Damage to Buildings Induced by Tatsumakis in Nobeoka City, Miyazaki and Saroma Town, Hokkaido in 2006

by

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ABSTRACT

Two big tatsumakis occurred in Miyazaki and Hokkaido in 2006. A tatsumaki damaged more than 1,200 houses in Nobeoka city, Miyazaki with an approach of Typhoon Shanshan on September 17, 2006. Another tatsumaki killed 9 persons in Saroma town in Hokkaido on November 7, 2006. BRI investigated damage to houses in Nobeoka city in Miyazaki and Saroma town in Hokkaido.

Collision of flying debris to claddings and scattering of roof materials in houses were very remarkable in two tatsumaki damage. Borderline of each damaged area by tatsumaki was very clear. Damage state of each house was applied to a high wind damage scale that the authors proposed and applied typhoon damage to houses in 2004.

1. INTRODUCTION

The gust wind occurred in Miyazaki, Oita and Kochi prefectures with an approach of Typhoon Shanshan on September 17, 2006. A large tatsumaki (F2) occurred in Nobeoka city Miyazaki. The gust wind damage such as tatsumakis occurred in some places in Hokkaido when a cold front passed over Hokkaido on November 7, 2006. Another large tatsumaki (F3) occurred and killed 9 persons in Wakasa region of Saroma town in Hokkaido. BRI investigated damage to buildings in Nobeoka city in Miyazaki and Saroma town in Hokkaido.

2. METEOROLOGICAL CONDITION AT TIME OF TATSUMAKI OUTBREAK

Fukuoka meteorological observatory reported that Typhoon Shanshan approached Kyushu district on September 17 and made landfall in the vicinity of Sasebo city, Nagasaki at past 18:00. The atmospheric pressure in the center of typhoon Shanshan was about 950hPa at the time of the landing and the maximum wind velocity were about 40m/s. The maximum wind velocity 46m/s was recorded in Nomozaki of Nagasaki city. The maximum instantaneous wind speeds were recorded 53.4m/s in Fukue city and 50.3m/s in Saga city. Fig.1 shows the track of typhoon Shanshan which is similar with the track of typhoon Mireille in 1991 or typhoon Songda in 2004 which brought the serious damage in Japan. At about 14:00 before typhoon Shanshn made landfall, a tatsumaki occurred in Nobeoka city, Miyazaki located in about 300km east-northeast from the typhoon center (See Fig.2). The gust wind damage occurred not only at Nobeoka city but also at Nichinan city and Hyugashi city in Miyazaki, at Usuki city and Ooita city in Ooita, and at Aki city in Kochi, with approach of typhoon Shanshan.

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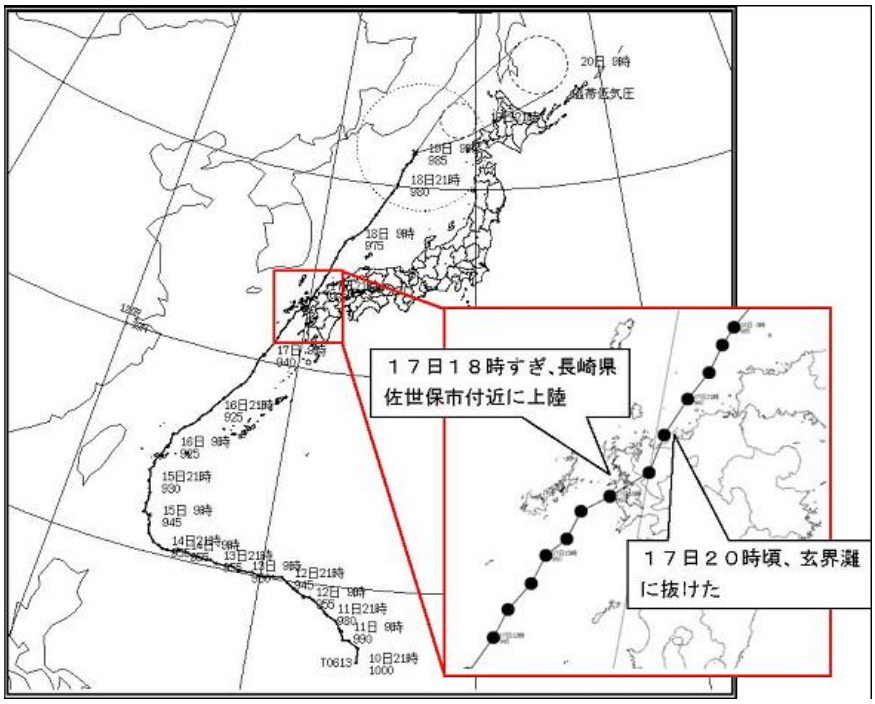


Fig.1 Track of Typhoon Shanshan (JMA)

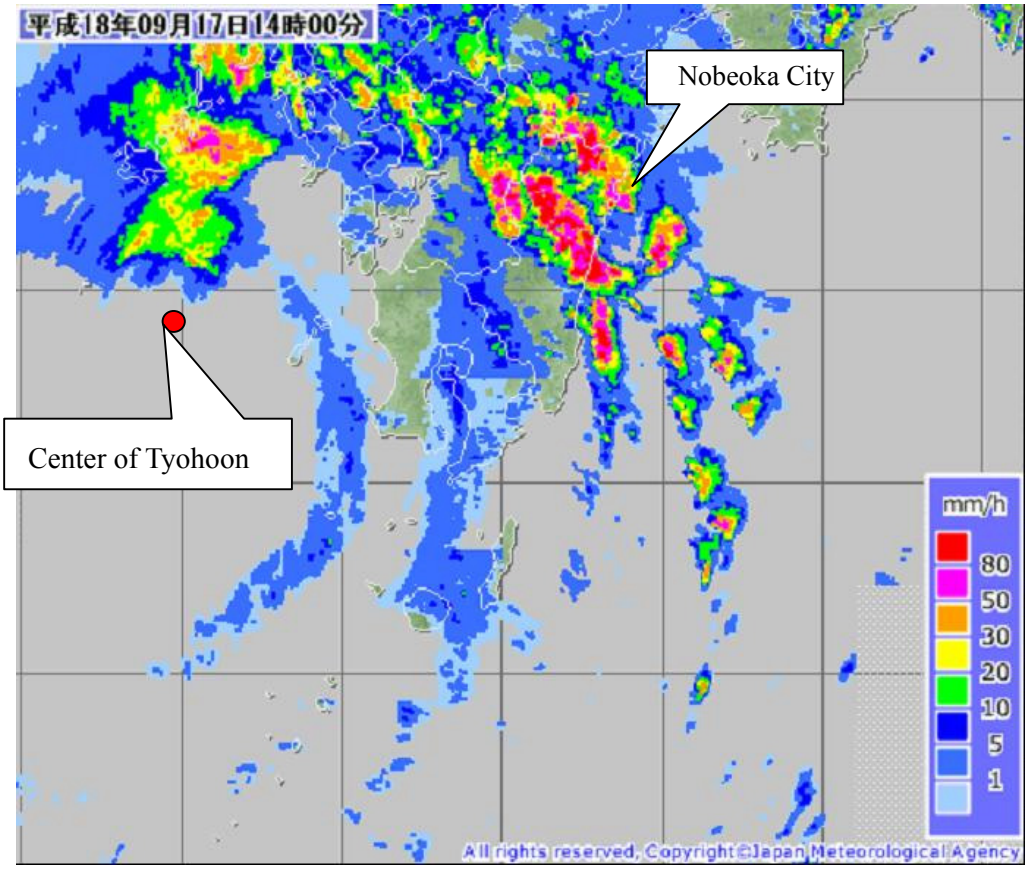


Fig.2 Center of Typhoon Shanshan and Nobeoka Tastumaki Outbreak at 14:00 on September 17 (JMA)

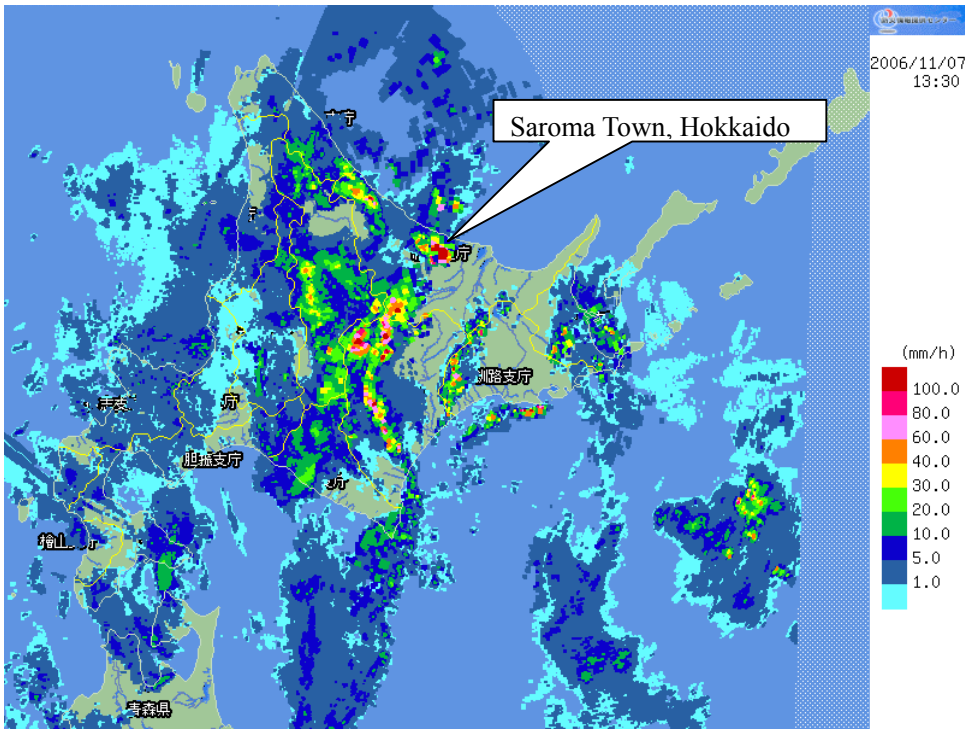


Fig.3 Rain band over Saroma town, Hokkaido at Tatsumaki Outbreak (JMA)

A depression was developing in the vicinity of Soya Channel on November 7, and a cold front spread from the center of the depression passed over the central part of Hokkaido. The state of the atmosphere became unstable. An active thundercloud passed over Saroma town and a gust wind occurred at Wakasa in Saroma town at 13:30 on November 7. Another tatsumakis occurred in Hidaka town and Toyotomi town, Hokkaido on the same day and Okushiri Island on November 9.

3. DAMAGE TO BUILDINGS INDUCED BY TATSUMAKIS

This section shows the main outlines about damage to buildings by tatsumakis on which the authors obtained information during the post disaster investigations. In the following, damage of commercial facility in Nobeoka city and that of temporary working office and houses in Saroma town are described, respectively.

3.1 Damage to Commercial Facility

A commercial facility of mass grocery retailer in Nobeoka city experienced serious damage and which induced lots of economical loss of goods and display racks as well as external claddings. On the roofing materials, there were lots of marks of attack by flying debris. This facility is supposed to locate just in the course of the tatsumaki. Based on the observed damage state, the sudden decrease of internal pressure had generated first because of the peeled-off steel roofing materials and then the damage of indoor goods was supposed to become extensive very much.

Figs. 4 to 10 show the main damage state of this commercial facility. This retailer rapidly began repairing just after the disaster and only five days was needed for resuming business.

Fig.4 Damage State after Disaster

Fig.5 Overturning of Sash in Entrance

Fig.6 Overturning of Sash in Entrance

Fig.7 Damage State of Commercial Goods

Fig.8 Breakage of Window in Entrance

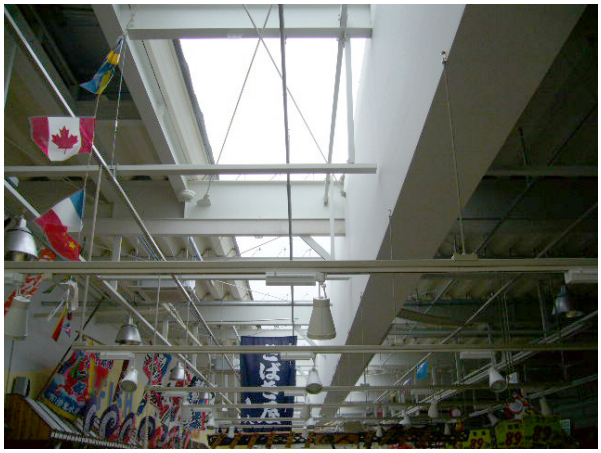


Fig.9 Peeled-off Steel Roofing Materials

Fig.10 Repaired Steel Roofing Materials

3.2 Damage to Temporary Working Office

In Wakasa region of Saroma town, two of three temporary working offices were severely collapsed by the approaching tatsumaki (See Fig.11). Office A was flown off to the north direction and the other office C was collapsed to the same direction. Series of wooden piles of them were still left on these sites and lots of broken structural elements such as lattice girder were observed to be scattered in the neighboring site (See Figs. 12 and 13). The left temporary working office (office B) which was connected to the office C by connecting corridor had several breakages of windows, but was observed to experience not so severe damage compared to those collapsed.

There were marks of pulled-up nails on the top of the wooden piles of offices A and C as shown in Fig.14 and these nails were considered to fasten floor joists with wooden piles. There also left crump irons on the side of the outer wooden piles as shown in Fig.16, which were considered to fasten ground sill with outer wooden piles. Based on the result of the serious damage, the pull-out performance of these fasteners with the given fastening interval is supposed to be totally inadequate against wind load induced by the tatsumaki.

Fig.11 Damaged Temporary Working Offices

Fig.12 Collapse of Offices A and C (See Fig. 11)

Fig.13 Scattered Structural Elements and Others

Fig.14 Wooden Pile of Office A

Fig.15 Wooden Piles of Office A

Fig.16 Clump Iron Left on Wooden Pile

3.3 Damage to Houses and Warehouses

Houses in Wakasa region of Saroma town are mainly built by conventional method of timber construction and lots of them experienced severe damage by the tatsumaki. According to the survey by Saroma town office, the damage of houses accounts for 12 of total collapse, 8 of partial collapse and 18 of partial damage, respectively. As the main damage state, breakage of external claddings such as wall and window by flying debris and flown-off roofing materials were observed. As for the damage state of the totally collapsed houses and warehouses, structural elements such as columns and bearing walls were collapsed and the whole roofing system including roofing material, ridge, rafter and vertical roof strut was flown off. Figs. 17 to 24 show main examples of damaged houses by the tatsumaki.

Fig.17 Damage to Ceiling

Fig.18 Out-of-joint between Vertical Roof Strut and Purline

Fig.19 Damage to Roofing Materials

Fig.20 Damage to Roofing System and Part of Wall

Fig.21 Severe Damage to External Cladding by Flying Debris

Fig.22 Damage to Wall by Flying Debris

Fig.23 Damage to Roofing System

Fig.24 Residual Deformation of External Cladding

4. CHARACTERISTICS OF DAMAGE STATE AND DISTRIBUTION OF BUILDINGS DAMAGED BY TATSUMAKIS

4.1 Characteristics of Damage State of Buildings

Damage of building envelopes such as roofing materials and walls can be generally observed as typical wind-induced disaster of buildings. Recently in Japan, it has been often pointed out that peeled-off external claddings may become flying debris and attack neighboring buildings and structures as a consequent disaster. These modes of damage are also true in the damage by the effect of tatsumakies. Figs. 25 to 32 show several examples of damage to building envelopes such as external claddings induced by flying debris.

Fig.25 Damage to Wall by Flying Debris

Fig.26 Damage to Wall by Flying Debris

Fig.27 Damage to Wall by Flying Debris

Fig.28 Damage to Wall by Flying Debris

Fig.29 Separation of Wall

Fig.30 Separation of Wall

Fig.31 Damage to Windows and Sash

Fig.32 Damage to Wall

4.2 Distribution of Buildings Damaged by Tatsumakis

The authors presented high wind damage scale which can associate the degree of damage state with several numerical ranks. Researchers or local government officials, who carry out post disaster investigation, can make use of this scale in order to easily grasp overall disaster by high wind including the effect of tatsumakis. Table 1 shows the high wind damage scale.

The authors applied observed damage states of each houses in Wakasa of Saroma town to the high wind damage scale shown in Table 1. The result is illustrated in Fig. 30. If the line which covers buildings ranked 4 or 5 is supposed to the route of the tatsumaki, how the tatsumaki went across the area can be estimated as shown in the figure. The width of disaster area was ranging from 100m to 250m and the damage area may be more extensive in the eastern side of the estimated route of the tatsumaki.

As the typical characteristics of disaster by tatsumaki, it can be pointed out that the width of the disaster area is narrower than that by typhoon and the estimated boundary between damaged area and non-damaged one is very clear. Figs. 34 and 35 are examples of the clear boundary between damaged and non-damaged houses.

Table 1 High Wind Damage Scale

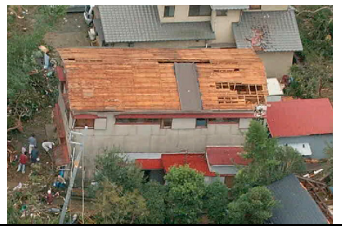
Rank	Damage state
1	Antenna or gutter on the roof is broken. Twigs are folded and lots of leaves are scattered. 
2	Roof tiles are shifted. Roofing materials such as roof tile, shingle and steel roof are blown off from edge of eaves or gable (less than 30% of total area of the roof). Thick branches are folded.   
3	Roofing materials such as roof tile, shingle and steel roof are blown off and extensive area of sheathing roof board can be exposed (30% and more of total area of the roof). Windows and nonstructural external walls are partially broken. Thick trees are fallen down.   
4	Rafters and purline of roof are broken. Roofing system is collapsed. Lots of windows are broken.   
5	Houses are totally collapsed. 

Fig.33 Distribution of Damaged Buildings in Wakasa of Saroma Town

Fig.34 House with Collapsed Roofing System and House with Small Damaged Roofing Material

Fig.35 House with Peeled-off Roof and Non-damaged House

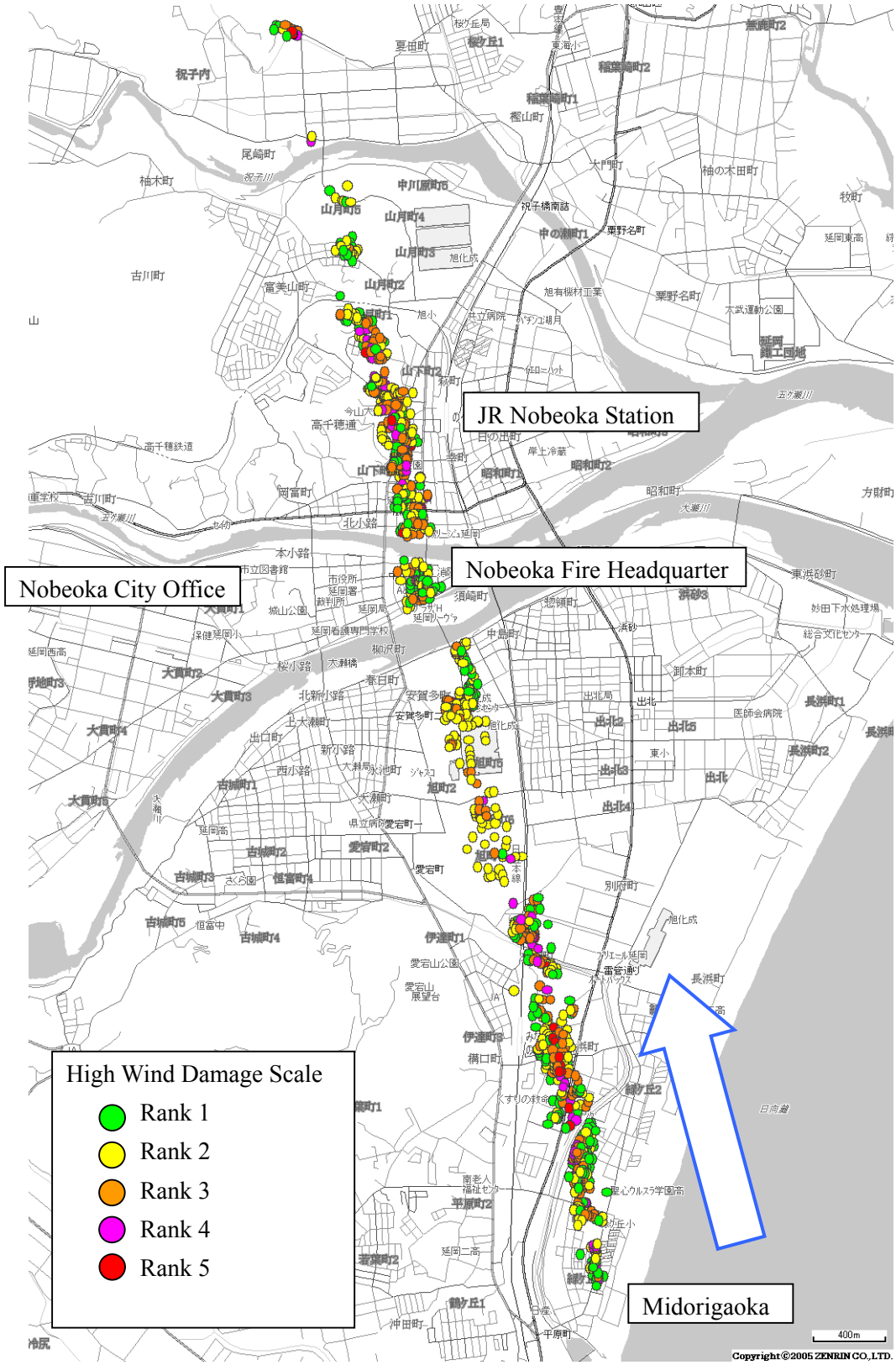


Fig. 36 Distribution of Damaged Buildings in Nobeoka City

The damage is almost distributed for about

7.5km in a straight line to run through a center of Nobeoka city. A Tatsumaki generated on the sea in the offing of Midorigaoka, Nobeoka city and moved up to the north from the south. According to the Meteorological Agency, movement speed of a tornado estimates it with about 90km/h. A Tatsumaki struck Nobeoka Fire Headquarter and all windows of the building were broken.

5. WIND LOAD OF TATSUMAKI AND FLYING DEBRIS IN BUILDING STANDARD LAW

Basic wind velocity Vo in Building Standard Law of Japan[1)] is provided from records of the maximum wind velocity (10 minute averaged velocity) observed at weather stations in Japan, and is not considered of gust wind such as a tatsumaki. "Tornadoes have not been considered in developing the basic wind speed distributions" in ASCE[2)], because the wind-resistant design for almost buildings that considered action of a tornado is not economical. However, tornadic gust wind speed map corresponding to annual probability of 10^{-5} are illustrated in Appendix of ASCE for special buildings.

It is not explicitly written how walls can be designed against flying debris in Building Standard Law of Japan. On the other hand, in ASCE, it is demanded that shutter or glass should be used of which the strength is confirmed by examinations for flying debris according to buildings or building site.

6. CONCLSIONS

BRI investigated the damage to buildings by two tatsumakis. Collision of flying debris to claddings and scattering of roof materials in houses were very remarkable in tatsumaki damage. Borderline of each damaged area by tatsumaki was very clear. Damage state of each house was applied to a high wind damage scale that the authors proposed and applied typhoon damage to houses in 2004.

REFERENCES

1. The Building Standard Law of Japan 2004, The Building Center of Japan, 2004

2. Minimum Design Loads for Buildings and Other Structures: 6.Wind Loads, ASCE 7-05, 2005