# Japanese Country Report 2009

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ABSTRACT: This paper reviews domestic activities in the wind engineering field in Japan in 2008, including activities of the Architectural Institute of Japan (AIJ), the Japan Association for Wind Engineering (JAWE), and other organizations.

KEYWORDS: Wind resistant Design, Cladding and Components, Wind-induced Disaster, Building Code, Tornado, Nuclear Facility

## 1 ACTIVITIES OF WIND LOADING COMMITTEE OF ARCHITECTURAL INSTITUTE OF JAPAN (AIJ)

The AIJ Wind Loading Committee (chaired by H. Kawai) consists of three working groups: Working Group on Wind Resistant Design System, Working Group on Wind-Resistant Performance of Claddings/Components and Working Group on Wind-Resistant Structural designing by CFD. The following describes the activities of each working group during the past year.

### 1.1 *Working Group on Wind Resistant Design System*

This WG (chaired by H. Kawai) investigated the performance and usability of various building codes and standards to revise AIJ-RLB-2004. Flow-charts for estimating wind loads for AIJ-RLB-2004, ASCE7-05, AS/NZS1170.2, BS6399-2, EN1991-1-4 and ISO FDIS4354 were compared to check their performance and usability to clarify improvement points for AIJ-RLB-2004.

### 1.2 *Working Group on Wind-Resistant Performance of Claddings/Components*

Recent wind-induced damage to buildings has demonstrated the importance of wind-resistant design of cladding/components as well as problems caused by wind-born debris. The objective of the working group on wind resistant performance of claddings/components (chaired by Y. Uematsu) was to develop more reasonable wind-resistant design of claddings/components to reduce wind-induced damage. The Working Group consisted of the following three sub-working groups:

#### 1.2.1 *Sub-Working Group on Wind-Induced Damage, Building Research Institute*

The objective of this sub-working group (chaired by Y. Okuda) was to investigate the features and causes of damage based on damage investigations. It also focused on the effects of wind-born debris. By clarifying the problems in design and construction of claddings/components, the working group suggested countermeasures for reducing damage, considering wind loads and wind-resistant performance of claddings/components.

### 1.2.2 *Sub-Working Group on Wind Loads on Claddings/Components*

The objective of this sub-working group (chaired by Y. Asami) was to review the results of recent investigations on wind loads on claddings/components, and to thus develop methods for determining wind pressure and force coefficients, considering the time-space correlation of wind pressures acting on the tributary areas of claddings/components. It also focused on the internal pressure coefficients for buildings with openings of various sizes and locations.

### 1.2.3 *Sub-Working Group on Performance of Claddings/Components*

The objective of this sub-working group (chaired by H. Nishimura) was to propose reasonable methods for evaluating the wind-resistant performance of claddings/components, considering not only the dynamic load effects of wind pressures but also the wind-induced responses of claddings/components, including fatigue damage. This working group consisted of engineers and researchers from various industries. The following items were discussed: wind resistant performance to be considered in design, testing method for verifying performance, and safety factor.

Following two years of activities of the working group, a textbook "*Wind Resistant Design and Evaluation of Wind Resistant Performance of claddings/Components*" was published in 2008. It consists of the following five chapters:

Chapter 1 Importance of claddings/components in wind resistance of buildings
Chapter 2 Lessons from recent wind-induced disasters
Chapter 3 Wind loads on claddings/components
Chapter 4 Evaluation of wind resistant performance of claddings/components
Chapter 5 Flying debris

## 1.3 ***Working Group on Wind-Resistant Structural Designing by CFD***

Recent speeding up of High-Performance Computers (HPCs) and achievements of numerical techniques enabled us to predict the time-dependent as well as the time-averaged structural wind forces using the modeling of Computational Fluid Dynamics (CFD) mainly formulated by unsteady analytical methods such as large eddy simulation (LES). Since CFD has some advantages over wind-tunnel experiments for data acquisition or modeling of terrain and urban surfaces, CFD-based design would introduce a new concept and a unique methodology for wind-resistant structural design. For example, vertical wind velocity profiles affected by elevated building blocks or terrain undulations could be estimated appropriately by CFD in each case of a specified area using data of the Geographic Information System (GIS). Thus, wind profiles need not to be classified for all areas in advance.

The objectives of this working group (chaired by T. Tamura) were to reveal the availability and effectiveness of CFD-based wind-resistant structural design and to discuss its novelty as a design methodology, and to verify its validity and accuracy as a design tool by carrying out CFD-based design of actual buildings. The working group consisted of the following two sub-working groups:

### 1.3.1 *Sub-Working Group on Methodology of Wind-Resistant Structural Designing by CFD*

This sub-working group (chaired by H. Kataoka) discussed the new wind-resistant design methodology exploiting CFD techniques. The following topics were examined: design based on a scenario of a disastrous virtual typhoon, the effect of atmospheric stability conditions on wind loads, evaluation of urban surface roughness or geographical conditions, wind load estimation for lattice structures and examination of the validity and accuracy of wind loads estimated by LES. Pilot guidelines of numerical techniques for CFD-based designing were also reviewed and checked.

### 1.3.2 *Sub-Working Group on Practice of Wind-Resistant Structural Design by CFD*

This sub-working group (chaired by K. Nozawa) planned to validate the accuracy of CFD for wind-resistant structural design of actual buildings. The numerically obtained design wind loads on structural frames and claddings were compared with those estimated from experimental data. Time-dependent simulations were performed using turbulent inflow generating techniques and LES was mainly applied to estimate fluctuating wind forces. In the model set up for CFD, target buildings with complex shapes as actual buildings were mounted in an urban terrain with neighboring buildings. Some of the simulations were performed using commercial codes but most of them were done using home-made codes.

## 2 ACTIVITIES OF RESEARCH COMMITTEE ON WIND-INDUCED DISASTER, JAPAN ASSOCIATION FOR WIND ENGINEERING (JAWE)

(http://www-windlab.ce.tokushima-u.ac.jp/kaze-saigai/)

Recently, many typhoons and tornados have caused severe damage to buildings, structures, crops, etc in Japan. Some have caused significant economic losses. Table 1 shows claim payments for weather-related disasters. Lessons learned from disasters can greatly contribute to countermeasures against future natural calamities.

Table 1 Claim payments for weather-related disasters (The General Insurance Association of Japan)

(in billions of yen)

| Name of Disaster | Place | Date | Claims Paid (incl. estimates) |
|---|---|---|---|
| Typhoon No. 19 | Nationwide | Sep. 26-28, 1991 | 567.9 |
| Typhoon No. 18 | Nationwide | Sep. 4-8, 2004 | 387.4 |
| Typhoon No. 18 | Kumamoto, Yamaguchi, Fukuoka, etc. | Sep. 21-25, 1999 | 314.7 |
| Typhoon No. 7 | Kinki | Sep. 22, 1998 | 160.0 |
| Typhoon No.23 | Western Part of the Nation | Oct. 20, 2004 | 138.0 |
| Typhoon No.13 | Fukuoka, Saga, Nagasaki, Miyazaki, etc. | Sep. 15-20, 2006 | 132.0 |
| Typhoon, No.16 | Nationwide | Aug.30-31, 2004 | 121.0 |
| Downpour, Sep.2000 | Aichi etc. | Sep. 10-12, 2000 | 103.0 |

The Research Committee on Wind-Induced Disaster (RCWD), Japan Association for Wind Engineering, was founded in 1998 to organically cope with many problems related to wind-induced disasters. The aims of RCWD are as follows:

1) To establish investigation methods from which useful information can be secured.
2) To collect and analyze information of damage caused by strong winds.
3) To prevent or mitigate the effects of disasters.
4) To establish technologies to predict and prevent disasters.

5) To carry out positive awareness activities for administrative officials and citizens as well as for specialists, and to implement collaborative work.
6) To establish networks for the prevention or mitigation of disasters extending from villages, towns and cities to the world.

| | | | |
|---|---|---|---|
| Building Name | | | |
| Address | | | |
| Building Use | ☐Single Family ☐Duplex ☐Apartment ☐Warehouse ☐Commercial ☐Industrial Other___ | | |
| Construction | ☐Wood ☐Reinforced Concrete ☐Steel ☐Masonry Other________ | | |
| No. of Stories | | Building Layout | ☐ I ☐ L ☐ U ☐ H ☐ T Other______ |
| Roof Shape | ☐Gable☐ Hip ☐Gable/Hip Comb. ☐Flat ☐Mono-slope ☐Mansard Other_______ | | |
| Roof Pitch | ☐Shallow (< 1.5/10) ☐Moderate (1.5/10 – 3.5/10) ☐Steep (> 3.5/10) | | |
| Type of Roof Covering | ☐Tile☐Asbestos Cement Slate ☐Corrugated Asbestos Cement Board ☐Standing Seam Metal ☐Folded Plate ☐Other Metal Other______________ | | |
| Roof Damage | Covering | ☐Ridge ☐Eaves ☐Verge ☐Corner ( $m^2$) Other________ ( $m^2$) | |
| | | Damage Rate (Total) | ☐ <10% ☐10 - 25% ☐25 – 50% ☐ 50 – 75% ☐ >75% |
| | Sheeting | ☐Ridge ☐Eaves ☐Verge ☐Corner ( $m^2$) Other________ ( $m^2$) | |
| | | Damage(Total) | ☐ <10% ☐10 - 25% ☐25 – 50% ☐ 50 – 75% ☐ >75% |
| | Frame | ☐Rafter ☐Truss ☐Roof to Wall Connection Other _____________ | |
| Exterior Wall | ☐Mortar☐Asbestos Cement Slate ☐Corrugated Asbestos Cement Board ☐Metal Sheet ☐Folded Plate ☐Board Other _____________ | | |
| Wall Damage | Location and Damage | ☐Corner ( %) ☐Edge ( %) ☐Central ( %) | |
| Opening Damage | ☐Window ( ) ☐Door ( ) ☐Shutter ( ) | | |
| Remarks | | | |

Fig. 1 Survey form for building damage.

The RCWD was organized by approximately 50 members, mainly researchers and engineers in the fields of meteorology, civil engineering, transportation, agriculture, insurance and others. The practical activities of the committee are as follows:

1) *Damage investigation*. Once a wind-induced disaster has occurred somewhere in Japan, the damage is investigated by members of the RCWD using a common manual. The survey form for building damage investigation is shown in Fig. 1. The result is reported at a meeting of RCWD, which is held four times a year, and on the web pages of the RCWD. Furthermore, an Annual Report is published once a year (see Fig. 2), in which wind-induced disasters are summarized. For large-scale and/or severe disasters, damage investigation teams are organized by the RCWD and the investigation results are published (see Fig. 3).
2) *Actions for publicity to society and local communities*. By means of seminars, forums, lectures and so on, which are usually organized with local governments, the outcomes of RCWD are conveyed to various constitutions of society, for example, in Nobeoka and Saroma in 2007, Saga and Tokushima in 2008, and Kumamoto and Kochi in 2009. Many administrative officials and citizens participate and discuss disaster prevention. A textbook based on an elaborate revision of the original version of "*Changes and Lessons in Strong Wind-Induced Disaster*" will be published by RCWD next year, and will be used in the forums.

3) *Accumulation and analysis of past wind-induced disaster records*. Reports on past wind-induced disasters were collected to construct a database. Any member of the JAWE can use the data and carry out analysis from various viewpoints: meteorological conditions; wind characteristics; forecast and alert; damaged objects (structures, agricultural products, traffics and lifelines, etc.); and influence on society, economy and human behavior.


Fig. 2 Annual Report 2008 by RCWD, JAWE

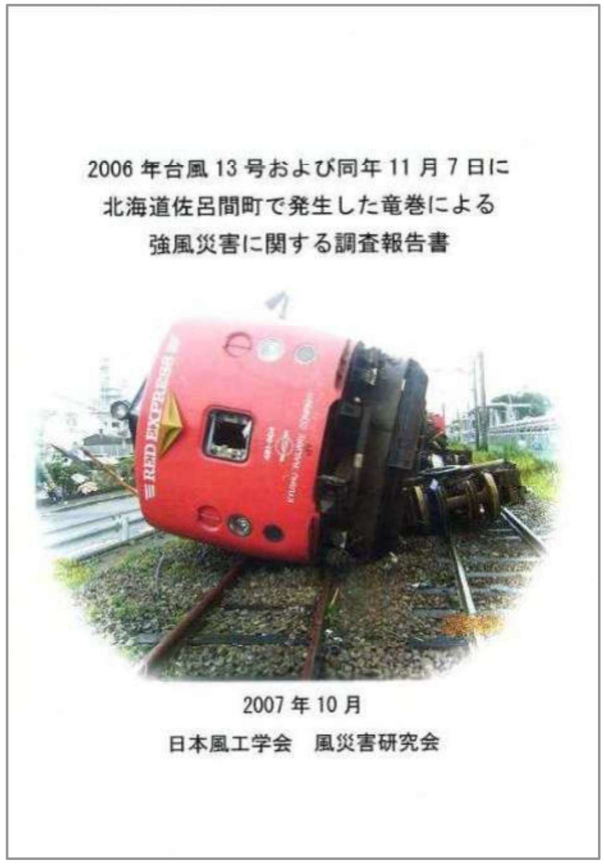


Fig. 3 Report on wind-induced disasters caused by Typhoon 16 of 2006 and Saroma Tornado on November 7, 2006, published by RCWD, JAWE, in October, 2007

## 3 NEW NATIONAL PROJECT FOR MAINTENANCE OF BUILDING CODE IN JAPAN

### 3.1 *Outline*

A new project to promote maintenance of the Building Standard Law of Japan sponsored by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) started in August, 2008. It had 21 tasks. One of them related to studies on rationalization of wind load and wind resistance design, which was carried out as a cooperative study with the Building Research Institute.

In order to carry out the project, driving institutions were recruited from the public. The Wind Engineering Institute and the Japan Housing and Wood Technology Center applied jointly with a proposal. Three items were proposed for the study: (1) complement of aerodynamic force/pressure coefficients, (2) improvement of method for evaluating wind resistance performance of cladding and components of a building and (3) rationalization of the structural design of tower-like structures. In order to carry out the study, a committee and three working groups composed of academic experts and practical engineers were proposed. One working group was in charge of each study item.

As a result, a joint proposal was adopted and they became the driving institutions for the theme related to wind. A committee chaired by Y. Tamura was formed and three working groups were organized.

### 3.2 *Working Group on Wind Force/Pressure Coefficients*

For the estimation of design wind load based on the Building Standard Law of Japan (hereafter referred to as BSLJ), wind force/pressure coefficients should be given. Wind force coefficients for fundamental building shapes are given in the BSLJ, but wind force coefficients with complex building shapes are not given. Furthermore, when the BSLJ was revised in June 2007, separate estimations of wind loads for main structural frames and for cladding and components were required. Thus, the wind force/pressure database given in the BSLJ needed enrichment. In this way, investigation for enhancement of the wind force/pressure database started as a 3-year consecutive study.

In 2008, the wind force/pressure coefficients given in the BSLJ were re-checked to clarify deficiencies, and literature surveys of the following items were made:

(1) Peak wind force coefficient for hip roofs and roofs with eave
(2) Peak wind force coefficient for lozenge and triangle sectional building
(3) Influence to the wind force on roof with parapet
(4) Peak wind force coefficient for roof tiles and slate roofing
(5) Peak wind force coefficient for eaves, under the eaves and guard fence of balcony
(6) Estimation method of wind force coefficient for double skin facade with small unit type
(7) Peak wind force coefficient for solar panels on roof
(8) Peak wind force coefficient for advertising boards and fins on wall
(9) Wind force coefficient of flags

As the data listed above were not necessarily sufficient, further aerodynamic data to compensate for the lack of information in the BSLJ should be accumulated by conducting wind tunnel studies and investigations. Wind tunnel tests will be conducted for hipped roofs and roofs with eaves.

### 3.3 *Working Group on Evaluation of Wind Resistance Performance of Cladding and Components*

In Japan, there were indefinite areas with regard to the responsibility of the designer, the constructer and building material makers for structural members and building envelope elements. However, attachment of structural calculations and documents on building envelope elements in the design approval process were specified in the revised BSLJ in June 2007 as follows:

(1) Lists of building envelope elements (materials, region, structural performance of materials etc.)
(2) Documents on wind loads on building envelope elements
(3) Documents on structural calculations for building envelope elements

Designers have been responsible for the structural safety of building envelope elements as well as structural members in buildings. Building material makers also have to provide designers with information on the structural performance of materials.

In this working group, an investigation and questionnaire study on the current status of wind resistance design of building envelope elements were conducted. Questionnaires on the application area, required performance, structural method and structural calculation for building envelope elements, etc, were sent out to each building materials industry, such as clay tile roofing, slate roofing, metal roofing, asphalt single roofing, membrane waterproofing, sash, shutter, door, window glass, metal siding, ceramic siding, ALC panel, etc.

A method for estimating the structural safety of building envelope elements that building materials industries provide will be determined, and standard testing methods on the structural safety of building envelope elements will be proposed. A method for testing the impact resistant performance against wind-borne debris will also be discussed.

### 3.4 ***Working Group on Tower-like Structures***

The BSLJ provides a prescription for tower-like structures such as chimneys and towers for advertisements. It is a Notification of the Ministry of Construction on Structural Calculation for Structures, 2000. It covers design wind loads, design seismic loads and structural calculations. Dynamic characteristics of structures have some influence on the loads. However, the notification does not seem to adequately reflect the influence on its design load prescriptions.

In 2008, actual conditions of structural design of tower-like structures were proposed, including basic data such as dynamic characteristics, shape, and so on of chimneys and wind turbine towers. Relevant domestic and foreign guidelines, regulations, recommendation were also surveyed.

#### 3.4.1 *Chimney*

Steel and reinforced concrete are major structural materials. Steel chimneys include the steel tower supported type, the multi-leg type and the self-supported type. RC chimneys are commonly of the self-supported type.

Most are cylindrical, but other shapes are used for harmonization with the environment. These include cantilever structures, and given their plastic deformation, they are prone to instability.

Items requiring attention in structural design of steel structural chimney are:
- Wind loads are major external ones.
- Open terrain area is commonly selected for construction sites.
- Lower structural damping compared with ordinary buildings.
- Thermal effects are fairy large because of constant heated smoke emission.
- Local buckling should be taken into structural consideration because the stack comprises a thin shell.
- The open mouth is a structural weak point.

Items requiring attention in structural design of RC structural chimney are:
- Seismic loads are major external ones.
- Crosswind load is more important than along-wind load. Crosswind load is sometimes greater than seismic load.

### 3.4.2 *Wind Turbine Tower*

Construction sites selected for wind turbines are commonly windy. Local topographic effects should be taken into consideration for design wind velocity. Control system effects, which change wind loads on wind turbine towers, should also be taken into account.

Wind turbines may stop operation under strong wind conditions and change their direction and blade pitch in order to reduce wind loads. Therefore, wind load during operation during non-extreme wind speeds can sometimes be greater than wind load during extreme wind speeds. The possibility of power-off of the control system should be also taken into consideration in structural design. Structural damping of the tower is smaller than that for ordinary buildings. They are generally top-heavy and therefore high stresses may arise at connections between the tower and its basement. In determining seismic load design, wind load during operation also has to be taken into consideration.

## 4 OUTLINE OF RESEARCH ON EVALUATION OF TORNADO EFFECTS ON NUCLEAR FACILITIES IN JAPAN

Tornadoes and other local meteorological disturbances affect small areas but cause severe and extreme damage to people and structures. Against such meteorological disturbances, countermeasures taken by individuals and public administrations, and design methods implemented in th wind resistant design in Japan, have been insufficient compared to those in the US.

It has been considered that most tornadoes in Japan are a sort of water spout and that big tornadoes caused by super-cells are seldom generated. In recent years, however, extremely severe damage induced by tornadoes has occurred frequently in Japan. It has been suggested that some of them were generated by the same climates as super-cells. According to tornado damage reports, their major causes have been related to wind-borne debris, unlike those of typhoons and normal winds.

As stated above, analysis and studies are required to ensure safety of nuclear facilities, considering the characteristics of Japanese tornadoes. Estimation is also required whether the countermeasures like those carried out in the US are necessary or not.

In Japan, studies on tornado effects on nuclear facilities started in 2008. Research items included tornado risk modeling, tornado effects on nuclear facilities and a design-based tornado model, study on existing foreign guidelines on tornado effects and trials for making guideline drafts.

### 4.1 ***Tornado risk modeling***

In order to evaluate the occurrence rate of tornadoes and to study their distribution in Japan (see Fig.4), a historical tornado database was created based on the Japanese Meteorological Agency data and original investigated data. This database showed a wide variety and large number of events, because the recording conditions changed for three different periods. These periods were from 1961 to 1990, from 1991 to 2006, and 2007 and later (see Fig.5). To capture the actual situations of tornadoes, the latest dataset should contain more tornadoes. The geographical conditions for tornado generation were studied. It was found that the observed number within 10km of the seacoast was significant, as shown in Fig. 6. It was also found that the Fujita-scale was closely related to the amount of damage, the damaged area and the length of the tornado’s path, while clear relations were not seen between the

Fujita-scale and the translation direction, the position relative to synoptic disturbance which cause tornadoes, and climate conditions.

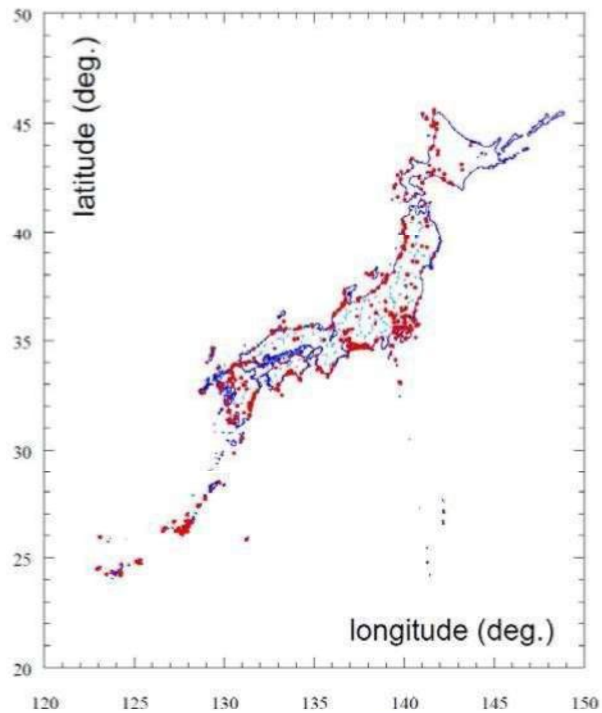


Fig.4 Position of tornado generation in Japan (1961-2008)

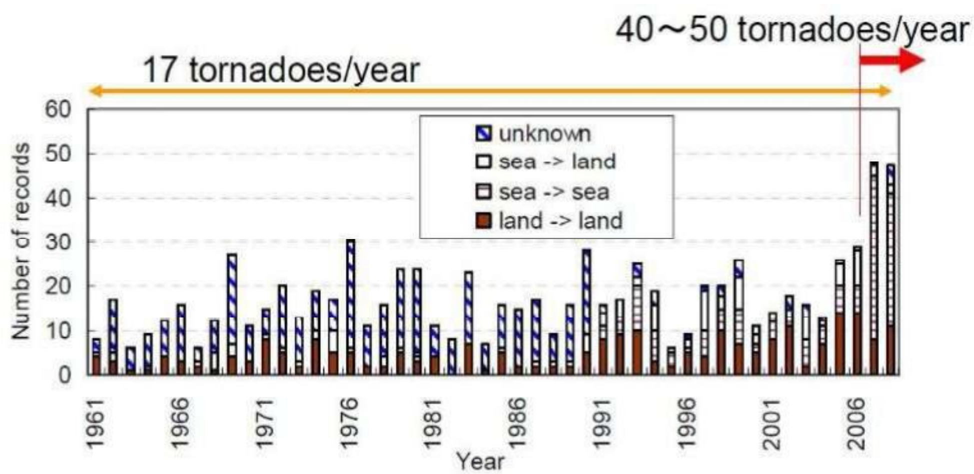


Fig.5 Annual number of tornado records in Japan

## 4.2 *Tornado effects on nuclear facilities and design base tornado model*

Transient aerodynamic effects of gusty winds were investigated. It was found that sudden wind speed change generated more aerodynamic force than stationary winds. It was recognized as "overshoot of aerodynamic force" and could have occurred in full scale structures. It was considered that the level of overshoot was related to non-dimensional rise time. These transient effects should be considered for the tornado effects on nuclear facilities.

The wind pressure distribution was studied using past wind pressure data obtained from a wind tunnel experiment where scaled tornado-like flow was generated. Despite the limited case of the experiment, concentric pressure patterns and higher suctions on the roof were observed.

Investigation into past tornado disasters showed that wind-borne debris was the major factor in damage to building structures. The origins of wind-borne debris were studied from the tornado database. Small compact objects such as gravel and pieces of broken roof tiles were identified. Metal roof covers, advertising boards and outdoor units of air conditioners were recognized as big objects. Pieces of broken buildings including the contents of buildings, traffic sign boards, tree branches and cars were recognized as flying debris. There were also records of flying prefabricated buildings, warehouses and container boxes.

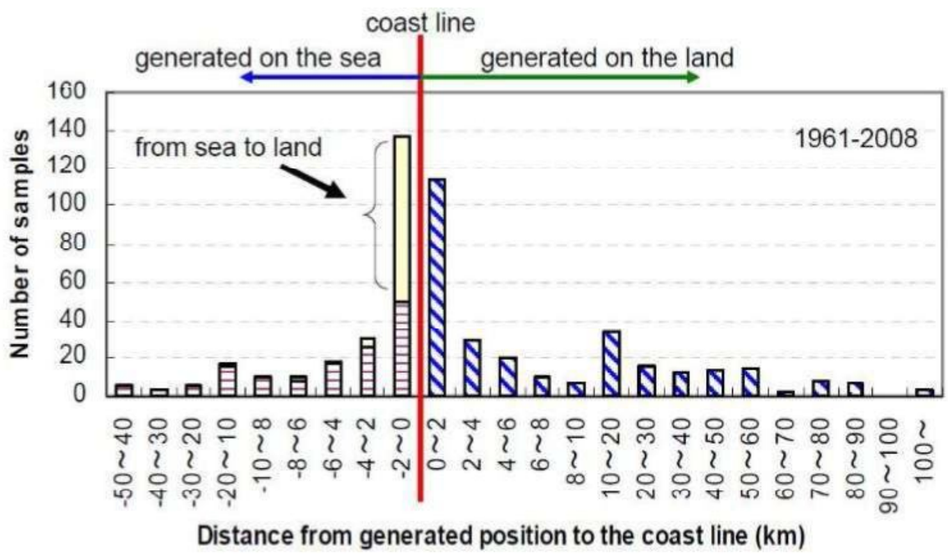


Fig.6 Tornado observed positions in Japan

To identify the characteristic parameters of tornadoes through study of meteorological theory and full scale observation of tornadoes, some parameters were selected as important parameters that characterize tornadoes. In the full scale observation, it was very hard to observe or measure the tornadoes directly. By post damage investigations and remote sensing such as Radar observations, vortices near the ground were estimated as Fujita-Pearson scale, sizes of funnel clouds or tornado vortices, translation speeds, maximum wind speeds, high speed durations and sizes of meso-cyclones. These parameters were studied using Doppler-Radar observation records.

### 4.3 *Study on existing foreign guidelines of tornado effects*

Most guidelines were from the US. The guideline "USNRC (Design Basis Tornado for Nuclear Power Plants, Regulatory Guide)" in the US and its references were studied. The following nine items were thus recognized as important factors: occupied area of facilities, tornadoes paths and widths, zoning of design base wind, process of evaluating tornadoes, statistic period for evaluating tornado occurrence rate, variety of affected wind-borne debris, evaluation of tornadoes generated over the sea and actual conditions of nuclear facilities.

As stated above, researches on tornado risk modeling, tornado effects on nuclear facilities and design base tornado model, study on existing foreign guidelines of tornado effects started in 2008 and are continuing.

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