APEC-WW2012 Economy Report: Chinese Taipei

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ABSTRACT: This article describes the current status and the ongoing revision on Taiwan building wind code. Two wind code related research projects that are important to the next version building wind code are also described. The first project is to study the characteristics of nature wind by field measurement and wind tunnel simulation; the second research project is to build an aerodynamic database as the basis for the development of e-wind code and the future wind code revision. On the environmental issues, EPA of Taiwan preannounced the draft Indoor Air Quality Act Enforcement Rules in 2012. According to the 2011 statistics of Taiwan's Pollutant Standard Index (PSI), the percentage of days with "good air quality" was better than before. The results indicate that the nation's air quality in recent years has been greatly improved and that efforts to control air pollution have paid off.

KEYWORDS: building wind code, field measurement, wind tunnel simulation, air pollution control, indoor air quality standard, wind environment

1 INTRODUCTION

The Taiwan building wind code “*Specifications for Building Wind Resistant Design*“ is constructed primarily based on the wind load provisions in the ASCE Standard: *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-02), with augmentations on the acrosswind and torsional design wind loads from the AIJ Recommendations for Loads on Buildings (AIJ-96). In July 2012 a wind code revision team was assembled to update the wind load provisions to meet the requests from building designers. This report will describe the main revisions, which includes: (i) specified acrosswind and torsional design wind loads for building aspect ratio less than 3, (ii) update the pressure and force coefficients, (iii) amend the procedure for the estimation of accelerations at building top.

This report describes two wind code related research projects that will be the foundation of next version Taiwan building wind code. The first project is to study the characteristics of nature wind. Due to lack of local field data, the wind profile and turbulence features in Taiwan building wind code were based on those of ASCE-7. Taiwan is a densely populated mountainous island with complex terrain which is quite different from the continental nation such as the Unite States. This project is first to acquire the field mean wind speed profile by Lidar. Based on that, a scaled replica topographic model would be used to simulate the atmospheric boundary layer in wind tunnel. In such an arrangement, the detail characteristics of atmospheric boundary layer can then be obtained. The other major shortfall of Taiwan building wind code is that the procedures for design wind loads are adopted from two different sources. In order to make design wind loads in better harmony and easier for future adjustment, it is necessary to develop an aerodynamic database for wind code. Therefore, the second research project is to build an aerodynamic database as the basis for the development of e-wind code and the future wind code revision.

According to the 2011 statistics of Taiwan's Pollutant Standard Index (PSI), Taiwan's air quality in recent years has been greatly improved and that efforts to control air pollution have paid off. The most important progress in past two years is that the EPA of Taiwan preannounced the draft Indoor Air Quality Act Enforcement Rules in 2012. The controlled substances include carbon dioxide, carbon monoxide, formaldehyde, total volatile organic compounds, bacteria, fungi, suspended particles with a diameter under 10 micrometers, suspended particles with a diameter under 2.5 micrometers, ozone, and any other substances indicated in announcements by the central competent authorities.

2 CURRENT STATUS AND FUTURE DEVELOPMENT OF TAIWAN BUILDING WIND CODE

2.1 *General instructions Current status*

The Taiwan building wind code “*Specifications for Building Wind Resistant Design*“ , formally announced in 2007, consists of six chapters; including (i) General (ii) Design Wind Loads for Main Wind Force Resisting Systems (iii) Design Wind Loads for Components and Cladding (iv) Wind Induced discomfort (v) Wind Tunnel Test (vi) Other Issues. Details of the Specification can be found in the APEC-WW 2004 report (Cheng &Chang, 2004). This building wind code, which was the major overhaul of wind code in past 30 years, is constructed primarily based on the wind load provisions in the ASCE Standard: *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-02), with augmentations on the acrosswind and torsional design wind loads from the AIJ Recommendations for Loads on Buildings (AIJ-96).

2.2 *Future development*

In July 2012 a wind code revision team was assembled to update the wind load provisions to meet the requests from building designers. The new draft of the Specifications for Building Wind Resistant Design will be submitted to the building code review board in 2013. The main revisions include:

(1) The acrosswind and torsional design wind loads for building aspect ratio less than 3, $h/\sqrt{BL}<3$, have been specified.

$$W_{Lz} = 0.87\frac{L}{B}W_{Dz}$$

$$M_{Tz} = 0.28(BW_{Dz})^* \tag{1}$$

In which,

W_{Dz}: alongwind loads at height z,
M_{Tz}: torque at height z,
B is building breadth, L is depth, $(BW_{Dz})^*$ is the larger value of the product of alongwind load and building breadth.

(2) Simplified procedure has been proposed for buildings under 20 meters in height and aspect ratio less than 2, $h/\sqrt{BL}<2$, and side ratio less than 3, $1/3<L/B<3$.

$$W_{Dz} = 1.49[IV_{10}(C)]^2 \lambda \mathrm{K}_{zt}(h) A_z \tag{2}$$

In which, I is the importance factor between 0.9-1.0, $V_{10}(C)$ is basic design wind speed, $K_{zt}(h)$ is a topographic factor, A_z is windward area and λ is a tabulated coefficient.

(3) The external pressure and force coefficients are updated based on the changes in ASCE7-10.

(4) Improved procedure for the estimation of accelerations at building top has been proposed.

3 WIND CODE RELATED RESEARCH PROJECTS

For many countries, provisions of building wind code are primarily for low-rise buildings and warehouse. In Taiwan, almost all residential buildings are engineered reinforced concrete structures to resist strong earthquake, these buildings are generally robust for the wind loads. Unlike ASCE7, Taiwan building wind code is mainly for the wind resistant design of tall building and large span roof structures during strong typhoon. In other words, by adopting wind code from nation with different building types, terrain configurations and wind climates, there will be inevitably some deficiency in the wind code that needed to be modified to better fit into Taiwan's unique requirements. Another major shortfall of Taiwan wind code is that the equations for design wind loads are adopted from two different sources, namely, ASCE7 and AIJ recommendations. In order to make design wind loads in better harmony and easier to future adjust; it is necessary to develop an aerodynamic database for wind code. This report will describe two research projects that are designed for these purposes.

3.1 *Wind profile characteristics*

The characteristic of the nature wind exerts probably the most significant impact on the design wind load. At the same time, it is one of the few factors that have local influences. Due to lack of local field data, the wind profile and turbulence features in Taiwan building wind code were based on those of ASCE-7. Taiwan is a densely populated mountainous island with complex terrain. The topographic features of the so called "large city", "suburban" and "open terrain" in Taiwan are quite different from the continental nation such as the Unite States.

In the current Taiwan building wind code, the wind profile was classified into three categories: Exposure A (large city) with power law exponential $\alpha = 0.32$ and gradient height $\delta = 500m$; Exposure B (suburban) with $\alpha = 0.25$ and $\delta = 400m$; Exposure C (open country) with $\alpha = 0.15$ and gradient height $\delta = 300m$. This classification was originally from ASCE7 with some modification. In order to improve the existing building wind code, it is essential to define the turbulent boundary layers that would truly reflect the local wind characteristics and the terrain effects.

The traditional strategy for wind profile measurement is to install anemometers on a high tower or mast. Normally it is difficult to find an appropriate tall mast on the frequent typhoon routes. The other option will be introducing portable remote sensing devices that can be brought to meet the high wind. There are many instruments designed to measure the velocity and wind direction of the wind. In recent years, Lidar has shown promising results in wind profile measurements for wind energy assessment (Mann *et al.*, 2008; Honrubia *et al.*, 2010). Although Lidar is one of the better remote sensing instrumentation for the measurements of low-level atmospheric data, it can only produce reliable mean wind speed profile. The profile of turbulence remains an intractable atmospheric feature. The strategy of this project is first to acquire the field mean wind speed profile by Lidar. Based on that, a scaled replica topographic model would be used to simulate the atmospheric boundary layer in wind tunnel. In such an arrangement, the detail characteristics of atmospheric boundary layer can then be obtained.

3.1.1 *Field Measurements*

Three monitoring sites that represent the typical city, township and open country of Taiwan were chosen for the Lidar measurement. Monitoring site A locates in a residential-commercial mixed region of Taipei, a city of 2.5 million populations. Most surrounding buildings are 4 to 7 stories residential apartment buildings, with some 10 to 12 story commercial buildings and very few higher buildings. In the wet monsoon weather condition, the Lidar measurement range (with acceptable S/N ratio) is no more than 400m. Monitoring site B locates inside an elementary school at I-Lan which is a medium size town. The majority building in the neighborhood of site B are 2-4 stories, only small percentage of buildings are more than 5 stories. Monitoring site C locates at an open terrain area. This monitoring site is an elementary school play ground in a farming community. The surrounding landscape is mostly rice paddy with scattering trees and one or two story farm houses.

Table 1: Wind profiles from Lidar measurements in monsoon seasons

	Monsoon		
Monitoring site	A	B	C
Gradient Height (m)	>420	326(91)	231(38)
Power Law Index, α	0.28(0.04)	0.22(0.05)	0.15(0.04)
Roughness Height z_0 (m)	0.43(0.30)	0.31(0.30)	0.22(0.15)

Note: values in parentheses are standard deviations

At monitoring site A, 24 valid one-hour wind records from 4 measurements in monsoon season were taken for wind profile analysis. Mean and standard deviation for power law index α were found to be 0.28 and 0.04, respectively. Mean and standard deviation for the surface roughness length were found to be 0.43m and 0.30m, respectively. Gradient height exceeds 420 m. At monitoring site B, 8 one-hour wind records from 3 measurements in monsoon season were taken for the wind profile analysis. Mean and standard deviation for power law index α were found to be 0.22 and 0.05, respectively. Mean and standard deviation for the surface roughness length were found to be 0.31m and 0.30m, respectively. Mean and standard deviation for the gradient height were found to be 326 m and 91m, respectively. At monitoring site C, 10 one-hour wind records from 4 measurements in monsoon season were taken for the wind profile analysis. Mean and standard deviation for power law index α were found to be 0.15 and 0.04, respectively. Mean and standard deviation for the surface roughness length were found to be 0.22m and 0.15m, respectively. Mean and standard deviation for the gradient height were found to be 231 m and 38 m, respectively.

3.1.2 *Wind tunnel simulations*

Wind tunnel simulations were carried out for two purposes. The first goal is to validate the scale down modeling procedure by comparing the wind profiles of wind tunnel simulations to the in situ measurements. Then the entire turbulent boundary layer characteristics of this particular site can be studied in detail. Shown in Figure 1(a) is the upstream scaled topographic model of field monitoring site A. 1/500 scale ratio was adopted and total length equivalent to 6.75 km of topographic model was used to simulate this atmospheric boundary layer. Shown in Figure 1(b) is the 1/400 scale topographical model of the monitoring site B. 5.4 km upstream models were used in these two cases. Under such arrangement, it was found that the gradient heights of the generated boundary layers were noticeably less than the full scale data in terrain category A and B. It is evident that spires installed at test section entrance are necessary for a typical medium length wind tunnel to properly simulate fully developed atmospheric boundary layers. Based on this arrangement, the turbulence features of the generated turbulent boundary layer were carefully measured and compared with the existing building wind codes.


(a)urban (b) suburban

Figure 1: Scaled terrain models for wind tunnel simulation.

Shown in Figure 2 are mean speed, turbulence intensity and integral length scale profiles of the monitoring data and scaled tunnel simulation in urban terrain. Turbulence intensity of the simulated turbulent boundary layer is significantly less than the value suggested for Terrain Cat-

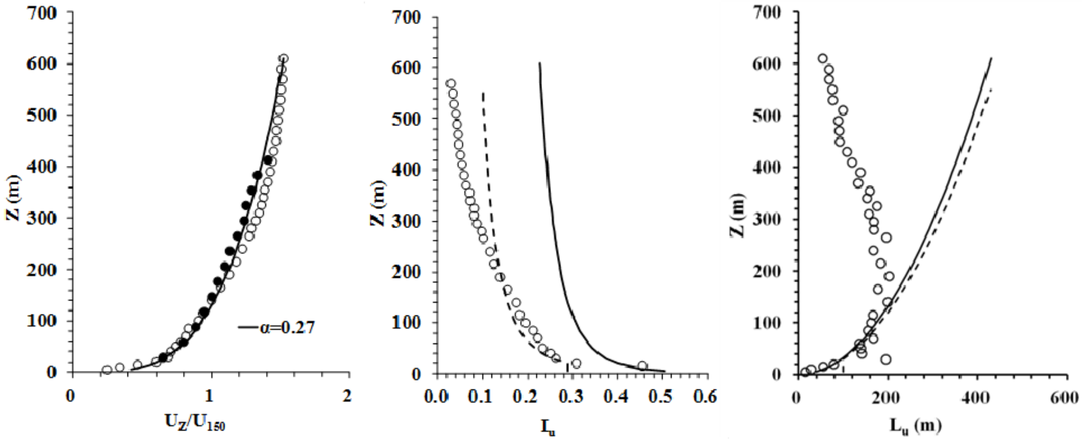


Figure 2: Mean speed, turbulence intensity and integral length scale profiles in urban terrain. (○ : wind tunnel ; ● : field data ; — : ASCE7(A) ; - - : AIJ(IV))

egory A (large city) in ASCE7-02 (ASCE, 2002). However, it agrees quite well with AIJ recommendations (AIJ, 2004) for terrain Category IV (City with 4 to 9-story tall buildings) up to 250m. At higher altitude, AIJ recommendations become slightly conservative. ASCE7 and AIJ recommendations give similar values for turbulence integral length scale. Field measurement data agree well with both wind codes up to 150m. After that, both wind codes become significantly overestimated. Similar comparisons can be observed for the simulated boundary layer characteristics of suburban terrain shown in Figure 3.

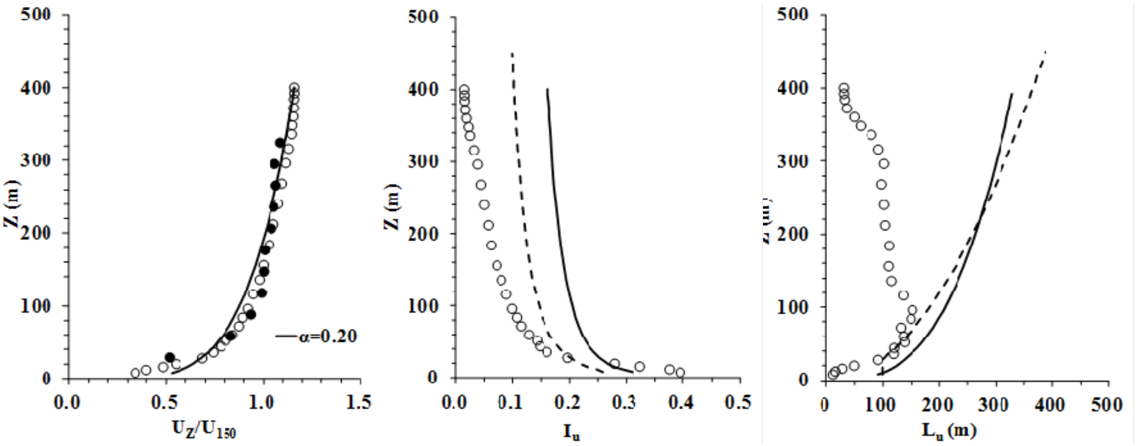


Figure 3: Mean speed, turbulence intensity and integral length scale profiles in suburban terrain.
(○ : wind tunnel ; ● : field data ; — : ASCE7(B) ; - - : AIJ(III))

3.2 *Aerodynamic database for tall buildings*

A systematic wind tunnel test program has been carried out to build an aerodynamic database as the basis for the development of e-wind code and the future wind code revision. Three turbulent boundary layer flows with power law index α=0.32, 0.25, 0.15, respectively, were generated to represent wind profiles over urban, suburban and open country terrains. All pressure models are rectangular with the following geometrical variations: aspect ratio $H/\sqrt{BD}$=1-7; side ratios *D/B*= 1/5 to 5/1. For model with aspect ratio of 7, 380 pressure taps were installed on 15 levels along the model height. High speed electronic pressure scanner was used so that global and local mean and RMS pressure/force coefficients, spatial correlations and spectra were obtained to develop the design wind load models. Based these aerodynamic data, a better harmonized design wind load articles can be expected in the future Taiwan building wind code. Furthermore, a more sophisticated procedure for alongwind, acrosswind and torsional design wind loads can be developed for an e-version wind code.

4 CURRENT STATUS AND RECENT ISSUES OF AIR QUALITY IN TAIWAN

4.1 *Air pollution overview in TAIWAN*

In terms of controlling sources of air pollution, the Environmental Protection Administration (EPA) of Taiwan has set gradually tightening emissions standards and continues to promote improvement of the quality of oil products. Collection of the Air Pollution Fee began in 1995 to ensure that air quality in Taiwan reaches a level comparable to that of advanced nations. From the collection of this fee the Air Pollution Control Fund was established to support air pollution prevention and control work. These steps have already resulted in a gradual reduction in the number of poor air quality days. Current air pollution prevention and control working plans encompass the following main items: 1. Improving Air Quality and the Planning and Implementation of Air Pollution Control Policies. 2. Promoting International Environmental Protection. 3. Control of Stationary Sources of Air Pollution. 4. Control of Mobile Sources of Air Pollution

4.2 *Air Quality in 2011 Best in Years*

The unstinting efforts of local government environmental protection bureaus resulted in 2011 being the best year recently in terms of average nationwide air quality and improvement in quality over the previous year.

The EPA of Taiwan pointed out that statistics for 2011 showed the number of days when air quality was poor (PSI＞100) at only 1.38%, an improvement of 4.2% over the figure of 1.44% for 2010. Among the 1.38%, PM10 contributed 0.42%, the same as 2010, while ozone contributed the rest 0.96%, showing a 5.9% improvement over the 2010 figure of 1.02%.

The EPA of Taiwan points out that although the air quality figures for 2011 showed considerable improvement, other negative factors such as the slow increase in the overall burden on the environment, changes to global climate patterns, and the dramatic increase in long-range aerial transportation of pollutants to Taiwan are still present. Further improvement of air quality will therefore require continuous effort by central and local government environmental protection agencies. The EPA of Taiwan will continue interdepartmental cooperation to improve air quality and protect public health – as is expected of it by Taiwan's citizens -- by working with local governments to review and improve existing systems and regulations.

4.3 *Draft of Indoor Air Quality Act Enforcement Rules Preannounced*

On 4 June 2012, the EPA of Taiwan preannounced the draft Indoor Air Quality Act Enforcement Rules, which will take effect in conjunction with the Indoor Air Quality Act on 23 November 2012.

In order to effectively promote and administer the Indoor Air Quality Act, the EPA has formulated enforcement rules according to Article 23 of the Act. Among other things, the rules stipulate the required items to be included in indoor air quality management plans, indications as to lengths of improvement periods, and the format to be used for written documents.

As the EPA of Taiwan points out, the quality of indoor air directly affects human health and *the productiveness of workers. Pollutants in indoor air has become an issue that has been* gathering increasing attention in recent years, and so the EPA has been charged under the Act with drawing up Indoor Air Quality Act regulations in order to improve indoor air quality and maintain healthy indoor environments for the benefit of everyone's health. The enforcement rules will be the legal basis for making the administration of the Act more comprehensive and complete.

5 STUDY OF THE WIND ENVIRONMENTS AFFECTED BY THE WIND TURBINES

Renewable energy production and demand are gaining momentum in many ways across the world. There is a booming demand of the wind power today. Wind turbines are used to generate electricity from the kinetic power of the wind. To understand the effects on wind environment by the wind turbines are essential.

This project presents a combined experimental and computational study into the wind environments affected by the wind turbine. The wind tunnel tests were carried out to obtain the downstream wind speed of the area of the wind turbines by using the hot film probes. Three dimensional unsteady CFD models were generated to predict the same data as the wind tunnel test. Considering the dynamics similarity between the wind tunnel test and the field measurement, the wind tunnel test performed with the lower rotating speed of the wind turbine than the full scale wind turbine.

5.1 *Experimental Setup*

5.1.1 *Fluid modeling*

The experiments were performed in a low-speed environmental wind tunnel located at Tamkang University in Tamsui, Taiwan. The test section of the wind tunnel has dimensions of 3.5×18× 2.0 m and can generate an average wind speed of up to 16 m/sec. To avoid having the walls of the tunnel interfere with the flow rates and streamlines, the cross-sectional area of an obstacle should be less than 5% of the tunnel cross-sectional area. The boundary layer thickness from the tunnel walls showed less than a 5% change (from 14 to 14.5 cm thick) with the model present. Therefore, we can safely assume for our experiments that the tunnel wall has a negligible effect on the bulk of the flow field within the test section. Figure 4 showed the setup and locations of the measurements of wind speed at downstream of the wind turbine by hot film probes

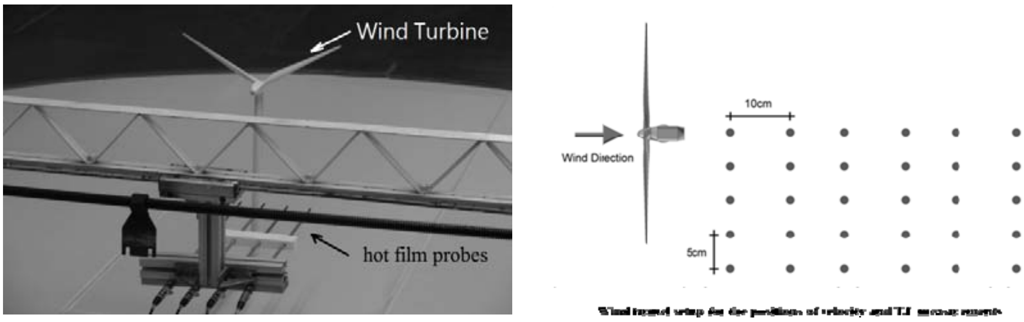


Figure 4: Measurements of wind speed at downstream of the wind turbine by hot film probes.

5.1.2 *Numerical modeling*

The numerical simulation tool used in this study was the computational fluid dynamics software, Fluent. The Fluent CFD software was based on a finite volume discretization of the equations of motion. In this study, steady and unsteady with the RNG kappa-epsilon ($\kappa - \varepsilon$) and Large Eddy Simulation turbulence models were adopted to calculate the flow fields around the wind turbine

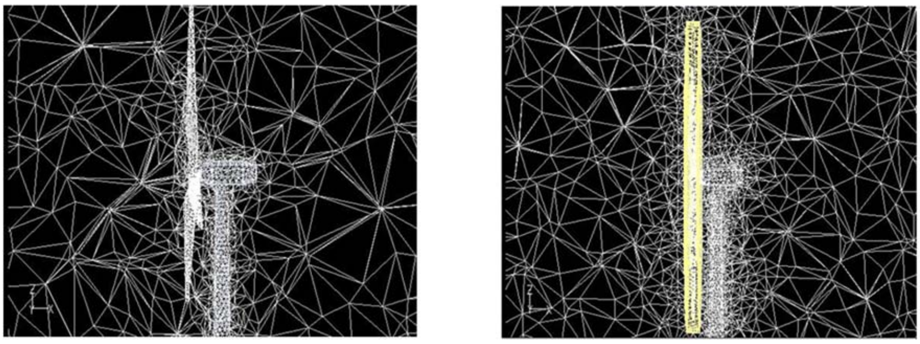
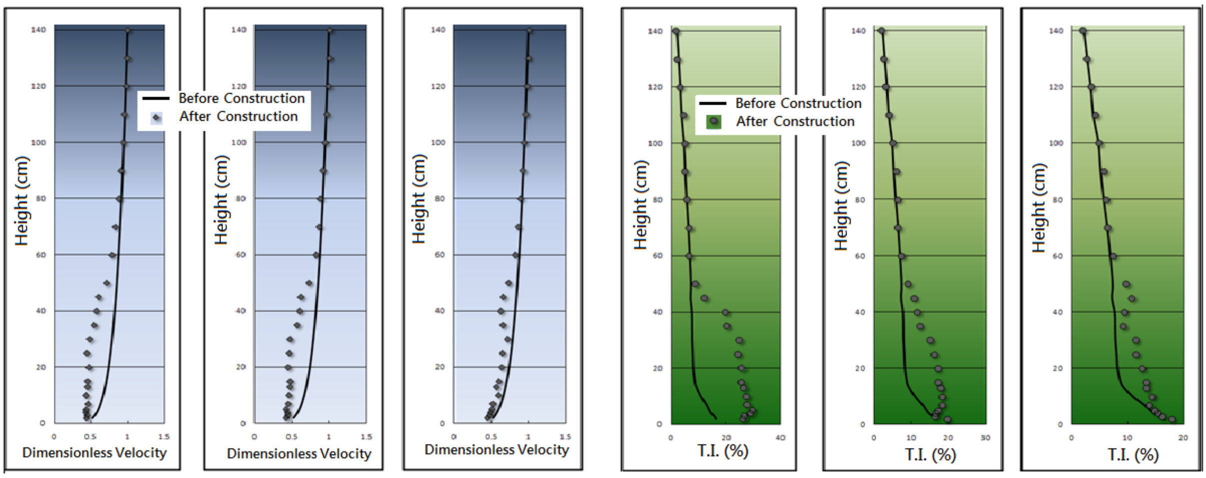


Figure 5: Grid point setup image with (a) Dynamic Mesh Model and (b) Sliding Mesh Model.

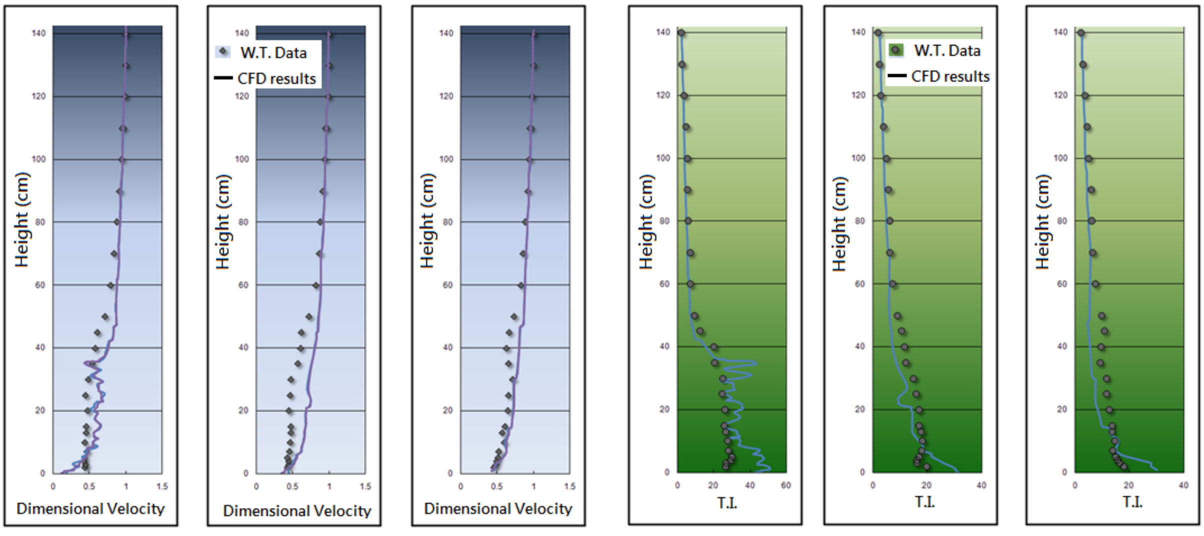
and examine the results of the wind velocity and turbulence intensity profiles downstream of the wind turbines. Both of the sliding mesh model and the dynamic mesh model were also used. Figure 5 demonstrated the different grid point setups for both of Dynamic Mesh Model and Sliding Mesh Model

5.2 *Results and discussions*



Downstream 10 cm 30cm 50cm Downstream 10 cm 30cm 50cm

Figure 6: Comparison of Velocity & T.I. at along wind direction between the before and after constructions.



Downstream 10 cm 30cm 50cm Downstream 10 cm 30cm 50cm

Figure 7: Comparison of Velocity & T.I. at along wind direction between the measured and calculated.

This study is expected to find the correlation of the wind turbine and the wind environment by using the wind tunnel experiment and computational fluid dynamics to set up an assessment method to predict wind environments. Both the numerical dynamic mesh and sliding mesh models were selected for the numerical simulations. Figure 6 showed the comparison of Velocity & T.I. at along wind direction between the before and after constructions. The velocities at along wind direction were decreasing after constructions at height lower the wind turbine. However, the results of turbulence intensity got the opposite results. Figure 7 showed the comparison of Velocity & T.I. at along wind direction between the measured and calculated. Since the wind tunnel experiment can't (reflect) satisfy the real flow field of the wind turbine, the study is attempted to find the best mode and parameter by comparing the numerical simulation with the flow characteristic of wind tunnel experiment. The mode and parameter are set up to imitate the real dimensions of the wind turbine. The result is then utilized to cooperate with wind tunnel experiment to assess the influence on wind environment. Slide mesh is selected for use on the technology of the numerical simulation for there is not much difference after comparing the function test of dynamic mesh and slide mesh. However, in the result of the numerical prediction of the wind turbine, the wind velocity profiles have the same trends with the wind tunnel experiment results and the results of the turbulent intensity profile are close to wind tunnel data.

6 CONCLUDING REMARKS

This article describes the current status and the ongoing revision on Taiwan building wind code. Two wind code related research projects that are important to the next version building wind code are also described. The first project is to study the characteristics of nature wind by field measurement and wind tunnel simulation; the second research project is to build an aerodynamic database as the basis for the development of e-wind code and the future wind code revision. For the wind profile project, Lidar was used to measure wind profiles at city, township and farm field environments during monsoon season. Based on the field wind velocity profile, scaled replica topographic models augmented by spires were used to simulate the atmospheric boundary layer. The detail characteristics of atmospheric boundary layer were obtained and compared with the existing building wind codes. Results indicate that ASCE7 tends to overestimate both turbulence intensity and integral length scale. AIJ recommendations agree well with wind tunnel measurements of the scaled replica topographic models at lower altitude.

Collection of air pollution control (APC) fee and efficient usages make improvement in Taiwan's air quality. Year of the 2011 be the best year in terms of average nationwide air quality and improvement in quality over the previous year. Draft of Indoor Air Quality Act Enforcement Rules Preannounced. The EPA of Taiwan has set indoor air quality standards for two categories of indoor spaces on the first day of 2006. The new measure covers CO_2, CO, HCHO, TVOCs, bacteria, fungi, PM_{10}, $PM_{2.5}$, O_3 and temperature.

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