Japanese Country Report 2012

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ABSTRACT: This paper reviews domestic activities in the wind engineering field in Japan for two years 2010 - 2012, 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 Component, Wind-induced Disaster, Building Code, Tornado, Nuclear Facility, Base-isolated Building

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

The AIJ Wind Loading Committee (chaired by Y. Uematsu from April 2012) consists of four working groups: Working Group on Design Wind Speed, Working Group on Wind Pressure/Force Coefficients, Working Group on Wind-induced Response and Working Group on Wind Load Estimation by CFD. The following describes the activities of each working group during the past year. This committee has been discussing the revision of AIJ-RLB-2004 planned for 2014.

Fig.1.1 AIJ-RLB-2004 Software

1.1 *Working Group on Design Wind Speed*

This WG (chaired by M. Matsui) has been investigating the possibility of introducing the seasonal factor to design wind speed and the duration of strong wind events.

1.2 *Working Group on Wind Pressure/Force Coefficients*

This WG (chaired by Y. Uematsu) has been trying to enrich peak pressure information on various building configurations for cladding/component design. This WG consists of two Sub-WGs: Spatial and Temporal Fluctuation Characteristics of Wind Forces acting on Cladding/Components; and Performance Evaluation and Testing Methods for Cladding/Components.

1.3 *Working Group on Wind-induced Response*

This WG (chaired by H. Kawai) has been investigating simpler but accurate response evaluation methods for along-wind, crosswind and torsional responses of buildings and structures. It is also studying the Equivalent Static Wind Loads corresponding to the along-wind, crosswind and torsional components, as well as the ESWL for roof structures and the combination effects of those wind load components.

1.4 *Working Group on Wind Load Estimation 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. The objectives of this working group (chaired by T. Tamura) are to reveal the applicability and effectiveness of CFD-based wind load estimation for structural design, 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.

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, local storms caused by tornados, downbursts and others have caused severe damage to buildings, structures, crops, etc in Japan. Lessons learned from disasters can greatly contribute to countermeasures against future natural calamities. 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.

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 following report on the North Kanto Tornado on May 6, 2012, is an example of practical activities of the RCWE in 2012.

2.1 *Post-Disaster Investigation of North Kanto Tornadoes on May 6, 2012*

2.1.1 *Outline of North Kanto Tornadoes*

Four tornadoes, shown in Table 2.1, occurred on May 6, 2012, in the north part of the Kanto area. The information shown in Table 2.1 is given by the Japan Meteorological Agency (JMA) homepage. Figure 1 shows the locations of these four tornadoes. Damage statistics by JMA are shown in Table 2.2. Figure 2.2 shows the estimated tornado path.

Table 2.1 North Kanto Tornadoes on May 6, 2012, by JMA

Tornado	City or Town [Prefecture]	F-scale by JMA	Damaged Area L×W
1	Joso, Tsukuba [Ibaraki]	F3 *	17km × 0.5km
2	Chikusei, Sakuragawa [Ibaraki]	F1	21km × 0.6km
3	Mooka, Mashiko, Motegi [Tochigi] Hitachi-omiya [Ibaraki]	F1 – F2	32km × 0.65km
4	Ohnuma [Fukushima]	F1	2km × 0.3km

* NOTE: F4 according to TPU investigation.

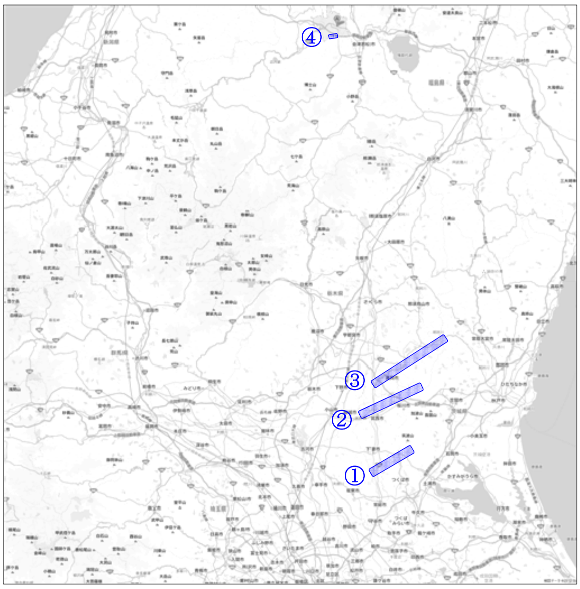


Fig. 2.1 Locations of tornado-damaged areas

Table 2.2 Damage statistics of North Kanto Tornadoes on May 6, 2012

Prefecture	City	Human		Damage to Residences			Damage to Non-residential buildings		
		Dead	Injured	Totally	Half	Partially	Totally	Half	Partially
Ibaraki	Tsukuba	1	37	76	158	388	105	60	243
	Joso	0	0	0	0	12	0	0	16
	Chikusei	0	1	0	0	115	7	1	104
	Sakuragawa	0	2	0	1	29	9	1	42
	Hitachiomiya	0	1	0	1	18	5	1	30
Tochigi	Mooka, Mashiko, Motegi	0	11	13	34	420		453	
Fukushima	Aizumisato	0	0		3			16	

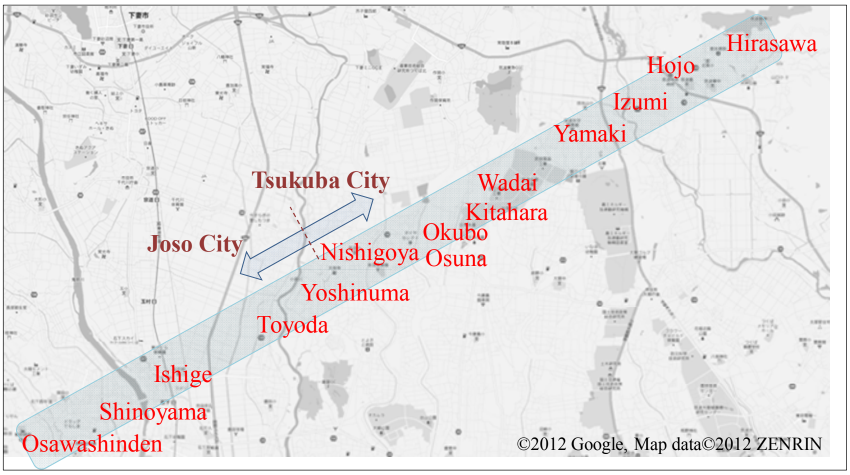


Fig. 2.2 Damaged area in Joso city and Tsukuba city

2.1.2 *Estimation of Wind Speed from an Overturned 2-story Residential Wooden House with Foundation Slab* (Tamura et al., 2012)

2.1.2.1 Damage scenario

The superstructure and foundation of a 2-story wooden house were both overturned due to the tornado. The 1st floor was crushed to the foundation, and the 2nd floor was turned upside down and was lying on a rice field. The building had a hip roof. The northern side of the building faced a national road, while all other sides faced rice fields. The building was built on an embankment.

Figure 2.3 shows traces of slippage of the house caused by wind forces, suggesting rotational movement.

(a) View from east (b) View from west (c) View from south-west

Fig. 2.3 Trace of slippage and linear lump of soil formed due to slippage (Tamura et al., 2012)

As shown in Figs. 2.3(b) and 2.3(c), the house slipped and rotated counterclockwise from its original position to the black line in Fig. 2.3(c). The reason for the counterclockwise rotation was considered to be the degree of fixity. There was a stump around point "A" shown in Fig. 2.3(c), so the friction that counteracted slipping was higher at this point than at other parts. The slippage generated a linear lump of soil along the edge, which stopped the slipping movement, causing the house with its foundation to overturn around the black line shown in Fig.2.3(c). As the house overturned, the undersurface of the foundation slab directly faced the oncoming wind. The strong wind created a drag force that pushed the building about 3m.

Consequently, the 2nd floor and roof fell toward the rice fields and turned upside down. Most of the wooden frame members such as rafters remained on the east side of their original position. It was assumed that the house's collapse started immediately after overturning.

2.1.2.2 **Geometry of overturned 2-story wooden house**

Due to privacy concerns, the actual plans and elevations cannot be described or shown in this paper. Thus, only schematic views are shown in Fig. 2.4. The width, breadth, and height are 9.0m, 6.3m, and 6.0m, respectively. The height of the foundation is 0.4m.

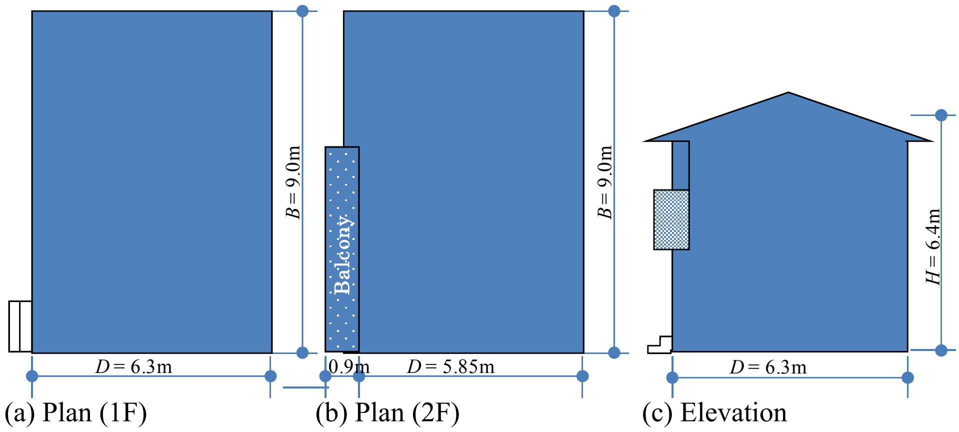


Fig. 2.4 Outline of overturned 2-story hip roof wooden house (Tamura et al., 2012)

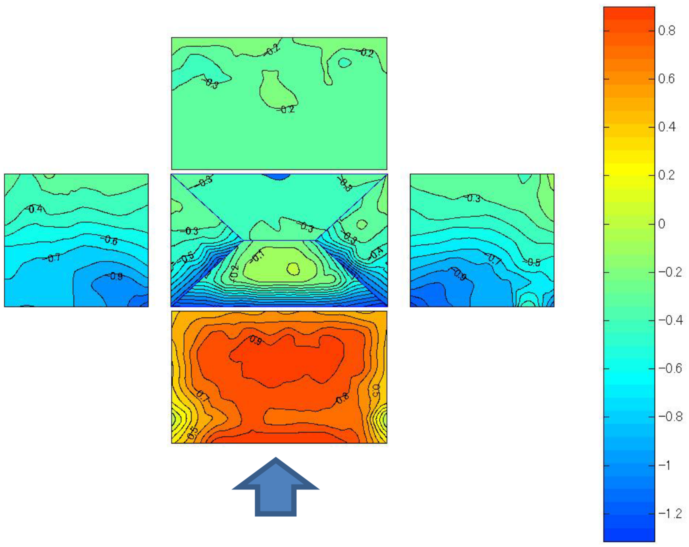


Fig. 2.5 Example of wind pressure distribution (Hip roof, Roof slope: 27 degrees)
(TPU Aerodynamic Database; http://wind.arch.t-kougei.ac.jp/system/contents/code/tpu)

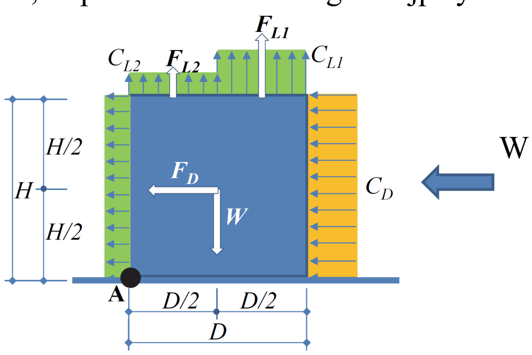


Fig. 2.6 Assumption for calculating critical overturning wind speed

The house's weight was calculated using typical material weight specifications. However, for the estimation of critical wind speed, a range of values was adopted. The total weight, inclusive of both superstructure and foundation, was then assumed to be between 595kN and 737kN. The lower bound value (595kN) was roughly estimated based on unit weights of 4 kN/m^2 and 4.4 kN/m^2 for the upper structure and foundation, respectively, resulting in weights of 333kN and 262kN, respectively. The upper bound value (737kN) was based on a more detailed estimation, where the foundation height (including an embedment length of 25cm) and foundation thickness were assumed to be 65cm and 15cm, respectively. Considering that the exterior wall was made of mortar finishing on metal lath and floors were made of wood, the weight of the superstructure and foundation were calculated to be 429kN and 308kN, respectively.

2.1.2.3 **Aerodynamic coefficients and calculation of critical overturning wind speed**

The mean pressure coefficients shown in Fig. 2.5, based on values from the TPU Aerodynamic Database, were used for estimating external forces.

Simulating the scenario described before, the critical overturning wind speed was calculated by assuming equilibrium of moments about point A, as shown in Fig. 2.6. W (kN) is the total weight of the structure, including the foundation. C_D, C_{L1}, and C_{L2} are the drag force coefficient, the wind force coefficient for the roof on the windward side, and the wind force coefficient for the roof on the leeward side, respectively. Aerodynamic wind force coefficients based on Fig. 2.5 are then as follows:

$C_D = 1.0$ for F_D (N),

$C_{L1} = 0.49$ (Negative value) for F_{L1} (N)

$C_{L2} = 0.31$ (Negative value) for F_{L2} (N)

With $B = 9.0$ m, $D = 6.3$ m, $H = 6.4$ m, and $W = 595$~737 kN, the overturning critical wind speed V_{OT} is estimated as:

$V_{OT} = 109$~121 m/s

Incidentally, assuming that the roof was blown off before the structure started to overturn, V_{OT} could be higher. For this paper, it is assumed that the entire structure of the house was overturned at the same time as the roof was being blown off. Furthermore, note that if the roof were flat, C_{L1} would become 1.1 (negative pressure) and C_{L2} would become 0.5 (negative pressure), and thus V_{OT} would be between 94 m/s and 105 m/s.

As mentioned above, the calculated V_{OT} was higher than expected. To confirm the calculated value of V_{OT} , a wind tunnel experiment was conducted. The Tachikawa number maintained compatibility with the real situation, and a flat roof was used for the model. In the experiment, when the wind speed was gradually increased, the test model started to rotate and move sideways around the calculated critical wind speed.

In the calculation presented here, a stable horizontal wind was assumed to be acting on the structure. This means that an equivalent instantaneous wind speed was calculated for consistency with the estimation of the Fujita F scale. From this standpoint, the wind speed around the dwelling can be classified as F4, or no lower than F3. As mentioned earlier, the house was surrounded by flat land, or more specifically, by rice fields. There were no obstacles around the house, so the strong wind struck it directly.

On the other hand, when a tornado is approaching, wind speeds increase suddenly and change dramatically. On such occasions, it is well known that the increase in aerodynamic forces closely compares with those for the uniform flow case.

When such a situation is considered, the overturning critical wind speed V_{OT} (m/s) is

V_{OT} = 72m/s～80m/s

The Fujita scale is then estimated to be F3. To estimate the wind forces under this situation, the size of the tornado core, the building location with respect to the center of the core, and the translational speed of the tornado are required. More discussions are necessary to estimate these results using this theory. Tornadoes are highly localized. Therefore, an overestimation of the F scale of the entire tornado can be made using this logic.

In any case, the traditional estimation method for the tornado's scale (F-scale) classifies according to an equivalent wind speed based on the damage level due to more stable strong winds such as typhoons.

As additional information, assuming that the house was lifted by the tornado, the wind velocity should have been higher than 200m/s, which is not a realistic assumption. This conclusion can likewise be derived in the investigations.

The estimation method in this paper is based on an equivalent horizontal wind speed. It can be said that when the Japanese-style Enhanced Fujita Scale, instead of the original Fujita Scale, is discussed and proposed, more detailed investigations and studies related to the structures, the pressure characteristics, and the aerodynamic forces due to the tornado, and to structural behavior under impulse loading, and many others, may be necessary.

2.2 *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,

- The 10th Wind Disaster Reduction Forum in Miyazaki, November 23, 2010 with special reference to Nobeoka Tornado in 2006
- The 11th Wind Disaster Reduction Forum in Okinawa, September 22, 2011 with special reference to the East Japan Earthquake and Tsunami Disaster on March 11, 2011
- The 12th Wind Disaster Reduction Forum in Saroma, November 7, 2011 with special reference to Saroma Tornado in 2006
- The 13th Wind Disaster Reduction Forum in Tokyo, December 5, 2011, Revised version of *Changes and Lessons in Strong Wind-Induced Disaster published in 2011*
- The 14th Wind Disaster Reduction Forum in Okinawa, October 10, 2011 with special reference to North Kanto Tornadoes on May 6, 2012

Many administrative officials and citizens have participated in and discussed disaster prevention. A textbook based on an elaborate revision of the original version of "*Changes and Lessons in Strong Wind-Induced Disaster* (2000)" was published by RCWD in 2011.

Annual reports No.8 and No.9 were published by RCWD as shown in Fig.2.7.

Fig.2.7 Annual reports for 2010FY and 2011FY by RCWD, JAWE

3 NATIONAL PROJECT FOR MAINTENANCE OF BUILDING CODE IN JAPAN

3.1 *Outline*

A project to promote maintenance of the Building Standard Law of Japan (BSLJ) 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. A committee chaired by Y. Tamura was formed and three working groups were organized.

3.2 *Activities in 2011FY and 2012FY*

In the national project for maintenance of the BSLJ in 2011, investigations were carried out by two working groups: (1) WG on Evaluation of Wind Resistance Performance of Cladding and Components and (2) WG on Seismic Response of Chimneys and Towers. In 2012, investigations were carried out by 3 additional groups: (3) WG on Topographic Effects for Design Wind Speed, (4) WG on Seasonal Effects for Design Wind Speed, and (5) WG on Member Vibrations. The main activities of each group are as follows.

(1) WG on Evaluation of Wind Resistance Performance of Cladding and Components (2008~2012)
Method for evaluating wind resistant performance of cladding and components
(2) WG on Seismic Responses of Chimneys and Towers (2012)
Arrangement of technical data for structural analysis using the seismic-response- spectrum method for chimneys and wind turbine structures
(3) WG on Topographic Effects for Design Wind Speed (2011, 2012)
Investigation of the influence of geographical features on design wind speed
(4) WG on Seasonal Effects for Design Wind Speed (2012)
Investigation of reduction of design wind speed by season effect for temporary structures
(5) WG on Member Vibrations (2012)
Providing information for judgment of vortex induced vibration, wind load for vortex induced vibration and fatigue evaluation method.

3.3 *Working Group on Wind Force/Pressure Coefficients (2008~2010)*

Activities of the working group on wind force/pressure coefficients finished in 2010. The following wind force /pressure coefficients were suggested by this working group.

a) Wind force coefficients for roof structure
b) Peak wind pressure coefficients of cladding for hip roof
c) Wind force coefficients for roofs with eaves
d) Wind force coefficient for billboard on roof
e) Wind force coefficient for Balcony Handrail
f) Wind force coefficient for solar panel

Wind force / pressure coefficients, b) Peak wind pressure coefficient of cladding for hip roof and d) Wind force coefficient for billboard on roof are introduced.

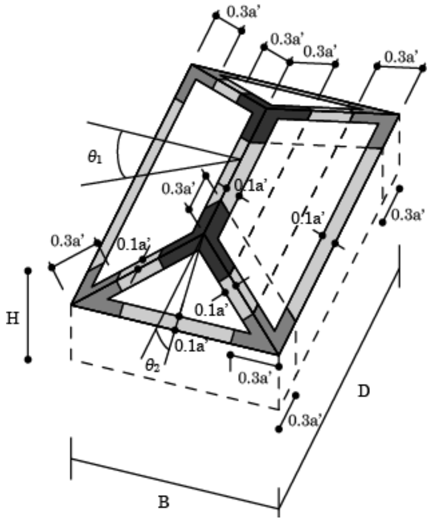
From the results of wind tunnel tests of hip roofs, wind pressure coefficients are suggested by the working group as shown in Fig.3.1. Wind pressure coefficients for the back side of the eaves are also proposed as shown in Table 3.1.

For billboards 4m or higher, it is necessary to estimate wind load in accordance with BSLJ. However, no wind force coefficient is given for billboards in the BSLJ. Thus, wind tunnel experiments for billboards on a roof were carried out to determine appropriate coefficients.

Experiments were carried out under the following conditions:

a) Building height 30m or less
b) Billboard height 8m or less
c) Space between billboard and roof: 1m or less

Four types of billboard, type I, type L, type C and closed type, were tested as wind pressure models in wind tunnel tests as shown in Fig.3.2. The boards were divided into three zones: end zone, corner zone and center zone as shown in Fig.3.3. The end zone and corner zone were defined in the range of 5m in from the end or the corner of the board as shown in Fig.3.4. The remaining zone was called the center zone. The wind tunnel test results yielded wind force coefficients as shown in Table 3.2.



Zone \ Roof pitch	10 degrees or less	20 degrees	30 degrees or more
	−2.5	−2.5	−2.5
	−3.2	−3.2	−2.5
	−4.3	−3.2	−3.2
	−3.2	−5.4	−3.2

Fig. 3.1 Peak pressure coefficient for hip roof

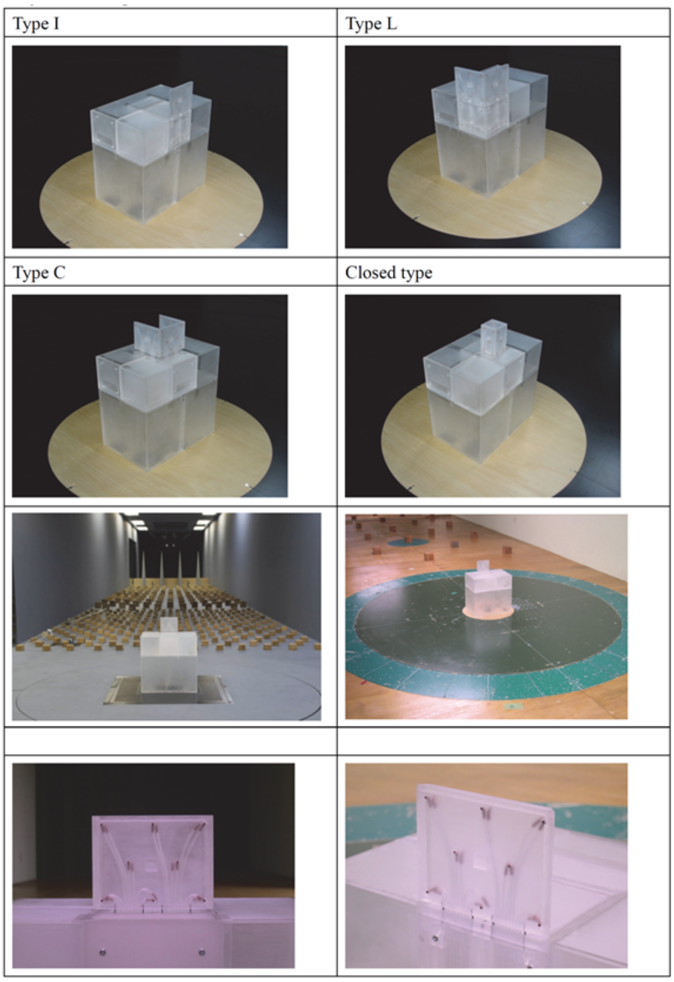


Fig. 3.2 Wind pressure model for billboard on roof

Table 3.1 Peak pressure coefficient for undersurface of eaves

Positive	0.8Gpe
Negative	−2.1

NOTE: Gpe is specified in BSLJ-Notice No.1458

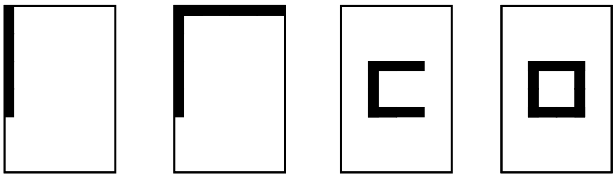


Fig. 3.3 Plan shape of billboard: Type I, L, C and closed type

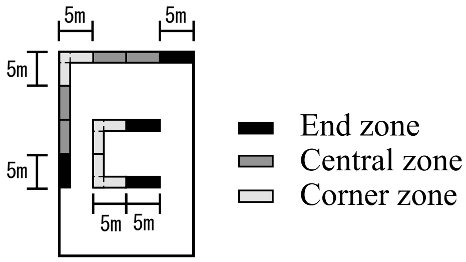


Fig. 3.4 Zones of billboard

Table 3.2 Peak wind force coefficient of billboard on roof

Plan shape		Type I	Type L	Type C	Closed type
End zone	Positive	−7.0	6.5	4.5	
	Negative	−6.0	−5.5	−6.0	
Corner zone	Positive		5.5	5.0	5.0
	Negative		−5.5	−5.0	−3.5
Center zone	Positive	6.0	5.0	4.5	4.5
	Negative	−4.0	−5.5	−4.0	−3.0

3.4 *Working Group on Evaluation of Wind Resistance Performance of Cladding and Components (2008~2012)*

In this WG, a questionnaire survey and hearing investigation were conducted on the building-materials manufacturer's organization (Table 3.3). The scope defined by demand performance, construction method, calculation method, etc., of claddings was investigated. Based on this survey and investigations, a confirmation sheet for structural calculations for cladding and components was suggested from this WG. This confirmation sheet assists in understanding the range of each cladding along with the loading pass.

A confirmation sheet, which easily identifies the range of calculation for cladding, is proposed. The cladding system is represented as the same order as the load pass of the wind load from cladding surface to structural member.

3.5 *Working Group on Seismic Responses of Chimneys and Towers (2012)*

This group investigated wind forces on chimneys and wind turbine structures from 2008 to 2010. The applicability of the seismic-response-spectrum method for chimneys and wind turbine structures is investigated in 2012.

3.6 ***Working Group on Topographic Effects for Design Wind Speed (2011, 2012)***

The design wind speed shall be affected by topographic effect. CFD techniques have been increasingly used for estimation of wind speed affected by topography. The following terms are investigated by CFD techniques in this working group.

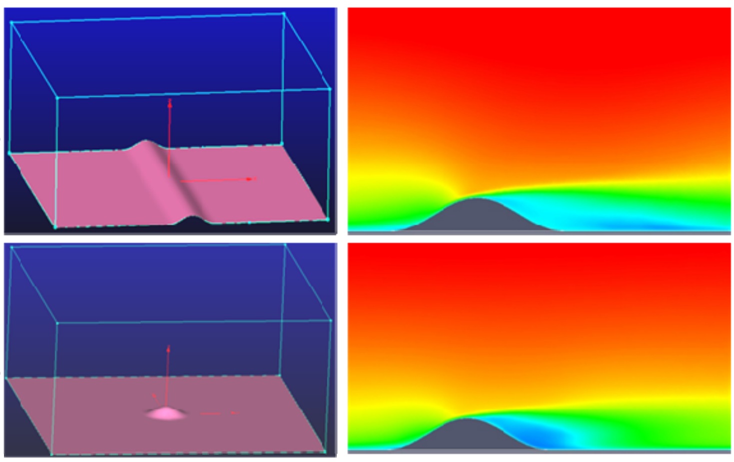
(1) Proposal of benchmark test for performance evaluation of CFD program
(2) Arrangement of conditions for applying appropriate CFD calculations
(3) Establishment of database for increasing wind speed area from the results of CFD calculations

Table 3.3 Building-materials manufacturer organization which conducted a questionnaire survey and hearing investigation

	Building-materials	Manufacturer organization
1	Clay roof tile	Zentouren
		Zengaren
2	Roof with slate	NPO Japan Exterior Furnishing Technical Center
3	Metal roofing Folded-plate roofing	Japan Metal Roofing Association
4	Sheet copper roofing	Japan Copper Development Association
5	Asphalt shingle roof	Asphalt Roofing Kougyokai
6	Waterproof by synthetic polymer	KRK
7	Window sash	Japan Sash Manufactures Association
8	Roll-up door	Japan Rolling Shutters & Doors Association
9	Flat glass	Flat Glass Manufactures Association of Japan
10	Fiber reinforced cement sidings	Japan Fiber Reinforced Cement Sidings Manufactures Association
11	Metal sidings	Japan Metal Siding Association
12	Extruded Cement Panel	ECP Association
13	ALC panel	ALC Association
14	Curtain wall	Curtain-wall Fire Window's Association
		Precast Concrete System Association

2D analysis

3D analysis



Analysis model Analysis results

Fig. 3.5 Examples of analytical models and results by CFD calculation

3.7 *Working Group on Seasonal Effects for Design Wind Speed (2012)*

Reduction of design wind speed by season effect for temporary structures is investigated applying monthly maximum wind speed data to extreme value distribution.

3.8 *Working Group on Member Vibrations (2012)*

For several sections of structural members, information for judgment of vortex induced vibration and wind load for vortex induced vibration are investigated. A fatigue evaluation method for some case examples is introduced.

4 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 the wind resistant design in Japan, have been insufficient compared to those in the US (US Nuclear Regulatory Commission, 2007). 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 to determine whether 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*

4.1.1 *Tornado database*

In order to evaluate the occurrence rate of tornadoes and to study their distribution in Japan, a historical tornado database was created based on the JMA 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. 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 near the seacoast was significant as shown in Fig.4.1. The damaged area and the length of the tornado's path were examined, but 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.

The study items on tornado risk modeling were as follows.

(1) Japanese tornado database, which was historically changing its characteristics, was studied.
(2) Application of Poisson's distribution and Polya distribution for the occurrence of Japanese

tornadoes.
(3) To estimate the exceedance probability of tornado winds, basic statistics in 7 subareas of Japan (see Fig.4.1) were examined.

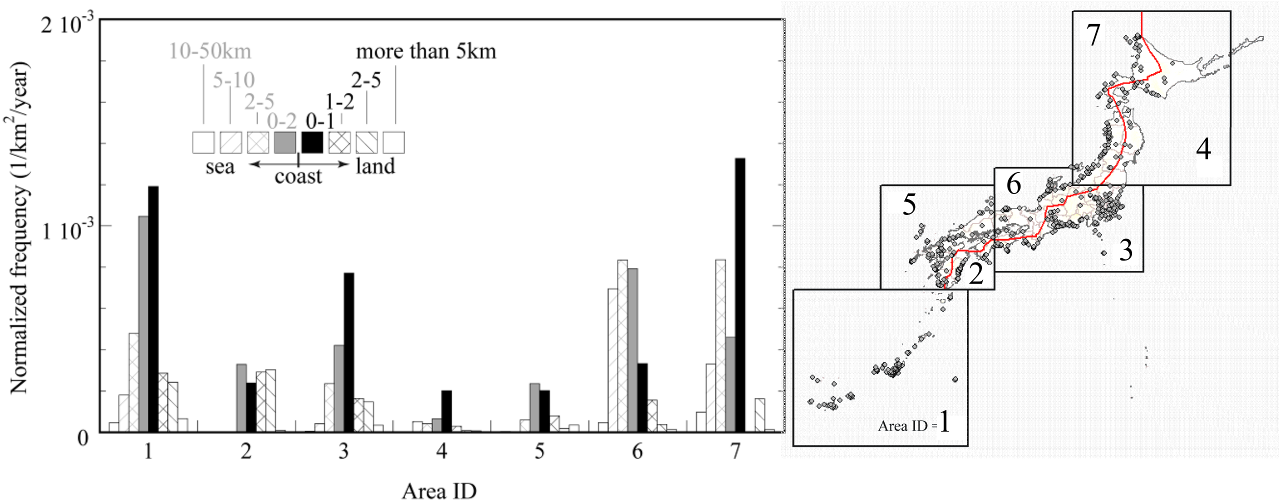


Fig. 4.1 Annual Number of Tornado Occurrence per Unit Area for 7 Subareas
[Statistical Period: 2007-2009 (on the sea), 1961-2009 (F2 and F3, inland), 1991-2009 (F0 to less than F2, inland), 2006-2009 (F0 and unknown, inland)]

4.1.2 *Modeling of tornadoes and their parameters*

Tornadoes are characterized by their absolute maximum wind speed, the radius of their maximum wind speed, their maximum swirling (tangential) wind speed, their vertical wind speed, their radial wind speed, their translational speed, their central pressure and their differential of central pressure. The following five parameters were selected from observation data and examined:

(1) Absolute maximum wind speed
(2) Translational speed
(3) Tangential wind speed
(4) Radius of maximum wind speed
(5) Central pressure

4.2 *Site Investigation of Nuclear Power Plant*

4.2.1 *Possible windborne debris in a nuclear power plant*

Windborne debris which might cause serious damage has one of the following characteristics.

(1) Windborne debris with high kinetic energy
(2) Windborne debris hard enough for penetration
(3) Windborne debris hard and small enough to pass through a protection of opening

Based on the site investigation of the nuclear power plant, objects corresponding to each category are found as follows.

(1) Automobiles (passage cars, dump trucks and buses), fork lifts, backhoes, cranes, machine tools, prefabricated temporal buildings, containers, sheds and tents in the power plant yard

These are heavy but aerodynamically light and easy to be blown, thus becoming windborne debris with high kinetic energy.

(2) Steel pipes, reinforcing bars, line-like metal materials lying on the ground of the stock yard outside the plant, and just lying loose on roof tops

These materials are stiff enough to penetrate.

(3) Gravel observed on the ground for pavement in the power plant

Most structures of main buildings are made of reinforced concrete. They are stiff enough to withstand windborne debris. Some auxiliary buildings and facilities, openings, window panes for office buildings are sensitive to windborne debris.

4.3 *Design Tornado*

The maximum wind speed of the design tornado is tentatively proposed at 100m/s, which corresponds to the annual probability of exdeedance 10^{-7}. Characteristic values of the design tornado are shown in Table 4.1. (Tamura, et al., 2011)

Table 4.1 Characteristics of Design Tornado

Translational speed	Maximum tangential wind speed	Radius of maximum tangential wind speed	Pressure depression	Pressure depression ratio
16m/s	84m/s	30m	85hPa	45hPa/s

This aims to consider the effects of extreme level tornadoes, of at least F4.

4.4 *Evaluation of Tornado Effects*

Evaluation of tornado effects should be based on the following:

- Pressure depression effects in the design tornado
- Unsteady wind force effects due to the design tornado
- Impacts of windborne debris specified in Table 4.2

Table 4.2 Design windborne debris

Debris	Rod		Plate	Lump	
	Steel Pipe	Steel Members	Concrete Panel	Container	Truck
Size	2m×0.05mϕ	4m×0.3m×0.2m	1.5m×1m×0.15m	2.4m×2.6m×6m	5m×1.9m×1.3m
Mass	8.4kg	135kg	540kg	2,300kg	4,750kg
Horizontal Speed	49m/s	57m/s	30m/s	60m/s	34m/s

The final report of the three year study (Tamura et al., 2011) was submitted to the Japan Nuclear Energy Safety Organization on March 7, 2011. However, based on the accident of the Fukushima No.1 Nuclear Power Plant after the East Japan Earthquake and Tsunami on March 11, 2011, the results obtained by questionnaire studies from officers of the electric power company at the times of the site investigations seemed to be unreliable. Therefore, another research project on “Tornado effects on high risk facilities including nuclear power plants” was started by the TPU group in April 2012.

5 ACTIVITIES OF THE JAPAN SOCIETY OF SEISMIC ISOLATION

Committee on Wind Resistant Design of Buildings with Seismic Isolation System (chaired by T. Ohkuma) of the Japan Society of Seismic Isolation (JSSI) published "*Guidelines for Wind-resistant Design of Base-isolated Buildings*" (GWDBB-2012) in September, 2012. This Committee consists of two Working Groups: WG on Base Isolation Devices (chaired by Y. Takenaka); and WG on Estimation of Wind-induced Response of Base-isolated Buildings (chaired by K. Yoshie).

The guidelines mainly document:
1) how to classify wind loads on base isolated stories and devices from the view point of elasto-plastic characteristics of these stories and devices;
2) how to conduct performance tests for base isolation devices for wind loads;
3) examples of performance tests for several types of base isolation devices and damping devices; and
4) how to estimate application duration of extreme winds.

The contents of "*Guidelines for Wind-resistant Design of Base-isolated Buildings*" are as follows:

1. General
1.1 Scope of applications
1.2 Fundamental concept
1.3 Remarks on wind resistant design of base isolated buildings
2. Estimation of wind loads
3. Design of base isolated story
3.1 Items for estimation
3.2 Verification of wind resistant performance
4. Design of base isolated devices
4.1 Items for estimation
4.2 Verification of wind resistant performance
Appendix
A1 Performance test for base isolated devices
A2 Characteristics of base isolated devices for wind load
A3 Total application time of extreme wind
A4 Simplified procedure for cumulative application time of extreme wind
A5 Simplified procedure for wind response of base isolated story
A6 Example of calculation for wind response of base isolated story

Guidelines for Wind-resistant Design of Base-isolated Buildings (151 pages)

Short courses of lectures on the guidelines were held in Tokyo on September 21, 2012 and in Osaka on October 19, 2012.

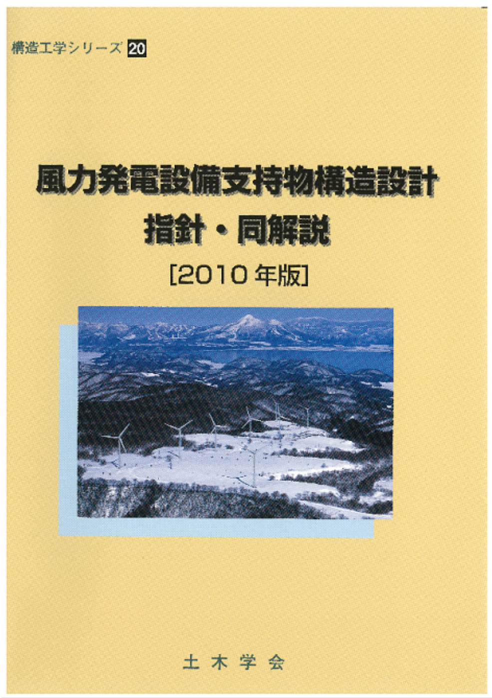
6 REVISION OF GUIDELINES FOR DESIGN OF WIND TURBINE SUPPORT STRUCTURES AND FOUNDATIONS, JAPAN SOCIETY OF CIVIL ENGINEERS (JSCE)

In Japan, the utilization of wind energy has been dramatically increasing since the late 1990s. In September, 2003, three wind turbines in Miyako Island collapsed during a typhoon, and some other accidents due to Japan's unique meteorological and geographical conditions have been reported. Accident investigations in Japan have shown that many points have to be considered when designing wind turbine support structures. The major points include:

- Assessment of design wind speeds
- Large turbulence in mountainous region
- Loss of electrical power network in a typhoon
- Earthquake
- Low damping of wind turbine support structures
- Buckling of towers
- Destruction of foundations.

A Task Committee on Wind Resistance Design of Wind Turbine Generator Systems published "*Guidelines for Design of Wind Turbine Support Structures and Foundations*" (JSCE-GDWT-2007) in October 2007 for the design of wind turbine support structures in Japan. Its revised version, JSCE-GDWT-2010, was published in 2010. The four major revisions relevant to wind load are as follows:

(1) Following the recent revision of BSLJ, required performance, load levels to be considered, available materials and design methods for wind turbines higher than 60m have been introduced.
(2) Typhoon simulation techniques and wind directionality have been adopted in design wind speed evaluation.
(3) The evaluation method for peak wind load during operation has been formulated.
(4) The evaluation method for fatigue effects due to winds has been formulated.



Guidelines for Design of Wind Turbine Support Structures and Foundations (JSCE-GDWT-2010, 582 pages)

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