STRATEGY ON WIND ENGINEERING RESEARCHES IN BRI AND NILIM

by

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ABSTRACT

This paper describes current strategy on wind engineering researches in the Building Research Institute (BRI) and the National Institute for Land and Infrastructure Management (NILIM). As for the strategy on wind engineering researches, based on performance-based structural design of buildings, it is significant to evaluate more reasonable wind loads on buildings by means of numerical simulations, wind tunnel experiments and field measurements. The outputs of such evaluations may be complementary to the new wind load provision[1] revised in 2000. The strategy presented here includes various themes of wind engineering about not only a building structural aspect but also meteorological or social/economical aspects.

Key Words: Performance-Based Design
Index of Roughness Terrain
Numerical Simulation
Wind Tunnel Experiment
Strong Wind Damage
High-Rise Building

1. INTRODUCTION

Every year relatively strong and large-scale typhoon hit Japan, so it is indispensable to design buildings considering serviceability and safety limit criteria based on wind engineering. In Japan, structural designers usually refer several design regulations and standards on wind engineering, which are the Building Standard Law of Japan, Recommendations for Loads on Buildings of Architecture Institute of Japan (AIJ)[2] and so on. BRI and NILIM have already had important roles in making out drafts of them. As for the Building Standard Law of Japan, it was revised in 1998 and it is a so-called performance-based regulation. The new wind load provision entrusted by the Building Standard Law of Japan consists of several new design concepts based on Recommendations for Loads on Buildings of AIJ and other national or international standards such as ISO4354, and the main concepts[1] are as follows:

- Setting return period of design wind speed
- Introduction of exposure factor and gust effect factor
- Definite separation of loads for design of structural frames and design of claddings

However, there is still further discussion for reasonable improvement in the new wind load provisions.

Under the present circumstances as mentioned above, it is more important to design buildings based on performance-based design of wind loads. BRI and NILIM have set up the strategy on wind engineering researches for more rational wind load provisions and some themes of the strategy have been already started. The outlines of them are

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introduced in this paper. We consider that the following themes will get satisfactory results under international collaboration with US and Japan.

2. STRATEGY ON WIND ENGINEERING RESEARCHES

2.1 Establishment of Design Wind Load Based on Numerical Index of Roughness Terrain

New wind load provision in the Building Standard Law of Japan regulates four roughness terrain categories in Table 1 for the exposure factor as pointed out in the Introduction. Fig.1 shows Er for each roughness terrain category. For example, it defines very flat area as Category Ⅰ and high density metropolitan area as Category Ⅳ, respectively. Originally, Recommendations for Loads on Building of AIJ as well as other national or international standards define roughness terrain categories by descriptive expressions and/or photographs of typical examples. But the way to define them was considered to have a possibility of misunderstanding.

Therefore, in the new wind load provision, a clear definition was required from the viewpoint of administrative control of building construction and it has been developed as follows. The roughness terrain categories are regulated with considerations whether the construction site is inside the city planning area or not and how is the building height and the distance from seafront or lakefront in Fig.2. The area of Category Ⅰ is designated in the area of Category Ⅱ, and the area of Category Ⅳ is designated in the area of CategoryⅢ, respectively.

It is true that the way to define roughness terrain categories is distinct administratively, but it is not always reasonable evaluation from the viewpoint of wind engineering since the effects of configuration parameters such as element density[3] are not

Table 1 Parameters of E_r

Terrain Category	Z_b (m)	Z_G(m)	α
I	5	250	0.10
II	5	350	0.15
III	5	450	0.20
IV	10	550	0.27

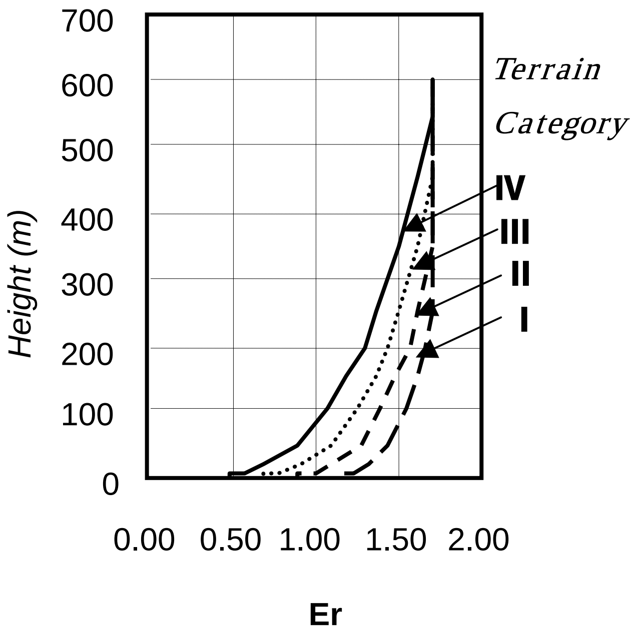

Fig.1 E_r (=Vertical distribution coefficient for mean wind speed)

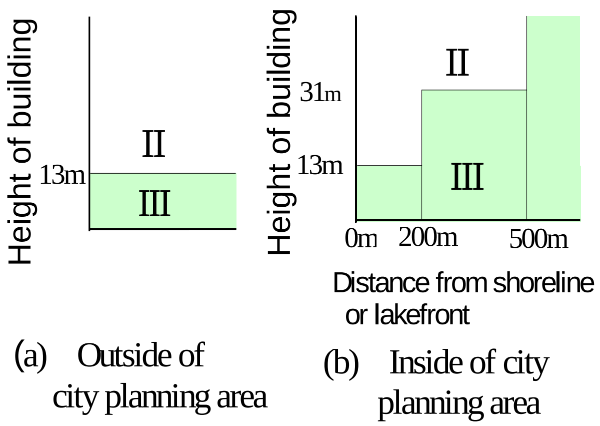

Fig. 2 Categories of Exposure Factor

evaluated numerically in the provision. Therefore, we are now planning new research theme concerning the above problem. Recently the local height of each building in the roughness terrain has been able to be measured numerically by means of remote sensing laser devices on the airplane which can precisely measure the distances from the airplane to objects on the ground. Such measured digital data become available in major cities, the populations of which are more than 150 thousands in Japan. They can be classified into two models which are called Digital Surface Model (DSM) and Digital Elevation Model (DEM). DSM contains digital information of absolute heights above sea level of surface objects such as buildings or trees as shown in Fig.3, while DEM contains digital information of absolute height above sea level of the ground level enveloped from DSM. The main purpose of the theme is proposition of new numerical index of roughness terrain category which reflects uneven of the surface of the ground by means of DSM and DEM.

We have already engaged in measuring wind speed at some field points. One of them is located at the rural area in Tsukuba as shown in Fig.4[4]. The others are located just near the coast of the Pacific Ocean in Wakayama and the coast of Tokyo Bay in Chiba. The roughness terrain category of them may be different by the possible index, though the roughness terrain categories of them are the same in the new wind load provision. Fig.5 shows the power law index α of the wind profile near the ground observed at Tsukuba. The roughness terrain category around Tsukuba also should be Ⅲ in the new wind load provision, but the results in Fig.5 shows between category Ⅱ and Ⅲ. And the Boundary Layer Wind Tunnel in BRI will introduce automatic roughness element system in this year. So we can evaluate validity of the possible index by both of field data and experimental data. We consider that the index will be more useful for the reasonable design wind load.

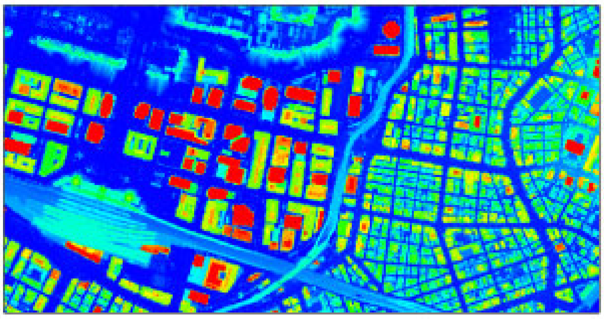

Fig.3 Example of Digital Surface Model at Maruno-uchi, Tokyo

Fig.4 Overview of Tower-Like Structure in Tsukuba

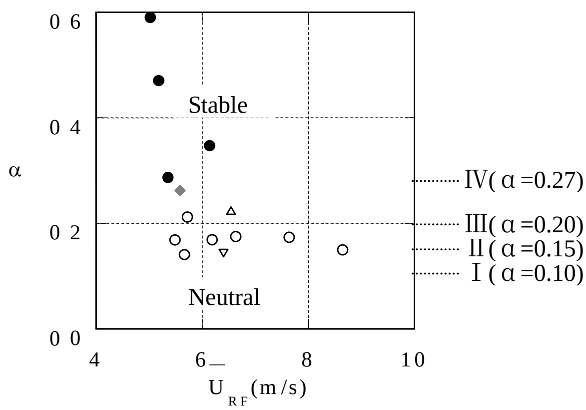

Fig.5 Power Law Index of Wind Profile near the Ground[4]

2.2 Estimation of Urban Disaster by the Strongest Typhoon

Lots of strong typhoons have hit Japan almost every year, while the maximum instantaneous wind speed in history is 105m/s at Guam in 1997 by Typhoon Paka. From now on we cannot deny the possibility that such a strong typhoon will hit Japan owing to the greenhouse effect of the earth. Therefore, it is important to evaluate the possibility of attack of such typhoons by means of probabilistic and numerical simulation. BRI and NILIM have already started the research in collaboration with Tokyo Institute of Technology, Kyoto University, Meteorological Research Institute and Property and Casualty Insurance Rating Organization of Japan. The outline of the research is as follows.

2.2.1 *Estimation of Possibility about Hitting of the Strongest Typhoon*

In the probabilistic viewpoint, probabilistic data about the generating area and magnitude of the typhoon are necessary to collect and then the probabilistic estimation will be carried out considering unusual meteorology, the greenhouse effect and so on. In the numerical viewpoint, on the other hand, the estimation model of generation of the strongest typhoon will be developed and numerical simulation will be carried out. From these results, it will be possible to discuss how often and where the strongest typhoon hits, how the structure of the strongest typhoon is and what meteorological phenomena including meso-scale cyclone are generated following it.

2.2.2 *Estimation of the Generation of Strong Wind in Urban Area*

Recently local digital data of roughness terrain over Japan are going to be available as explained in section 2.1 and Fig.2. Doppler radar is useful for measuring wind speed in the sky of urban area[5]. Moreover, as for the meteorological measuring network, Atmospheric Environmental Regional Observation System (AEROS)[6] by Ministry of the Environment and measuring network by Fire and Disaster Management Agency as well as the Automated Meteorological Data Acquisition System (AMeDAS)[7] are now provided. We gathered the surface meteorological data of Typhoon Vicki in Kansai distinct in 1998 and showed the distributions of the meteorological elements on the ground[8]. In this study, we will evaluate how the strong wind generates in urban area by the numerical simulation such as Large Eddy Simulation (LES) in Fig.6. These digital data of roughness terrain and measured meteorological data are useful as the boundary condition of this simulation. And then in order to estimate wind loads on buildings on the ground, it is important to understand the correlation of the wind speed above the buildings and the wind speed around the buildings on the ground. By the numerical simulation which takes into account such boundary conditions and the correlation of the wind speeds in different heights, it is possible to evaluate tendency of strong wind around buildings and estimate the degree of the structural damage of buildings.

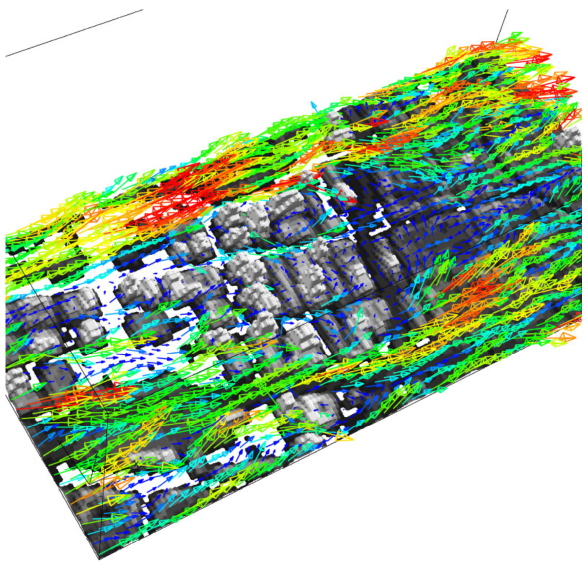

Fig.6 Example of Urban Area Simulated by LES with Local Digital Data of Roughness Terrain, Maruno-uchi, Tokyo

2.2.3 *Estimation of the Disaster Caused by the strongest Typhoon in Urban Area*

Based on the results of numerical simulation, it is necessary to estimate not only structural damage of buildings but also social or economical damages in order to understand the whole damage induced by the strongest typhoon. Therefore, the main outcome in this theme is presenting risk management system against the strongest typhoon in urban area.

2.3 Making out of Database on Buildings Damaged by Strong Wind

In this study, the main purpose is making out database of damaged low rise buildings based on technical reports[9] on past disaster by strong wind classifying damaged buildings into several patterns such as structure, height, shape of roof, roughness terrain and so on. Since above all low- rise wooden or lightweight buildings are relatively subject to attack of the strong typhoon and may end in collapse as shown in Fig.7, the damages of them must be discussed at the safety viewpoint as well as serviceability viewpoint. We consider this study will be useful for developing precise fragility curve of risk evaluation system against strong wind and for limit state design of low-rise wooden or lightweight buildings.

Fig.7 Example of Building Damaged by Typhoon Bart (Sep. 1999) The maximum instantaneous wind speed in Japan was recorded 83.9m/s.

2.4 Evaluation of Characteristics of Across-Wind Response of High-Rise Buildings

In order to design structures of high-rise buildings, wind load is supposed to be more considered rather than seismic load since across-wind response is significant under strong wind. In BRI, several wind tunnel experiments about across-wind response using tall building dynamic models have been already carried out and the tendency of the configuration of building section to influence across-wind response and aerodynamic damping effect has been evaluated[10].

As next study, it is important to understand how strong wind velocity surrounding the building model has an influence on across-wind aerodynamic responses. In order to understand it, we will introduce PIV (Particle Image Velocimetry) system and measure the wind velocities around the building model by the synchronous measurements of wind pressures or across-wind deflections. This concept of a new wind tunnel experiment can be useful for evaluation of aerodynamic interaction.

Fig.8 shows an example of a synchronous measurement of wind velocities around a cubic model and wind pressures in a wind tunnel experiment. This measuring system can clarify the

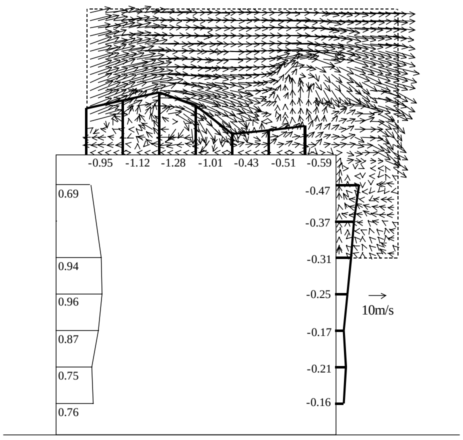

Fig.8 Synchronous Measurement of Wind Velocity around a Cubic Model and Wind Pressure[11]

instantaneous complex wind flows around a body and wind pressure distributions on it, which have been evaluated only by numerical methods.

2.5 Harmonization of Wind Pressure Coefficient among Several Codes or Standards

BRI has already held some international workshops on performance-based design as follows:

- International Workshop on Harmonization of Performance-based Buildings Structural Design in Countries surrounding the Pacific Ocean (Dec. 1997) [12]
- International Workshop on Performance Based Building Structural Design(Nov. 2000) [13].

In these workshops, importance of the harmonization of design load among countries was stressed. However, as for wind pressure coefficient of several codes or standards, there are differences among them since there are differences in averaging time of basic wind speeds and the reference heights of the velocity pressure, though the basic concepts of them are similar[14]. Therefore, from now on we will propose how to harmonize wind load among codes and standards in the international meeting like the above workshops.

3. CONCLUSIONS

In this paper outlines of the strategy of wind engineering researches have been introduced. We consider that the output of these researches will contribute to estimating reasonable wind load affecting low-rise and high-rise buildings on the basis of performance-based structural design and also stress that wind engineering area on wind load which has ever focused on almost only building structures has necessity to take account of meteorological or social/economic aspects as well.

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