WNW	03^h40^m	Wind is stronger in the rear side of eye.
28 Airport	19^h30^m	23^h-01^h	N-NNW	No significance of eye phenomena.			—	—	04^h-05^h	—
29 Kawamitsu	23^h	01^h-02^h	NNW	〃		〃	—	—	04^h-05^h	—
30 Sugama	20^h	00^h30^m-01^h30^m	NNW	〃		〃	—	—	04^h-05^h	—
31 Kadekari	21^h	01^h	NNW	—	0.3	light wind	—	NNW	03^h	Wind is almost const. in front and rear of eye.
32 Tomori	23^h	00^h-01^h	NNE	02^h	0.1	drizzle light wind	02^h-04^h	NNW	—	Wind is almost const. in front and rear of eye.
33 Morika	17^h	21^h-23^h	N	01^h	0.5	rain open sky	02^h-03^h	NW	—	Wind is stronger in the rear side of eye.
34 Nishisoedo	18^h	—	N	02^h	0.1	rain light wind	03^h	NNW	05^h	Wind is stronger in the rear side of eye.
35 Nishisoedo	22^h	—	NNW	No significance of eye phenomena.			—	—	06^h	Wind is almost sonst. in front and rear of eye.
36 Weather Station	18^h40^m	00^h06^m	NE	〃		〃	—	—	07^h30^m	—
37 Shimokawa	—	02^h-03^h	NNE	〃		〃	—	—	—	—

B-2 The meteorological situation obtained by field expedition within kumejima Isl.

No. of Place	Front of typhoon eye			Within typhoon eye			Rear of typhoon eye			Remarks
	Beginning time of strong wind	Time of the strongest wind	Wind dir. of the strongest wind	Beginning time of eye phenomena	Duration time of eye	Meteorological situation	Time of the strongest wind	Wind dir. of the strongest wind	End time of strong wind	
1 Shimajiri	08^h–09^h	11^h	E	12^h	2 hours	no rain open sky	15^h	SW-W	17^h	Wind is stronger in the rear side of eye.
2 Madomari	10^h	12^h-13^h	NE	13^h	1.5	no rain	14^h30^m-15^h	SW	15^h	—
3 Maja	07^h30	11^h-12^h	E	14^h	1	no rain open sky	16^h30^m	W	19^h	Wind is stronger of the rear side of eve.
4 Shimoaka	09^h	13^h-14^h	SSE	15^h	1	no rain	17^h-18^h	NW	18^h	Wind is stronger in the rear side of eye.
5 Uegusuku	13^h	14^h-14^h30	SSE	15^h30^m-16^h	2	no rain	18^h30^m	NNW	—	Wind is stronger in the rear side of eye. Thunder
6 Nakandagare	10^h	12^h-13^h	NE	14^h30^m	1.5	no rain open sky	17^h30^m	SW	18^h	Wind is stronger in the rear side of eye.
7 Yamasato	10^h	12^h	NE	14^h	1	no rain open sky	16^h	SW	18^h	Wind is stronger in the rear side of eye.
8 Kadekaru	05^h	07^h	E	11^h-12^h	1	drizzle open sky	14^h	WSW	19^h30^m	Wind is stronger in the rear side of eye.
9 Kitahara	09^h	11^h	E	12^h30^m	1.5-2	no rain open sky	15^h30^m-16^h	NW	17^h30^m	Wind is stronger in the rear side of eye.
10 Higa	—	14^h30^m	SE	13^h25^m	1.7	no rain open sky	--	WSW	—	—
11 Nakadomari	—	—	SE	14^h	0.3-0.5	no rain open sky	15^h	NW	--	Wind is stronger in the front of eye.

Appendix C

Hourly weather records

A. Yonagunijima

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press. mb	R. H. %	Wind Dir.	Wind Speed m/sec	Pre-cip. mm	ww	Cloud Amount	Cloud Form	Remarks
22nd 06	1006.6	25.7	28.0	85	NNE	12.3	—	02	10		
07	1006.4	25.7	28.0	85	N	11.7	—	02	10		
08	1007.0	26.0	28.3	84	N	13.3	—	02	10		▽^{c}0852-0858
09	1007.1	25.7	29.2	88	NNE	12.0	0.0	25	10		
10	1006.9	27.0	29.3	82	N	13.0	—	02	9		
11	1006.1	27.4	29.3	80	N	13.2	—	02	10		
12	1005.8	26.8	30.0	85	N	13.7	—	02	10		▽^{0}1245-▽^{0}1315
13	1004.8	26.4	29.7	86	N	15.0	0.0	80	10		············1435
14	1003.8	26.0	29.5	88	N	15.8	0.0	80	10		
16	1003.5	26.3	28.3	83	N	15.7	0.0	25	10		
15	1002.5	26.5	28.2	81	N	15.2	—	02	10		
17	1002.6	26.2	28.9	85	N	14.0	—	02	10		▽^{0}1713-1728
18	1003.0	26.0	29.5	88	N	14.7	0.0	25	10		▽^{0}1752-1754
19	1002.7	26.1	28.4	84	N	15.3	0.0	25	10		▽^{0}1842-1857
20	1003.3	26.4	28.0	81	N	16.3	0.0	80	10		▽^{0}1957-2024
21	1003.7	26.2	28.1	83	N	15.8	0.0	80	10		▽^{0}2056-2110
22					N	15.3	0.0				
23					N	15.5	—				
23rd 00	1004.7	25.9	26.7	80	N	14.8	—	02	10		

B. Ishigakijima

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press. mb	R. H. %	Wind Dir.	Wind Speed m/sec	Pre-cip. mm	ww	Cloud Amount	Cloud Form	Remarks
22nd 01	1007.3	26.6	28.6	82	NNE	7.2	—	02	4	Cu, Ci	
02	1006.5	26.5	28.9	83	NNE	5.8	—	02	7	Cu, Ci	▽^{0}0253-0258.
03	1005.4	26.5	29.2	84	NNE	7.2	0.0	25	7	Cu, Ci	▽^{0}0354-0355.
04	1005.3	26.9	28.4	80	NNE	8.2	0.0	25	8	Cu	▽^{0}0407······0441.
05	1004.3	26.5	28.7	83	NNE	7.5	0.0	25	10^{-}	Cu,	
06	1003.4	26.7	27.6	79	NNE	9.0	—	02	10^{-}	Cu, Ci, Ac	
07	1004.0	26.9	27.9	79	NNE	8.8	—	02	10	Cu, Ci, Ac	
08	1003.8	27.1	29.3	82	N	10.0	—	02	10	Cu, Ci, Ac	▽^{0}0801-0807.
09	1003.4	27.2	29.5	82	NNE	10.2	0.0	80	10^{-}	Cu, Ac	▽^{0}0827·········
10	1002.7	27.1	30.0	84	NNE	9.5	0.0	80	10	Cu, As	▽^{J}0920-0927.
11	1001.8	27.4	29.6	81	NNE	11.5	0.0	25	10	Cu, As	▽^{0}0931-1030.
											▽^{0}1136-▽^{0}1138-
12	1000.4	26.9	30.2	85	N	12.2	0.5	80	10	Cu	▽^{1}1140-▽^{0}1141-
13	999.0	27.1	30.3	84	N	14.0	0.5	80	10	Cu	▽^{1}1321-▽^{0}1322-
14	997.3	26.8	30.7	87	N	15.7	1.5	80	10	Cu	▽$_{1}$1331-▽^{1}
15	995.8	27.0	30.9	86	N	14.3	0.5	80	10	Cu	▽^{0}1332-▽^{1}1338-
16	994.9	26.8	30.7	87	N	13.8	0.0	80	10	Cu	▽^{2}1340-▽^{1}1341-
17	994.7	26.4	31.0	90	N	12.3	1.5	80	10	Cu	▽^{2}1342-▽^{1}1610-
									10		▽^{1}-▽^{0}1611-
18	994.4	26.2	30.6	90	N	13.8	2.0	80	10	Cu	▽^{1}1639-▽^{0}1640-
19	994.1	26.0	30.5	91	N	14.0	3.0	80	10	Cu	▽^{1}1707-▽^{0}1710-
20	994.4	25.8	30.4	91	NNW	17.7	4.0	81	10	Cb, Cu	▽^{1}1745- ▽ -
21	994.7	25.9	29.3	88	NNW	17.0	4.5	81	10	Cb, Cu	▽^{0}1747-▽^{1}1812-
22	995.1	25.6	29.3	89	NNW	15.0	4.0	81	10	Cb, Cu	▽^{2}1813-▽^{0}1814-
23	995.9	25.7	29.5	89	NNW	14.7	4.5	80	10	Cb, Cu	▽^{2}1818-▽^{1}1822-
23rd 00	996.2	26.0	29.5	88	NNW	15.5	1.5	61	10	Cu, Ns	▽^{1}-▽^{2}1824-
01	997.0	25.6	29.5	90	NW	12.5	1.5	61	10	Cu, Ns	▽^{1}1825-▽^{0}1832-
02	998.0	25.3	29.5	91	NW	11.3	1.5	61	10	Cu, Ns	▽^{1}1948-▽^{2}1957-
03	999.0	26.0	28.5	85	NW	12.7	0.5	60	10	Cu, Ns	▽^{1}1958- ▽^{1}-
04	999.5	26.0	29.2	87	NW	10.2	0.0	61	10	Cu, Ns	▽^{2}2023-▽^{1}2024-
05	1000.8	25.7	29.4	89	NW	11.2	0.0	61	10	Cu, Ns	▽^{0}2030-▽^{1}2033-
											▽^{0}2035-▽^{1}2038-
06	1002.0	25.5	29.3	90	NW	11.8	0.0	61	10	Cu, Ns	▽^{1}-▽^{0}2040-

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press. mb	R. H. %	Wind Dir.	Wind Speed m/sec	Precip. mm	ww	Cloud Amount Form	Remarks
07	1003.0	25.9	29.3	88	NW	10.3	0.0	61	10 Cu, Ns	▽^{1}2053-▽^{0}2131-
08	1004.0	26.1	29.4	87	NW	10.5	0.5	61	10 Cu, Ns	▽^{2}2214-▽^{1}2216-
09	1005.8	26.1	29.2	86	WNW	9.2	0.0	80	10 Cu, Ns	▽^{0}2222- ▽^{0}-
10	1006.6	26.6	28.4	81	NW	9.2	0.0	25	10 Cu, Ac, Cs	▽^{1}2228-▽^{0}2243-
11	1007.0	27.0	28.8	81	NW	9.3	0.0	25	10 Cu, Ac, Cs	▽^{1}2305-▽^{0}2307-
										▽^{2}2326- ▽^{1}-
12	1006.5	27.2	28.2	78	NW	10.2	—	02	10 Cu, Ac, Cs	●^{0}2330- -
13	1006.7	27.5	28.7	78	NW	8.2	—	02	10 Cu, Ac, Cs	▽^{2}-▽^{1}2329-
14	1006.9	27.5	29.5	80	NW	7.5	—	02	10 Cu, Ac, Cs	●^{0}2330-
15	1006.7	27.8	28.8	77	NNW	7.5	0.0	80	10⁻ Cu, Ac, Cs	
										=^{0}0640-1930.

-●^{0}-●^{1}0015-●^{0}0016-●^{2}0025-●^{1}0027-●^{0}0029 -●^{1}0105-●^{1}-●^{0}0108-●^{1}0114-●^{0}0115-●^{1}0125 -●^{0}0127-●^{1}0148-●^{1}-●^{0} 0151-0250. -●^{0}0259 -0805. ▽^{0}0816-0911. ▽^{0}0917-0921. ▽^{0}0938 -0941. ▽^{0}1003-1007. ▽^{0}1459-1502.

C. Miyakojima

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press. mb	R. H. %	Wind Dir.	Wind Speed m/sec	Precip. mm	ww	Cloud Amount Form	Remarks
22nd 03	1005.5	27.2	28.7	79	NE	12.5	—	02	9 Cu, Ac, Ci	
06	1002.9	27.1	30.8	86	NE	13.8	—	02	10 Cu, Ci	
07	1004.2	27.5	31.0	84	NE	12.8	—	02	10 Cu, Ac, Ci	
08	1004.0	27.7	30.9	83	NE	13.3	—	02	10 Cu, Ac, Ci	
09	1003.3	27.9	31.0	83	NE	14.7	—	02	10 Cu, Ac	
10	1002.6	28.1	30.9	81	ENE	15.3	—	02	10 Cu, Ac, Ci	▽^{0}1053-1110
11	1002.2	27.5	30.8	84	ENE	15.5	0.0	80	10 Cu	▽^{0}1134-1210
12	1000.6	27.1	31.3	87	ENE	16.0	0.0	80	10 Cu	▽^{0}1230-▽^{0}1310
13	998.7	27.8	31.1	83	ENE	17.2	0.0	80	10 Cu, As	-▽^{1}1418-▽^{1}-
14	997.2	26.9	31.7	90	ENE	19.2	0.0	80	10 Cu, As	▽^{0}1419-▽^{1}1432
15	995.0	26.3	31.6	92	NE	21.0	4.0	80	10 Cu, As	-▽^{0}1433-▽^{1}1449
16	992.8	26.2	31.4	92	NE	22.2	4.0	80	10 Cu, As	-▽^{0}1450-▽^{0}-
17	990.4	26.1	31.5	93	NE	25.8	5.5	80	10 Cu, As	▽^{1}1530-▽^{0}1545-
										▽^{1}1607-▽^{0}1619-
18	987.9	26.0	31.3	93	NE	28.8	6.5	80	10 Cu, As	▽^{1}1701-▽^{0}1720-
19	985.4	25.6	31.8	97	NE	30.0	13.5	81	10 Cu, As	▽^{0}-▽^{1}1840-
20	982.0	25.6	31.5	96	NE	32.3	17.0	61	10 Cu, Ns	▽^{2}1920-●^{2}2400
21	976.7	25.5	31.4	96	NE	38.2	10.5	62	10 Cu, Ns	
22	970.7	25.1	30.6	96	NE	41.2	11.0	62	10 Cu, Ns	gust 0224 --
23	957.9	24.7	30.9	100	NE	50.7	29.0	65	10 Cu, Ns	gust^{2}0956---
										=0730
23rd 00	950.2	24.5	30.0		NNE	53.0	38.0	65	10 Cu, Ns	
01	946.9	24.3			NNE	52.8	25.5	65	10	
02	945.8	23.9			N	44.0	24.5	65	10	
03	954.8	23.1	28.0	99	NW	47.7	26.5	65	10 Cu, Ns	
04	969.0	21.5			WNW	40.5	33.0	65	10	
05	977.7	25.2			WNW	36.5	11.0	65	10	-●^{2} ·●^{1}0540
06	984.4	24.6	30.4	98	WNW	30.2	4.0	65	10 Cu, Ns	●^{0}0730-1045
07	989.9	24.8	30.3	97	W	25.2	11.0	62	10 Cu, Ns	
08	994.4	25.6	30.3	92	W	20.7	2.0	60	10 Cu, Ns	
09	997.2	25.4	30.4	94	W	19.7	6.0	61	10 Cu, Ns	
10	1000.0	25.3	30.5	94	W	16.0	5.0	61	10 Cu, Ns	
11	1001.6	25.8	30.1	91	W	15.7	1.0	21	10 Cu, Ns	▽^{0}1105-▽^{0}1150
12	1003.4	25.6	30.0	91	W	14.7	0.5	80	10 Cu, Ac	……1250
13	1004.1	26.6	30.1	86	WNW	14.3	0.0	25	10 Cu, Ac	
14	1004.6	26.5	29.2	84	WNW	12.3	—	02	10 Cu, Ac	-gust^2—gust^1
15	1005.1	26.4	28.7	83	W	10.8	—	02	10 Cu, Ac	0956—1619-
16	1005.0	25.9	28.6	85	NW	13.5	0.0	80	10 Cu, Ac	=--
17	1006.1	25.7	28.5	86	WNW	10.5	0.0	25	10 Cu, Ac	

D. Kumejima

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press, mb	R. H. %	Wind Dir.	Wind Speed m/sec	Pre-cip. mm	ww	Cloud Amount Form	Remarks
23rd 00	1004.8	27.8	31.1	83	ESE	7.3	—	02	10	
01	1004.1	27.8	30.8	82	ESE	8.0		02	10	∇^{0}0152……0155-
02	1003.3	27.5	31.0	84	E	9.8		80	10	0213.
03	1002.2	27.6	30.7	83	ESE	10.3	0.0	25	10	
04	1001.2	27.7	30.4	82	ESE	11.5		02	10	∇^{0}0425……0446.
05	1000.3	27.4	30.6	84	ESE	12.8		25	10	∇^{0}0553……0608.
06	998.8	27.7	30.7	82	E	13.5	0.0	80	10	∇^{0}0645-∇^{1}0743-
07	996.9	27.4	30.9	84	E	15.3		80	10	∇^{2}1058-∇^{1}1310-
08	996.3	26.3	31.3	91	E	15.8		81	10	∇^{0}1323-∇^{1}1529-
09	993.1	26.1	31.0	91	ESE	18.3	7.5	81	10	∇^{1}-∇^{2}1541-
10	992.6	26.0	31.0	92	ESE	22.3		81	10	∇^{1}1633-∇^{2}1713-
11	983.0	25.8	30.9	93	ESE	27.0		82	10	∇^{1}1728-∇^{0}1820-
12	972.6	25.1	30.9	97	SE	35.0	32.5	82	10	2125.
13	956.3	24.9	30.5	97	SE	41.7		82	10	
14	949.2	25.8	33.0	99	WSW	33.0		80	10	
15	950.7	26.2	32.4	95	SW	12.2	41.5	80	10^{-}	
16	966.6	25.2	31.3	98	WSW	31.5		82	10	
17	981.9	25.2	31.3	98	WSW	27.0		81	10	
18	990.2	25.0	30.4	96	WSW	22.2	53.0	81	10	
19	995.5	25.1	30.3	95	WNW	15.5		80	10	
20	998.6	25.8	30.4	91	WNW	12.7		80	10	
21	1001.1	25.8	30.4	91	W	12.0	11.5	80	10	
22	1002.6	25.9	30.1	90	W	11.7		25	10	
23	1004.0	26.0	30.2	90	WNW	9.2		02	10	
24th 00	1004.9	25.9	30.0	90	WNW	9.3	0.0	02	10	

E. Naha

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press, mb	R. H. %	Wind Dir.	Wind Speed m/sec	Pre-cip. mm	ww	Cloud Amount Form	Remarks
23rd 00	1005.7	27.4	30.6	84	ESE	9.5	—	02	8	
01	1005.4	27.3	29.9	82	ESE	8.0	—	02	8	
02	1004.7	27.3	30.4	84	ESE	8.3	—	02	9	
03	1003.9	27.3	30.4	84	ESE	9.7	—	02	10^{-}	∇^{0}0337-0339
04	1003.4	27.5	30.0	82	ESE	10.2	0.0	25	10^{-}	
05	1002.8	27.6	29.5	80	SE	11.0	—	02	10	∇^{c}0512-0657
06	1002.6	27.1	30.0	84	SE	10.8	0.0	80	10	
07	1002.2	26.6	30.6	88	ESE	11.7	0.0	25	10	∇^{0}0708-0710
08	1001.9	27.1	30.5	85	SE	11.2	0.0	80	10	∇^{0}0721-0727
09	1001.4	27.6	30.0	81	SE	13.5	0.0	25	10	∇^{0}0742-0803
10	1000.4	27.7	29.9	80	SE	14.5	0.0	80	10	……0858
11	999.7	27.6	29.5	80	SSE	16.3	0.0	80	10	∇^{0}0917……0919
12	998.4	27.4	29.8	82	SSE	17.2	0.0	80	10	∇^{0}0932……0935
13	995.3	26.8	29.5	84	SSE	21.5	1.0	80	10	∇^{0}0951……1030
14	992.7	26.1	29.9	94	SSE	23.3	0.5	80	10	∇^{0}1042……1101
15	991.0	25.7	30.2	88	S	25.2	1.0	80	10	∇^{0}1141……1151-
16	991.7	24.3	28.9	95	S	29.3	12.5	81	10	∇^{1}1240-∇^{0}1244-
17	992.5	24.9	29.5	94	SSW	27.8	10.0	81	10	∇^{0}1250…∇^{0}1315-
18	994.8	25.0	28.9	91	SSW	27.0	4.5	81	10	∇^{1}1506-∇^{1}-∇^{2}1523-
19	997.1	25.4	29.2	90	SSW	21.3	3.5	81	10	∇^{1}1525-∇^{2}1531-
20	998.4	25.5	29.6	91	SSW	20.0	2.5	80	10	∇^{1}1532-∇^{2}1546-
21	1000.9	25.9	29.6	88	SW	18.7	0.0	80	10	∇^{1}1553-∇^{1}-∇^{2}1610-
22	1002.4	25.9	30.3	91	SW	18.2	0.0	80	10	∇^{1}1618-∇^{0}1901-
23	1004.0	25.9	30.1	90	SW	16.3	0.0	25	10	∇^{1}1923-∇^{0}1940-
24th 00	1005.1	25.7	30.0	91	SW	13.3	0.0	25	10	2004

Date Time JST	Sea-level press. mb	Air Temp. °C	Vapor press. mb	R. H. %	Wind Dir.	Wind Speed m/sec	Pre-cip. mm	ww	Cloud Amount	Cloud Form	Remarks
01	1005.9	25.7	29.9	91	SW	13.0	0.0	25	10		$\dot{\triangledown}^{0}$2053-2101
02	1006.5	25.7	29.9	91	SW	14.0	0.0	25	10		$\dot{\triangledown}^{0}$2103-2104
03	1006.9	25.7	30.2	91	SW	11.8	0.0	25	10		$\dot{\triangledown}^{0}$2110-2111
04	1007.2	25.9	30.6	91	SW	10.3	0.0	80	10		$\dot{\triangledown}^{c}$2115-2140
23rd							$\dot{\triangledown}^{0}$2144-2145 $\dot{\triangledown}^{c}$2147···2249 $\dot{\triangledown}^{c}$2310-2314 $\dot{\triangledown}^{c}$2333-2336 $\dot{\triangledown}^{c}$2356······2359 =0805-1240=^{0}2130-				
24th							$\dot{\triangledown}^{0}$0157······0202 $\dot{\triangledown}^{0}$0212······0217 $\dot{\triangledown}^{c}$0232-0232 $\dot{\triangledown}^{0}$0323-0330 -=^{0}-				

Appendix D

Following notations are used here :-

N_t = total number of households.

N_c = number of completely destroyed houses.

N_b = number of badly damaged houses.

R_c = rate of completely destroyed houses $= N_c/N_t$.

R_d = rate of damaged houses $= (N_c + N_b)/N_t$.

D-1 Damage to houses in counties of Miyakojima

	COUNTY	N_t	N_c	N_b	R_c %	R_d %	2nd Miyakojima Typh. R_c %	2nd Miyakojima Typh. R_d %
	HIRARA-CITY							
1	CITY AREA	4047	93	948	2.3	25.7	5.1	20.1
2	KOSHIBARU	50	5	24	10.0	58.0	17.6	42.2
3	FUNAKOSHI	79	9	16	11.4	31.6	5.7	43.2
4	KUGAI	231	7	69	3.0	32.9	12.2	48.6
5	MATSUBARA	286	7	45	2.4	18.2	12.6	38.2
6	NANABARU	33	2	14	6.1	48.5	34.2	75.2
7	CHIMORI	90	6	46	6.7	57.8	20.4	80.6
8	YAMANAKA	60	4	22	6.7	43.3	19.5	52.9
9	NOBARUGOSHI	94	12	28	12.8	42.6	29.9	62.4
10	MORIKA	27	2	12	7.4	51.9	8.4	14.0
11	KOMATAKE	44	4	21	9.1	56.8	23.1	65.6
12	MIYAHARA	195	12	57	6.2	35.4	22.2	47.3
13	TAKANO	46	0	14	0	30.4	0	5.6
14	SOEDO	108	5	47	4.6	48.1	11.1	24.1
15	SHIMOKAWA	115	13	38	11.3	44.3	13.8	61.4
16	NISHIHARA	338	22	98	6.5	35.5	16.6	60.5
17	FUKUYAMA	61	6	27	9.8	54.1	28.4	93.7
18	OURA	89	4	30	4.5	38.2	27.6	51.4
19	SHIMAJIRI	115	6	19	5.2	21.7	10.7	42.9
20	KARIMATA	281	35	106	12.5	50.2	19.0	71.1
21	OGAMI	25	5	10	20.0	60.0	12.0	84.0
22	IKEMAE	424	13	91	3.1	24.5	14.9	43.0
	Total	6838	272	1782	4.0	30.0	10.6	27.5

GUSUKUBE-CHO

	COUNTY	N_t	N_c	N_b	R_c %	R_d %	2nd Miyakojima Typh. R_c %	2nd Miyakojima Typh. R_d %
1	BORA	172	6	31	3.5	21.5	36.2	58.2
2	YOSHINO	104	7	14	6.7	20.2	23.4	43.0
3	NANAMATA	34	4	6	11.8	29.4	60.0	71.4
4	MINAFUKU	90	6	16	6.7	24.4	35.9	80.8
5	ARAGUSUKU	207	28	119	13.5	71.0	20.6	53.0
6	FUKUHIGASHI	96	5	22	5.2	28.1	24.3	68.7
7	FUKUNAKA	84	15	33	17.9	57.1	56.4	88.1
8	FUKUNISHI	96	3	27	3.1	31.3	24.3	51.6
9	FUKUMINAMI	80	4	25	5.0	36.3	40.5	84.8
10	FUKUKITA	55	13	16	23.6	52.7	30.9	76.3
11	NISHIHIGASHI	95	6	35	6.3	43.2	27.2	68.5
12	NAKAHARA	61	6	25	9.8	50.8	19.7	80.8
13	KAJIDO	82	9	32	11.0	50.0	24.4	56.4
14	HIKA	136	11	33	8.1	32.4	26.8	76.8
15	NAGAKITA	81	4	24	4.9	34.6	31.6	45.5
16	NAGANAKA	109	10	38	9.2	44.0	32.4	49.5
17	NAGAMINAMI	116	11	12	9.5	19.8	20.8	42.5
18	YOSHIDA	58	2	19	3.4	36.2	10.7	32.1
19	NISHINISHI	104	12	13	11.5	24.0	26.4	52.8
20	NISHINAKA	95	8	29	8.4	38.9	18.4	75.5
21	SHIMOKITA	180	12	62	6.7	41.1	18.1	40.1
22	SHIMOMINAMI	99	8	20	8.1	28.3	10.9	31.7
23	SUNAGAWA	180	6	29	3.3	19.4	6.6	24.3
24	TOMORI	177	4	15	2.3	10.7	20.5	52.1
	Total	2591	200	695	7.7	34.5	25.0	55.6

SHIMOJI-CHO

	COUNTY	N_t	N_c	N_b	R_c %	R_d %	2nd Miyakojima Typh. R_c %	2nd Miyakojima Typh. R_d %
1	KURIMA	91	32	25	35.2	62.6	49.0	76.7
2	YONAHA	243	72	42	29.6	46.9	30.0	64.2
3	UEJI	169	21	65	12.4	50.9	14.6	56.2
4	SUGAMA	130	24	35	18.5	45.4	21.5	66.1
5	IRIE	66	14	14	21.2	42.4	50.0	64.3
6	KATEKARI	36	14	10	38.9	66.7	70.6	90.1
7	TAKACHIHO	88	9	40	10.2	55.7	35.8	86.3
8	KAWAMITSU	120	24	35	20.0	49.2	24.6	60.7
	Total	943	210	266	22.3	50.5	30.8	66.9

UENO-MURA

	COUNTY	N_t	N_c	N_b	R_c %	R_d %	2nd Miyakojima Typh. R_c %	2nd Miyakojima Typh. R_d %
1	UENO	105	10	12	9.5	21.0	34.9	90.1
2	NAKAYAMA	89	9	18	10.1	30.3	41.7	96.4
3	MIYAGUNI	149	19	49	12.8	45.6	35.2	89.8
4	OMINE	41	3	18	7.3	51.2	35.0	90.0
5	SHINZATO	147	7	58	4.8	44.2	30.7	85.9
6	TAKATA	100	24	24	24.0	48.0	35.3	90.6
7	TOYOHARA	99	14	34	14.1	48.5	35.2	89.8
8	NOBARU	122	14	33	11.5	38.5	35.5	90.9
	Total	850	100	246	11.8	40.7	35.1	90.1

D-2 Damage to houses in counties of Kumejima

	COUNTY	N_t	N_c	N_h	R_c %	R_d %
	NAKAZATO-MURA					
1	UEGUSUKU	74	3	4	4.1	9.5
2	HIYAJYO	64	10	12	15.6	34.4
3	UEAKA	18	2	3	11.1	27.8
4	SHIMOAKA	30	0	0	0	0
5	MAJA	19	13	10	5.9	10.5
6	UNE	90	2	9	2.2	12.2
7	MADOMARI	74	14	13	18.9	36.5
8	NISHI-OH	19	0	3	0	15.8
9	HIGASHI-OH	14	1	3	7.1	28.6
10	TOMARI	40	3	5	7.5	20.0
11	JANADO	130	7	9	5.4	12.3
12	HIGA	148	7	16	4.7	15.5
13	MAGARI	45	9	11	20.0	44.4
14	ZENITA	55	4	6	7.3	18.2
15	SHIMAJIRI	97	12	16	12.4	28.9
16	YAMASHIRO	66	7	8	10.6	19.7
17	GIMA	307	13	21	4.2	11.1
	Total	1490	105	149	7.0	17.0
	GUSHIKAWA-MURA					
1	NAKANDAGARE	55	3	6	5.5	16.4
2	GUSHIKAWA	59	7	10	11.9	28.8
3	NAKAJI	91	4	24	4.4	30.8
4	YAMASATO	50	4	10	8.0	28.0
5	UEZU	33	2	16	6.1	54.5
6	NISHIME	101	6	16	5.9	15.8
7	KUMAJI	32	2	2	6.3	6.3
8	KITAHARA	45	4	14	8.9	31.1
9	OHARA	91	5	18	5.5	19.8
10	TORISHIMA	193	3	20	1.6	10.4
11	NAKADOMARI	121	3	12	2.5	9.9
12	OTA	42	0	11	0	26.2
13	KANEGUSUKU	95	4	24	4.2	25.3
14	KADEKARU	154	4	13	2.6	8.4
	Total	1162	51	216	4.4	18.6

D-3 Damage to houses in the city area of Hirara City

	COUNTY	N_t	N_c	N_h	R_c %	R_d %	2nd Miyakojima Typhoon R_c %	2nd Miyakojima Typhoon R_d %
1	MINAMI-NISHISATO	422	10	219	2.4	54.3	3.8	10.2
2	KAMIYA	199	0	4	0	2.0	3.0	9.0
3	OMITAWARA	380	0	31	0	8.2	0.7	4.4
4	MAEPIYA	168	1	52	0.6	31.5	2.7	6.1

	COUNTY	N_c	N_e	N_b	R_e %	R_d %	2nd Miyakojima Typhoon R_c %	R_d %
5	UEZUNO	175	0	39	0	22.3	3.1	16.4
6	OHARA	279	8	73	2.9	29.0	1.3	56.2
7	HARIMIZU	184	3	36	1.6	21.2	1.6	17.2
8	KITANISHISATO	228	12	56	5.3	29.8	1.0	7.8
9	NEMA	118	2	7	1.7	7.6	1.9	5.7
10	SHIMOYA	220	1	66	0.5	30.5	4.0	22.2
11	HADATE	*	*	*	*	*	5.5	52.9
12	DEGUCHI	184	2	15	1.1	9.2	2.8	11.3
13	AZUMA	208	5	51	2.4	26.9	10.1	38.6
14	SAKAE	162	13	50	8.0	38.9	9.2	23.0
15	NAKAYA	224	3	22	1.3	11.2	9.2	30.5
16	ASAHI	134	0	67	0	50.0	5.4	43.2
17	TAKAARA	146	5	25	3.4	20.5	7.0	34.9
18	HIGASHIKAWANE	189	14	63	7.4	40.7	8.1	20.6
19	NAKAHOYA	178	4	28	2.2	18.0	13.0	59.1
20	HOSATO	145	6	30	4.1	24.8	11.0	66.2
21	NIKAWADORI	104	4	14	3.8	17.3	13.9	98.1
	Total	4047	93	948	2.3	25.7	5.1	20.8

Appendix E

Building Code for Use in Okinawa

Clause 75. Wind Load shall be determined from the velocity pressure multiplved by the pressure coefficient.

2. The velocity pressure q, in kilograms per square meter, in the foregoing paragraph shall be determined by the following formula :

$$q=90\sqrt{h};$$

where h=height in meter above the ground level.

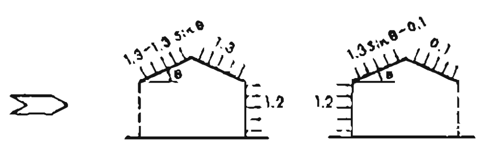
3. The velocity pressures can be decreased to the extent down to the half of the value given above to the direction of the effective wind shade, such as other buildings, wind breaks and others, if any.

4. The pressure coefficient in the first paragraph can be determined by wind tunnel tests or can be adopted in accordance with the table below. For structures that differ from the examples given in the table the pressure coefficient can be analogized out of the similar examples.

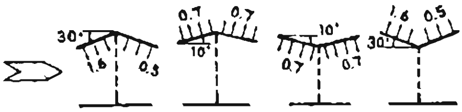
Table of pressure coefficients

In this table, ⇨, → and // show the wind direction, the pressure direction and the angle of the roof slope between the roof surface and the horizontal, respectively.

Buildings having predominantly permeable or completely open walls (shown in dotted lines)

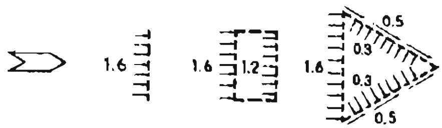


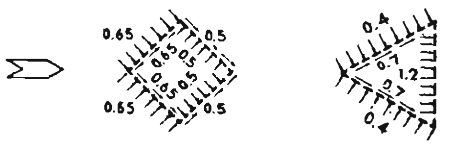
Free roofs



The pressure coefficient to be assumed over intermediate roof-slopes may be interpolated linearly.

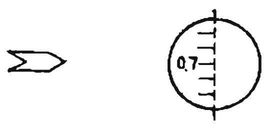
Lattice structures





These figures show the cross-section of the lattice beam or column. The exposed area subjected to the wind pressure shall be the total area of the lattices projected to the plane perpendicular to the latticed plane.

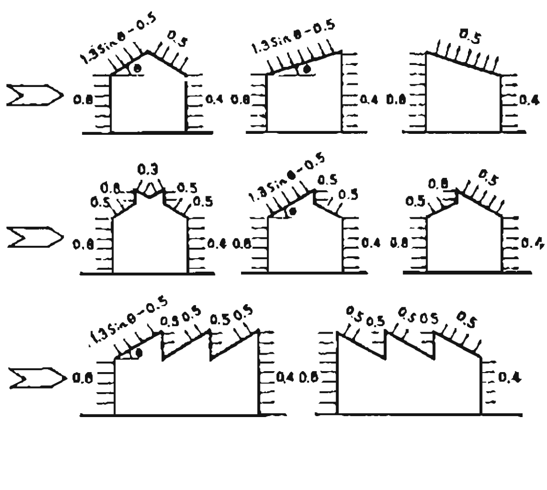
Chimneys and other structures of the cylindrical cross-sections.

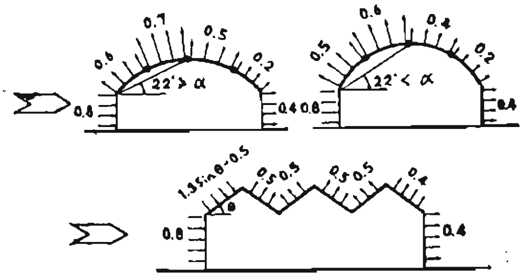


Dotted line shows the center line.

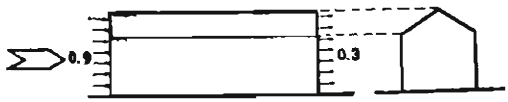
plates

Buildings having normal permeability or no openings





The wind pressure segments of curved roofs shall be divided into four equals.



Wind parallel to the roof-slopes