No. 43 December 2014

STEEL CONSTRUCTION TODAY & TOMORROW

http://www.jisf.or.jp/en/activity/sctt/index.html

【*kaze*】

"風 (*kaze*)" in Japanese, or wind in English

Serious building damage, particularly to exterior members,
that is caused by the strong winds of typhoons
and tornadoes occur worldwide.
How to deal wind load and how to mitigate strong
wind-induced damage are discussed in this issue, No. 43.

In this issue.....

Special Feature: Wind Resistance of Buildings

Photo: SUZUKI hisao

- **1** Advances in Wind-resistant Design and Wind Resistance Evaluation in Japan
- **4** Strong Wind-induced Damage to Buildings and Concepts for Mitigating Such Damage
- **6** Wind Load Provisions in the Building Standard Law of Japan
- **9** Evaluation of Habitability Related to Wind-induced Building Vibration
- **11** Performance-based Wind-resistant Design for 300-m Vertical City

15 Steel Application Technology: Basic Details about High-strength Bolt Joining

Back cover JISF Operations

Published Jointly by

The Japan Iron and Steel Federation

Japanese Society of Steel Construction

Advances in Wind-resistant Design and Wind Resistance Evaluation in Japan

by Yasushi Uematsu, Professor, Tohoku University

Establishment of the Enforcement Order of the Building Standard Law

In Japan, the Enforcement Order of the Building Standard Law of Japan was established in 1950. It was the first legal regulation that specified the wind-load evaluation method to be adopted in building design, which regulated the calculation of wind load P by use of the following equation:

$$P=C\cdot q\cdot A \qquad (1)$$

where

C : wind force coefficient

A : building area or tributary area of component under consideration (m^2)

q : velocity pressure (calculated by using Equation (2))

Meanwhile, the wind force coefficient C refers to the difference between external and internal pressure coefficients. Note that these two coefficients are not specified separately.

$$q=60\sqrt{h}\,(kg/m^2) \qquad (2)$$

where

h : height above ground level (m)

The equation is based on a maximum instantaneous wind velocity of 63 m/s that was observed at the top of the steel observation tower (15 m above ground level) of the Muroto Meteorological Observatory during the Muroto Typhoon in 1934. The equation was derived by assuming that the vertical distribution (profile) of the maximum instantaneous wind velocity is proportional to 1/4th the power of the height above ground level, and by substituting the above-mentioned observation value.

Incidentally, it is well accepted that the power exponent for the profile of the maximum instantaneous wind velocity during typhoons and other synoptic winds is about 1/2 the value for the mean wind velocity. Thus, the above-mentioned power exponent of 1/4 implies that the power exponent for the mean wind velocity profile corresponds to about 1/2. In those days, such a large value of power exponent was not used in any country in the world, which in fact did not reflect actual conditions. However in Japan, no so-called high-rise buildings had been constructed, and there were few buildings for which wind loads dictated the structural design, thereby causing no substantial problems. The wind force coefficients C were obtained from wind tunnel tests using uniform smooth flow, in which the effects of turbulence were not considered. Further, the social background that led to the establishment of Equation (2) included the following issues:

- In those days, because the Muroto Typhoon was of unprecedented scale in Japan, it was expected that, if wind loads of that level were adopted, buildings would have some safety margin for future typhoons.
- Unlike earthquakes, typhoons can be forecasted to a certain extent, and thus it is possible to take countermeasures against them. Therefore, it was considered that, even if lower wind loads were adopted for reasons of economic advantage, no serious problems would result.

Increasing Building Height Prompts Reexamination of Wind Load Calculation Method

Following the popularization of TV sets among general households during Japan's period of high economic growth, the nation's first large-scale television tower with a height of 180 m was constructed in Nagoya in June 1954. During the tower's design stage, the inadequacy of Equation (2) was pointed out. As a result, the profile of the maximum instantaneous wind velocity was reexamined in reference to the building codes and standards in foreign countries. This produced the following equation, which assumed a power exponent of 1/8 and was used in the design of the tower:

$$q=120\sqrt[4]{h}\,(kg/m^2) \qquad (3)$$

After completion of the Nagoya television tower, full-scale measurements taken during typhoons demonstrated that the measured results agreed relatively well with Equation (3). As a result, Equation (3) has played a great role in the blossoming of subsequent high-rise building construction in Japan.

Following the revision of the Building Standard Law in 1963, Japan's first full-scale high-rise building, the Mitsui-Kasumigaseki Building (36 stories above ground, 156 m in height), was completed in Tokyo, marking the dawn of the high-rise building age in Japan. In addition, the National Indoor Stadium with a 126-m main span was constructed for the Tokyo Olympic Games held in 1964, marking the beginning of large-span buildings in Japan.

As the height or clear span of buildings increases, the natural frequency generally decreases, thereby causing the significant dynamic effect of wind. That is, the contribution of the resonance component (resonance effect) in the dynamic response of buildings becomes more significant. On the other hand, when the scale of a building increases, the net wind load acting on the building decreases due to scale effect. In the case of a small-scale building, the load effect (for example, the stress involved in the structural members) becomes the maximum when the maximum peak wind velocity occurs. In the case of a large-scale building, on the other hand, the wind pressures acting on the structural members do not reach the maximum peak values at the same time for all members, and thus the load effect does not become the maximum at the moment of the maximum peak wind velocity.

Emerging from this background was a gradually increasing understanding of the dynamic load effects on buildings, which led to many surveys and researches on the turbulent structure of wind, wind tunnel test methods, the actual conditions of wind pressure, wind-induced vibration and other factors.

Along with the appearance of high-rise buildings, it was urgently required to establish a reasonable wind-resistant design method for curtain walls, particularly to establish a method for testing the wind resistance of glass plate and the water proof of curtain walls. During that period, Japan was successively struck by super typhoons, such as the Ise-bay Typhoon (1959) and the Second Muroto Typhoon (1961), causing great damage to roofing, exterior walls and other exterior members. The damage to these exterior members frequently triggered severe damage to the main wind resisting systems (structural frames), thereby pointing out the importance of preventing damage to cladding/components and promoting safe design.

In such situations, Notification No. 109, the first regulation concerning the wind-resistant design of exterior members, was issued by the Ministry of Construction in 1971. This regulation focused mainly on the following two topics:

1) Design velocity pressure is sorted into two classes respectively for roofing materials and for external walls, which are calculated by using the following equations:
   - For roofing materials:

     $q = 120\sqrt[4]{h}\,(\text{kg/m}^2)$ (4)
   - For external walls of buildings higher than 31 m:

     $q = 60\sqrt{h}\,(\text{kg/m}^2)$ for $h \le 16\,\text{m}$ (5a)

     $q = 120\sqrt[4]{h}\,(\text{kg/m}^2)$ for $h > 16\,\text{m}$ (5b)
2) The areas of local wind pressures in eaves, overhanging roofs, verges and wall surface corner sections are specified, where the design wind force coefficient is specified as $C = -1.5$.

Fig. 1 shows the profiles of velocity pressure provided by Equations 5(a) and 5(b). The curves of the two equations cross at a height of 16 m, and the lower value of these two curves at each height is used for evaluating wind loads.

Efforts to Establish a More Rational Method of Evaluating Wind Loads

Because the fluctuation of wind velocity is quite random in nature, the time-space correlation of wind velocity should be considered appropriately based on a statistical and probabilistic approach, when evaluating the wind loads on buildings. Prof. Alan G. Davenport of the University of Western Ontario, Canada proposed in 1967 a new approach, known as the gust loading factor method (Fig. 2). According to this method, the design wind load P is provided by the following equations:

$$P = q \times C \times G \times A \quad (6)$$

$$q = \frac{1}{2}\rho U^2 \quad (7)$$

where

U : mean wind velocity at height z above ground level

G : gust loading factor defined by the following equation:

$$G = \frac{\bar{X} + x_{\max}}{\bar{X}} = 1 + g_x\frac{\sigma_x}{\bar{X}} \quad (8)$$

where

$\bar{X}$: mean displacement of building due to the mean wind force

$x_{\max}$: maximum value of dynamic displacement ($= g_x \cdot \sigma_x$)

σ_x: standard deviation of dynamic displacement

g_x: peak factor.

Comparison of Equations (6) to (8) with the corresponding provision in the Enforcement Order of the Building Standard Law shows the following features:

- When considering the wind-induced vibration of structure, the maximum instantaneous wind velocity does not always give the maximum load effects (i.e., stress, displacement and other loading effects).
- The maximum peak wind force at each point on the building does not occur simultaneously. Therefore, the net wind force acting on the entire building decreases with an increase in the size of building.

In light of such conditions, the gust loading factor method adopts a probabilistic and statistical approach to evaluate the design wind loads on buildings by considering the temporal and spatial fluctuation characteristics of wind velocity. Further, the method provides the "equivalent static wind load" that gives the maximum load effect. Therefore, the commonly used conventional static analysis can be applied in the structural design, nevertheless the wind loading is dynamic.

When comparing Equations (1) and (6) each other, it is found that the design wind velocity is specified based on the maximum instantaneous wind velocity in Equation (1), while it is based on the average wind velocity in Equation (6). Further, the dynamic effect of fluctuating wind velocity on the load effects is taken into consideration by using the maximum instantaneous wind velocity in Equation (1), while it is taken into consideration by using the gust loading factor G that is based on the maximum peak value of the building response.

Fig. 1 Comparison of Design Velocity Pressure

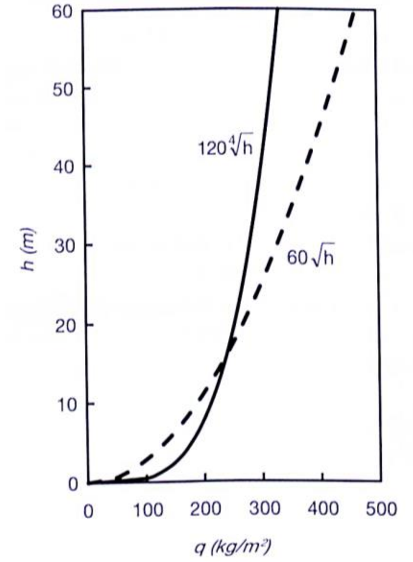
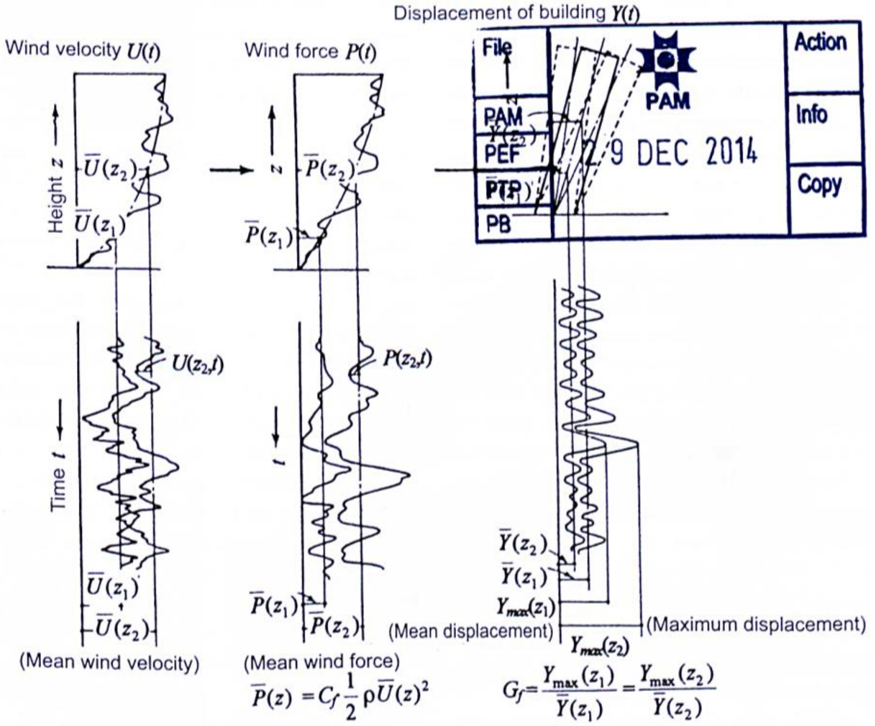


Fig. 2 Definition of Gust Loading Factor (*Recommendations for Loads on Buildings* 1981 Edition)



(a) (b) (c)

The building response depends not only on the wind velocity but also on many factors relating to the building; that is, the shape, scale and the dynamic characteristics, such as natural frequency and damping factor. All of these factors are reflected in the equation for G. In the case of small-scale buildings, it is thought that the maximum load effect occurs at the moment of the maximum peak wind velocity. Here, the ratio of the maximum peak wind velocity to the mean value is defined as the gust factor G_v. Because the wind force is proportional to the square of the wind velocity, Equations (1) and (6) imply that $G = G_v^2$.

It does without saying that the wind load evaluation by using Equation (6) is far more rational than the use of Equation (1). As a result, the use of Equation (6) to evaluate wind loads has been incorporated into the provisions of codes and standards in many countries. In Japan, the Architectural Institute of Japan (AIJ) published *Recommendations for Loads on Buildings* in 1981, in which the wind load evaluation was based on the Davenport method.

Then, because several inadequacies were found in the AIJ *Recommendations*, it was revised in 1993 to correct these inadequacies. The features of the revised *Recommendations* are as follows:

- The wind load calculation equation takes two forms: one for the main wind force resisting systems (structural frames) and the other is for cladding/components. This is because the scale and vibration characteristics of the structural frames are quite different from those of the cladding/components, and due considerations are made on the different ways that wind load works on the structural frames as opposed to cladding/components.
- The design wind velocity is settled by taking into account the frequency of the occurrence of strong winds and the safety level of the building during the service life of the building in respective areas. That is, the return period is settled according to the safety level required for the building, and the building is designed based on the wind velocity that corresponds to the return period thus settled. Meanwhile, the design wind velocity is evaluated by using the annual maximum wind velocity.
- The design velocity pressure q_H is to be set as the velocity pressure at a reference height H corresponding to the building (commonly the average height of the roof). Accordingly, the vertical distribution of the wind load is treated as the distribution of the wind force coefficient (or wind pressure coefficient).
- The effect of the time-space correlation of wind pressures on the building is evaluated using the probabilistic and statistical approach, which is expressed as the gust effect factor. While the gust effect factor is similar to the gust loading factor defined by Prof. Davenport, the gust effect factor is applied in a wider context as a factor that expresses the dynamic load effect of wind pressures and wind forces.
- The conditions of wind blowing at the site are classified according to "surface roughness," and the features of these conditions thus classified were reflected in the profiles of mean wind velocity and turbulence intensity.

Then in 2000, the Enforcement Order of the Building Standard Law was fully revised. The Order incorporated a wind load evaluation method that was based on the probabilistic and statistical approach, as in the case of many other countries. Although the method defined in the Order was simplified by imposing several restrictions, such as limiting the applicable building height to 60 m or less, the basic method of wind load evaluation used is almost the same as that provided in the AIJ *Recommendations* (1993).

The AIJ plans to revise the *Recommendations* approximately every 10 years by actively incorporating the latest information. In line with this policy, revisions were made in 2004 and preparations are being promoted to publish the 2015 revised version. In this revision, in order to allow more reasonable evaluation of design wind loads, due consideration is being given to many factors, such as the effect of local topography on wind velocity, the wind direction coefficient and seasonal coefficient, aerodynamic instability, and load combinations. Further, the revision will also employ the use of computational fluid dynamics (CFD) together with wind tunnel experiment.

The appearance of high-rise buildings has posed new and unexpected problems. In 1979, Typhoon No. 20 struck the Tokyo metropolitan area with winds of a strength seen only once every ten years. Also, it brought attention to the issue of wind-induced vibration of high-rise buildings, especially in the Shinjuku new urban center. Building vibration did not cause any serious problems to the structures. However, because of the typhoon's long duration and incessant blowing, a considerable number of people had discomfort and queasiness as they experienced in seasickness.

Triggered by such situations, the issue of habitability of high-rise buildings has received a great deal of attention, which led to the publication of *Guidelines for the Evaluation of Habitability to Building Vibration* in 1991 by AIJ. The *Guidelines* was then revised in 2004 by incorporating the latest available knowledge. In the *Guidelines*, the criterion for evaluating the habitability is given by use of the relationship between the maximum response acceleration for the wind velocity with a 1-year return period and the natural frequency of building.

Evaluation of Wind Resistance

In June 1998, the Building Standard Law was revised. In this revision, the design concept was widely shifted to the "performance-based design" while remaining the conventional concept of specification design. In building design, three limit states are generally assumed—serviceability, damage and safety limits, and the design criteria are given to each of these limit states. For example, the serviceability limit for high-rise buildings is determined by taking wind-induced vibration (habitability) into account.

In this regard, based on the *Guidelines for the Evaluation of Habitability to Building Vibration* mentioned above, the criterion for evaluating habitability is given employing the relation between the maximum response acceleration for wind velocity with a 1-year return period and the natural frequency of buildings. Particularly in the response and limit strength calculation in the Enforcement Order of the Building Standard Law, it is stipulated that, when determining damage limit, structural members should remain in the elastic range when subjected to rare strong winds with an approximately 50-year return period, and that, when determining safety limit, buildings should not collapse even when subjected to extremely rare strong winds with a 500-year return period. However, neither the *Guidelines* nor the Enforcement Order offers a clear prescription for cladding/components suffering great damage due to strong winds. Because of this, the AIJ has provided specific design approaches in its publication *Manual for Cladding Wind Resistance Evaluation for Designers and Engineers* published in 2013. ■

Reference

1) A.G. Davenport, Gust loading factors, Proc. of ASCE, Struc. Div., 1967.

Strong Wind-induced Damage to Buildings and Concepts for Mitigating Such Damage

by Hitomitsu Kikitsu, Building Research Institute

Serious Damage to Buildings Caused by Strong Wind

It is recently reported that serious tornado damage has frequently occurred both in Japan and abroad with great social impact. The scenes are still fresh in our memory of the damage inflicted by tornadoes in several Japanese cities, centering on Tsukuba in Ibaragi Prefecture in 2012 (Photo 1) and Koshigaya in Saitama Prefecture in 2013. Meanwhile, it is also true that damage is caused by typhoons, but this damage is liable to be obscured by the scale of the damage caused by tornadoes (Photos 2~3).

Among a building's various structures, it is the roofing members, exterior walls, openings and other external claddings and components that are vulnerable to the effect of strong wind. The primary measure for preventing wind-induced building damage is to mitigate the damage to them.

Concepts Conducive to Mitigating Damage to External Claddings and Components

• Specific Damage Conditions

When a building is subjected to strong wind of typhoon, the wind force attributable to the turbulence of approach flow generates on the windward roof and wall, and this results in localized peak negative pressure occurring along the edges of roof and sidewall. The Building Standard Law of Japan prescribes the method for calculating localized peak pressure. According to this method, the action of wind gusts generated by a translating tornado can be considered to follow those of a typhoon. However, unlike a typhoon, particularly as the whirling center of a tornado approaches closer to a building, the force produced by the updraft works on the building to increase the damage (refer to Fig. 1), to which due attention should be paid.

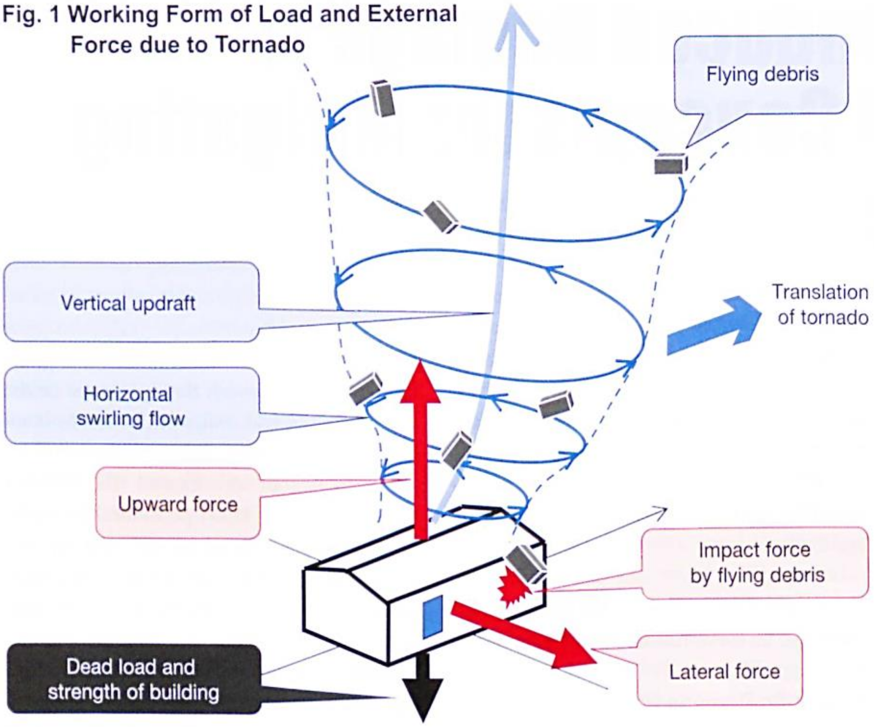
The damage caused by strong wind can be understood as the apparent damage of the most vulnerable section among wind-induced load paths in a building. Most of the damage can be found in the external cladding and components of the building. Accordingly, in order to mitigate such wind damage, it is important to settle the design load after gaining an appropriate understanding of how wind force will work on the building and, then, to give due consideration when selecting the specifications for the external cladding and components.

Photo 1 Example of damage caused by tornado (Tsukuba in 2012)

Photo 2 Example of damage caused by typhoon (Miyakojima, Okinawa in 2003)

Photo 3 Example of damage caused by typhoon (Miyakojima, Okinawa in 2003)

Fig. 1 Working Form of Load and External Force due to Tornado



• Concepts for Verification of the Strength of External Members

When verifying the strength of external cladding and components, two approaches are commonly applied: structural design based on the standard specification of the members and structural design based on their allowable strength.

In the former approach, the wind pressure resistance is secured by selecting standard specifications (distance between supports, plate thickness, etc.) from a product catalog according to the necessary level of the design load, and thus structural calculations are not required and wind pressure resistance can be easily verified.

In the latter approach, the wind pressure resistance is verified by calculating the allowable strength of each structural section based on the strength test results (Photo 4). In this verification process, for example in the case of steel roofing and walls, it is common that a value of 2.0 or higher be settled as the safety factor required to find the allowable strength of such members.

Based on the results of these verification processes, due care is taken in the design work, such as increasing the plate thickness or narrowing the fastening and installation spaces of the supporting members, in order to reduce the possibility of damage occurrence.

Further, there are many cases of production and commercial facilities that are large in scale and that require asset security and the preservation of building functionality. Facilities of this nature can be forecasted to incur several types of wind-induced damage. That is, when roofing and other exterior members are stripped off and scattered about, the resulting inflow of rain can extensively damage indoor equipment and make the entire facility functionally useless. In important facilities that house highly advanced functions, even if the main structures are intact, it is possible that striped-off and scattered roofing and other external claddings and components could cause enormous economic loss.

Related to wind resistance design in the Building Standard Law of Japan, return periods of approximately 50 years are supposed. It can be said that damage caused by strong wind can be mitigated, depending on the importance level of a facility, by assigning incremental wind loads to external members that are based on levels surpassing those in the Law and then verifying the wind pressure resistance of these members.

Currently, the wind force of tornadoes is not taken into account in common wind resistance design, but it is considered that the concepts mentioned above can, to a certain degree, mitigate tornado-induced building damage as well.

• Sharing of Information about Member Applications

Because the performance appraisal of external cladding and components is commonly entrusted to construction companies and the manufacturers of these members, how to assign appropriate roles in any structural verification is liable to be unclear. Therefore, it is imperative that information about the strength and other properties of these external members be adequately shared among the designers, construction companies and member manufacturers throughout the process from design to construction.

Further, studies of recent damage illustrates that the damage is often caused by secular deterioration of structural members and a subsequent loss of their strength and by the adoption of inappropriate repair methods. These examples suggest that appropriate maintenance of external cladding and components and proper repairs are indispensable in mitigating damage to members caused by strong wind. ■

Reference

Japan Metal Roofing Association and Japanese Society of Steel Construction: Standard of Steel Roofing, SSR 2007 (published in 2008)

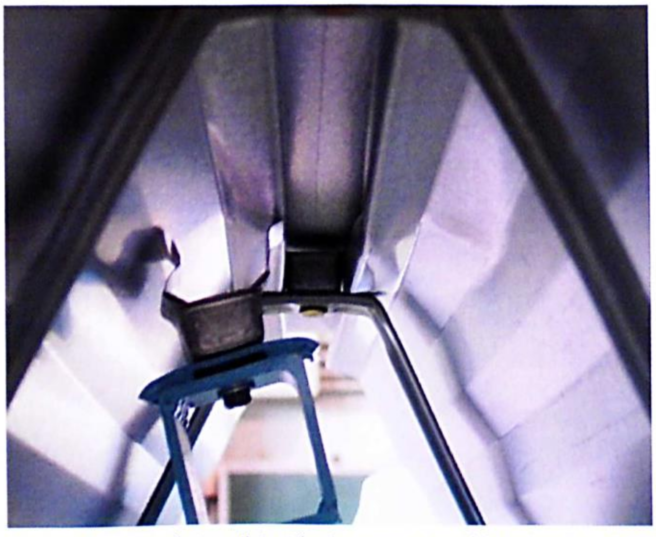


Photo 4 Example of strength test for the connection of folded roofing (SSR2007)

Wind Load Provisions in the Building Standard Law of Japan

by Yasuo Okuda, National Institute for Land and Infrastructure Management

Introduction

Article (1) Purpose of the Law and System of the Building Standard Law of Japan states, "The objective of this law is to establish minimum standards regarding the site, structure, facilities, and use of buildings in order to protect the life, health, and property of the nation, and thereby to contribute to promoting the public welfare." As stated, the Law regulates the construction of every type of building in Japan, and provides the minimum standard to be observed in building construction.

In 2000, the Enforcement Order of the Building Standard Law [Law] and its Notifications were widely revised, and the wind load-related provisions in the Enforcement Order and its Notifications were also widely revised based on *Recommendations for Loads on Buildings* (1993) [hereafter, *Recommendations*] issued by the Architectural Institute of Japan. The wind load values adopted with the establishment of the Law in 1950 were uniform throughout the nation and went unchanged for 50 years, but in the revision of the Law in 1998 and of the Enforcement Order and its Notifications in 2000, the wind load values were changed so as to take into account local and ancillary conditions. Further, in 2007, the Enforcement Order of the Building Standard Law was also revised to require the submition of a structural calculation document for exterior members at the time of building confirmation, a step that had formerly been exempted.

Meanwhile, the Architectural Institute of Japan has been revising *Recommendations* nearly every 10 years since it was first issued in 1981, and the latest version is scheduled for publication in February 2015.

In discussing the standards and specifications for wind-resistant design of buildings in Japan, an outline of the wind load specifications prescribed in the Building Standard Law and in *Recommendations* is introduced in this article. Also introduced is an outline of diverse guidelines conforming to the wind load provisions of the Building Standard Law as prepared by the respective industry organizations.

Wind Load Provisions of the Building Standard Law

While *Recommendations* has been revised nearly every 10 years by the Architectural Institute of Japan to reflect the latest advances in research, the wind load provisions of the Building Standard Law have not been so frequently revised since the Law's establishment in 1950. However, following the revision of the Law in 1998 (introduction of performance-based design in building standards), widely-ranging revisions and newly-established requirements were made to the Law's Enforcement Order and to related notifications in 2000. As this was happening, the wind load provisions of the Law were also widely revised based on *Recommendations* (1993). As regards the wind load values that were uniformly enforced nationwide following the establishment of the Law in 1950, it has recently become possible to prescribe more rational wind loads that reflect local and ancillary conditions and the structural characteristics of individual buildings. Among the specific approaches to determine more rational loads are:

- Clarification of separate wind loads for structural framing and exterior members
- Introduction of a standard wind velocity Vo
- Introduction of ground roughness classifications
- Introduction of gust loading factors
- Settlement of two load levels of damage criterion and safety criterion in the calculation of response and limit strength
- Adoption of SI units
- Enhancement of wind force coefficients, etc.

Difference between the Building Standard Law and *Recommendations for Loads on Buildings*

• Basic Principles Applied in the Building Standard Law and *Recommendations for Loads on Buildings*

Although the wind load provisions of the Law currently in use are based on *Recommendations* (1993), there are fundamental differences between them. Because the Building Standard Law has binding legal force, any judgment contrary to the Law would not be legally permissible. Further, while the minimum standard load level is settled, any design that uses a load level lower than the minimum standard prescribed in the Law is impermissible, but designs that use load levels surpassing the minimum standard are permissible. On the other hand, *Recommendations* itself has no legally binding force and shows its concept and parameters required to conduct structural design to structural designers so that it has become possible for the structural designer to select the necessary load level (the basic wind load is settled to meet a strong wind having a return period of 100 years, and the structural designer can select his optional load level obtained by use of the conversion coefficient more than the level of the Building Standard Law).

As stated above and in contrast to the Building Standard Law, *Recommendations* is not a legally binding document. Nevertheless, *Recommendations* is frequently referenced when specific evaluation methods in the Law are not applicable, such as wind force coefficients for buildings with a special architectural configuration, increased wind velocity caused by landforms, or a vibration response characteristic of high-rise buildings taller than 60 m. It can be said that *Recommendations* serves to complement the wind load provisions prescribed in the Law.

• Specific Differences in Wind Load Specifications between the Building Standard Law and *Recommendations for Loads on Buildings*

—Clarification of separate wind loads for structural framing and exterior members

While partially-common wind force coefficients were applied for both structural framing and exterior members in the Building Standard Law before its revision in 2000, wind loads were not so clearly distinguished between the two categories. But after revision of the Law in 2000, wind loads for structural framing and exterior members were more clearly distinguished in conformance with *Recommendations*, which were included in the Enforcement Order and related Notifications.

The wind load for structural framing is the wind force that works on an entire building structure, and differs depending on the wind direction. The load on exterior members is the wind force that works on roofing materials and other exterior members (area: about 1~5 m^2), and shows maximum and minimum values in all wind directions. Accordingly, the wind pressure per area has a relation: the load on exterior member ≥ the load on structural framing.

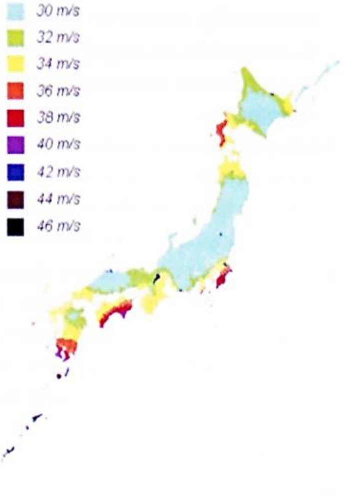
Table 1 Ground Roughness Classifications and Ground Conditions in *Recommendations for Loads on Buildings*

Classification of ground roughness	Ground conditions at peripheral areas	Representative examples
I	Flat area with nearly no obstacles	Coastal zone
II	Area with obstacles such as agricultural products, area where tress and low-rise buildings lie scattered	Rural zone
III	Area with dense trees and low-rise buildings, area where medium- and high-rise buildings (4~9 stories) lie scattered	Forest zone Industrial zone Housing zone
IV	Area with dense medium- and high-rise buildings (4~9 stories) in wider range	Medium- and high-rise urban zone
V	Area with dense high-rise buildings (10 or more stories)	High-rise urban zone

—Introduction of standard wind velocity Vo

Before its revision in 2000, the Building Standard Law defined velocity pressure q as 60 √h and made wind load uniform throughout the nation. Following the 2000 revision, velocity pressure q has been determined using the standard wind velocity Vo, the vertical distribution of wind velocity based on ground roughness classification, the gust effect factor and other influences and, further, takes into account local and ancillary conditions and the structural characteristics of individual buildings.

Fig. 1 Drawing of Standard Wind Velocity Vo



I

II

III

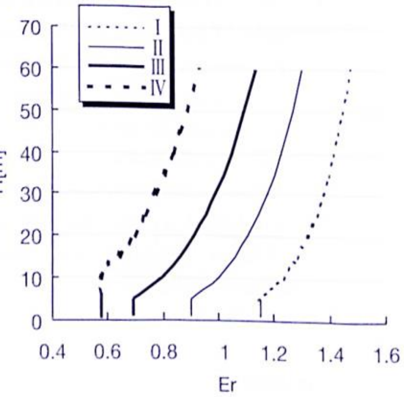
IV

Fig. 1 shows the standard wind velocity Vo in Japan, which is settled at "30~46 m/s depending on the rate of occurrence of wind damages based on the recorded history of past typhoons and associated wind properties." The value of 30~46 m/s is obtained by converting the annual maximum wind velocities recorded by meteorological offices nationwide to wind velocities with a return period of 50 years (10-minute average wind velocity at a height of 10 m over ground with a surface roughness classification II). The figure shows respective standard wind velocities in the cities, towns and villages of Japan in 2000 that were divided into nine areas classified by wind velocity level. The standard wind velocity thus obtained has allowed the dominant wind characteristics of each area to be reflected in the design wind velocity.

—Introduction of ground roughness classifications

In *Recommendations*, the specified ground roughness is selected by the structural designer from among the five classifications and photos shown in Table 1 based on his judgment. On the other hand, the Building Standard Law adopts a vertical distribution of wind velocity (Fig. 2) that is similar to that in *Recommendations*, but in the Law, ground roughness is clearly divided to four classifications depending on the specified area (Table 2) in order to eliminate as much vagueness in the classification as possible. Because ground roughness classifications I and IV are settled by specified administrative agencies based on the regulations, classifications II and III are to be adopted in most areas (refer to Table 2).

Fig.2 Vertical Distribution of Wind Velocity Prescribed by the Building Standard Law



—Introduction of gust loading factor

The gust loading factor G_f was introduced in the 2000 revision of the Law and conforms to *Recommendations*. The numerical value of the gust loading factor G_f is settled according to the ground roughness classification and the building height while taking into account wind turbulence and building scale and structural characteristics. On the other hand, in the method adopted in *Recommendations*,

Table 2 Classification of Ground Roughness Prescribed by the Building Standard Law

Ground roughness classification	Inside urban planning area	Outside urban planning area
I		◎
II	○	○
III	○	○
IV	◎	

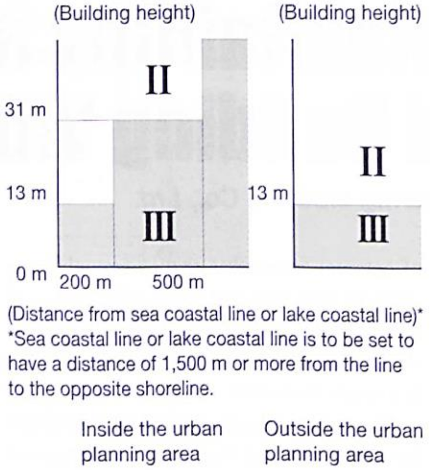
the structural designer finds the value of gust effect factor by taking into account wind turbulence, building scale and structural characteristics and by using the calculation formula.

—Settlement of two load levels of damage criterion and safety criterion in the calculation of response and limit strength

Before being revised in 2000, the Building Standard Law used allowable stress calculations and retained horizontal strength calculations to settle load levels; but, after its revision in 2000, the Law introduced critical strength calculations, too. In critical strength calculations, two criteria—damage criterion and safety criterion—were provided and their respective loads were settled. For the wind load, two load levels having 50-year and 500-year return periods respectively were settled, and loads conforming to the safety criterion were set at 1.6 times the loads conforming to the damage criterion.

—Adoption of SI (International System of Unit)

Before the Building Standard Law was revised in 2000, it had employed an engineering unit system, but following the adoption of SI (International System of Unit) in the Japanese Industrial Standards in 1991, SI was also adopted in the Law. In the system of engineering units that had been in use, both mass (kg) and force (kgf) were employed, but they were barely distinguishable and sometimes caused misunderstanding. However, in the SI system, mass (kg) and force (N) are clearly distinguished, and the force relationship is 1 kgf = 1 kg × g (gravitational acceleration) ≒ 9.8 N. As a result, wind pressure that had been expressed using kgf/m^2 is now expressed in SI units as N/m^2, and a numerical value of about 9.8 times the conventional value is adopted in the SI unit system. Meanwhile, SI units were introduced in *Recommendations* in 2004.



*Sea coastal line or lake coastal line is to be set to have a distance of 1,500 m or more from the line to the opposite shoreline.

—Enhancement of wind force coefficients, etc.

In the Building Standard Law before its revision in 2000, the wind coefficient and wind pressure coefficient were diagrammatically expressed using a two dimensional building section, but after the Law's revision in 2000, the two-dimensional section was changed to a three-dimensional expression. Further, from 2008, the building standard improvement subsidy project began implementing wind tunnel and other tests to derive wind force coefficients for hip roofs, rooftop advertising plates, porch handrails and other members. In 2013 it became possible for structural designers to reference these coefficients.

Wind-resistant Design Guidelines of Various Industrial Organizations

Structural designers have been obliged to submit a structural calculation document for exterior building members (roofing materials, exterior walls, openings, etc.) at the time of building confirmation, but often the design and installation of these members are trusted to people specializing in the particular structural members. Given such a situation, the industrial organizations of the exterior members industry have independently prepared the guidelines shown below. These guidelines aid structural designers, project owners and supervisors in confirming that the wind resistance of exterior members conforms to the wind load provisions of the Building Standard Law.

Roofing materials

- Japan Roof Tile Industry Association and others: Guideline for Tile Roof Standard Design and Installation (2001)
- NPO Japan Exterior Furnishing Technical Center: Guideline for Decorative Slate Covering for Housing Roof and Roof Wind-resistant Design and Installation (2002)
- Japan Metal Roof Association and Japanese Society of Steel Construction: Steel Sheet Roof Structure Standards SSR2007
- Japan Copper Development Association: Copper Sheet Roof Structural Manual (revised in 2004)
- Architectural Institute of Japan: Japanese Architectural Standard Specification JASS12, Roofing Work (2004)

Exterior walls

- Architectural Institute of Japan: Japanese Architectural Standard Specification JASS27, Dry Exterior Wall Work (2004)
- Japan Fiber Reinforced Siding Manufacturers Association: Fiber Reinforced-type Siding and Standard Execution (2nd version 2009), Improvement of Housing Quality and Durability and Exterior Wall Ventilation Structure (2001)
- Japan Metal Siding Industry Association: Execution Manual of Japan Metal Siding Industry Association (2008)
- Extrusion Cement Plate Association: Standard Specifications for ECP Execution (2010)
- Architectural Institute of Japan: Japanese Architectural Standard Specification JASS21 ALC Panel Work (2005)
- Autoclaved Lightweight Aerated Concrete Panel Association: ALC Panel Structure Design Guideline (2004), ALC Thin Panel Design and Construction Guideline (October 2002), ALC Attachment Structure Standards (2004)
- Architectural Institute of Japan: Japanese Architectural Standard Specification JASS14 Curtain Wall Work (1996)
- Curtainwall Fire Window's Association: Curtain Wall Performance Standards (2006)
- Precast Concrete System Association: Guidance for Design, Precast Curtain Wall Calculation Examples (Temporary revised version)

Openings (door, window glass, etc.)

- Japan Rolling Shutters & Doors Association: Wind Pressure-resistant Strength Calculation Standards for Shutters and Overhead Doors (2003)
- Architectural Institute of Japan: Japanese Architectural Standard Specification JASS17 Glass Work (2003)

* * * * *

An outline of the wind loads on buildings adopted in Japan is introduced by comparing the wind load provisions in the Building Standard Law and the guidelines in *Recommendations for Loads on Buildings* of the Architectural Institute of Japan. Further, the guidelines for wind-resistant design pertaining to exterior building members, prepared by related industrial organizations, were introduced. ■

Preparation of Reference Materials on Steel Construction Technologies in Japan

The Japan Iron and Steel Federation (JISF) has prepared a list of reference materials on steel construction technologies in Japan. In order to encourage wider use of Japanese steel construction technologies overseas and at the request of the Ministry of Land, Infrastructure, Transport and Tourism. JISF introduces in these reference materials 27 kinds of steel construction technologies and steel construction products that are widely applied in Japan in the fields of building construction and civil engineering.

These technologies and products help to improve the functions of buildings, port/harbor facilities and other infrastructures and are demonstratively effective in disaster prevention. These reference materials are now available at our website (http://www.jisf.or.jp/en/activity/sctt/index.html). The technologies and products introduced are:

- New Structural System Buildings Employing Innovative Steel Materials
- SN Steel - Structural Steels for Buildings
- Cold-formed Rectangular Steel Tubes for Buildings - BCR/BCP
- Low Yield-point Steel for Building Structures
- Buckling Restrained Brace - BRB
- Concrete-Filled Tube - CFT
- Thermo-Mechanical Controlled Process - TMCP Steel
- High Strength Steel for Buildings - SA440/H-SA700
- Port Renovation Method Employing Steel Materials
- Seismic Retrofitting of Quays, Seawalls and Breakwaters Employing Steel Materials
- Method of Reinforcing Existing Bridge Foundation with Steel Pipe, Sheet Piles and Steel Pipe Piles
- Lateral Flow Control for Revetment
- Steel Framed House
- Liquefaction Control Earthquake Resistance Measures Using Steel Sheet Piles
- Debris Flow Control Method Employing Steel Materials
- Landslide Disaster Control Method with Cribbing Structure (Steel Cribbing)
- Falling-stone Prevention and Slope Protection Work Using Steel Materials
- Steel Structure Disaster Protection Center Building
- High Tide and Tsunami Wave Control with Steel Materials
- Water Shield Revetment Using Steel Piles and Steel Pipe Sheet Piles
- School Facility Built with a Steel Structure (Multipurpose Institution)
- Floating Disaster Management Base (Mega-float)
- Fire Resistant Steel (FR)
- Ultra-High-Strength Bolt
- H-beam with Fixed Outer Dimensions
- Steels for Bridge High-performance Structure (SBHS)
- Weathering Steel for Bridges

Request for Participation in Survey of *Steel Construction Today & Tomorrow*

Steel Construction Today & Tomorrow, a joint periodical of the Japan Iron and Steel Federation (JISF) and the Japanese Society of Steel Construction, is published three times a year. It is the only English periodical that distributes technological information about steel construction in Japan to the worldwide construction community.

We are conducting a survey of the periodical's readership regarding publication of the three issues planned for fiscal 2014. The survey's major aim is to gain an accurate understanding of reader needs so as to enhance the usefulness of the publication. The survey forms are available as follows.

• At the JISF Website

→Enter "jisf" in the search window of your internet browser

jisf Search

→Click on the tab for JISF's English website

The **Japan Iron and Steel Federation**

→Click on the tab for Steel Construction Today & Tomorrow


Steel Construction Today & Tomorrow (Free Magazine)

→Click the survey form

Questionnaire

• Printed Form for Faxing

A survey form is enclosed in the magazines sent to our regular subscribers. Please answer the questions in the form and fax to +81-3-3667-0245.

Your positive participation in the readership survey will greatly help us to enhance the usefulness of *Steel Construction Today & Tomorrow*. This will benefit both your country and the Japanese steel industry. To attain this goal, we eagerly seek your ready cooperation in filling-out and returning the survey's "questionnaire". ■

STEEL CONSTRUCTION TODAY & TOMORROW

Published jointly by
The Japan Iron and Steel Federation
3-2-10, Nihonbashi Kayabacho, Chuo-ku, Tokyo 103-0025, Japan
Phone: 81-3-3669-4815 Fax: 81-3-3667-0245
URL http://www.jisf.or.jp/en/index.html

Japanese Society of Steel Construction
Yotsuya Mitsubishi Bldg. 9th Fl., 3-2-1 Yotsuya, Shinjuku-ku, Tokyo 160-0004, Japan
Phone: 81-3-5919-1535 Fax: 81-3-5919-1536
URL http://www.jssc.or.jp/english/index.html

Edited by
Committee on Overseas Market Promotion, The Japan Iron and Steel Federation
Chairman (Editor): Keiji Ando

Published three times per year, **STEEL CONSTRUCTION TODAY & TOMORROW** is circulated to interested persons, companies and public organizations to promote a better understanding of steel products and their application in the construction industry. Any part of this publication may be reproduced with our permission. To download content (PDF format), please go our website at: http://www.jisf.or.jp/en/activitity/sctt/index.html. We welcome your comments about the publication and ask that you contact us at: sunpou@jisf.or.jp.