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ORIGINAL ARTICLE

A Brief Introduction to Academic and Educational Activities in Taiwan's Wind Engineering Society

Y.L. Lo[1*], C.H. Wu[2] and Y.C. Li[3]

[1]Department of Civil Engineering, National Taipei University of Technology, 106 Taipei, Taiwan.
[2]Department of Civil Engineering, Tamkang University, 251 New Taipei, Taiwan.
[3]Taiwan Building Technology Center, National Taiwan University of Science and Technology, 106 Taipei, Taiwan.

ABSTRACT – This paper reviews domestic activities in the wind engineering field in Taiwan for the past nine-year period from 2012 to 2021, including activities of the Taiwan Association for Wind Engineering (TAWE), the Chinese Institute of Civil and Hydraulic Engineering (CICHE), and other related organizations. Among these activities, the activity of code revision is the main theme held by TAWE. Wind researchers and engineers were called to form seven working groups responsible for different revision targets. Besides the code revision, workshops have been regularly held every year to promote wind engineering education not only for students but also for engineers, together with several publications on theories or practices. Among these working groups, a complementary comparison work for the evaluation of pedestrian level winds is also attached to this paper in the appendix. Although still under discussion, a first national standard for offshore wind turbines in Taiwan is attempted to announce in the coming year. Taiwan's wind engineering society has provided professional advice to help the standard in a sound status and consistent with the current wind code for buildings.

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ACTIVITIES OF WIND CODE COMMITTEE OF TAIWAN ASSOCIATION FOR WIND ENGINEERING (TAWE)

The current version of the wind-resistant design code for buildings in Taiwan was announced by Construction and Planning Agency, Ministry of the Interior in 2015 (Figure 1). The design code covers four aspects for buildings structures – the design wind load for the main-frame resisting system of building structures, the design wind load for the cladding of building structures, the comfort evaluation of human habitation, and the evaluation of pedestrian level wind. The wind code committee consists of several working groups for different revision aspects: (1) basic design wind speed; (2) design methodology; (3) quality requirements of wind tunnel testing; (4) revision of across-wind and torsional wind loads; (5) revision of wind force/pressure coefficients; (6) revision of response acceleration; and (7) pedestrian level wind evaluation using CFD. The committee has been discussing revising the current design code planned for the year 2022 or 2023. The following describes the revision targets in working groups.

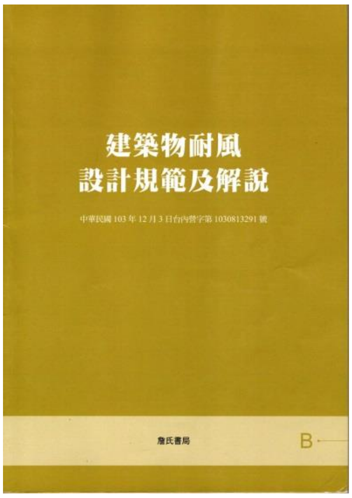
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Figure 1. Wind-resistant design code for buildings in Taiwan [1].

Working Group on Basic Design Wind Speed

This working group (WG) has been trying to revise basic design wind speeds by integrating recent research works, including the conventional method of independent storms, typhoon simulation using Monte Carlo simulation technique, Weather Research and Forecasting (WRF) simulation technique, etc. The possibility of introducing the directional factor to design wind speed has also been discussed in this WG.

Working Group on Design Methodology

The wind-resistant design code for buildings in Taiwan is independently announced by the government. It is obligatory to implement wind load in design codes of steel structures and reinforced concrete structures. This WG has been trying to explain design methodologies such as strength design method and allowable working stress method to enhance the bridging of different codes.

Working Group on Quality Requirement of Wind Tunnel Testing

This WG has been discussing the enhancement of the quality management of wind tunnel testing in the current code, including the model manufacturing precision, the quality of flow simulation, the acquisition precision of signals, the report format, and reservation requirement. The authentication of the wind tunnel testing report is also under discussion.

Working Group on Across and Torsional Wind Loads

This WG has been revising the across-wind and torsional wind loads based on systematic wind tunnel tests conducted in the past years. The combination rules of along-wind, across-wind, and torsional wind loads have also been discussed for possible revision. For those buildings with relatively rigid structural characteristics (with samller aspect ratio), the modification of simplified calculation formulas of across and torsional wind loads is also attempted.

Working Group on Wind Force/Pressure Coefficients

This WG has been enriching peak pressure information on various building configurations for the 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. The first and second versions of wind codes were developed, referring to different ASCE and AIJ recommendations versions. The application of force/pressure coefficients needs adequate background explanation in the two revision works mentioned above for integrity.

Working Group on Response Accelerations

This WG has been revising the evaluation return period and combination rules of the wind-induced response accelerations. The criteria to evaluate the habitation problem due to building vibrations is also under discussion. The current wind code in Taiwan has no classification in building types for the habitation evaluation. The return period for response accelerations is 0.5 years, which is inconsistent with international standards. The revision on response accelerations also attempts to stimulate the technology development of vibration reduction devices.

Working Group on Pedestrian Level Wind Evaluation using CFD

This WG has been discussing the wording of CFD application in evaluating pedestrian level wind for environmental assessments, including the requirement of meshing quality, the adequateness of the turbulence model, parameter precision, etc. The current wind code in Taiwan does not include the CFD technique; however, due to the rapid growth of high-performance computers, it is possible to replace wind tunnel tests with CFD simulations. Although other international codes are attempting to include estimating (temporal averaged) wind loads using CFD, the WG decided to integrate the CFD simulation technique into the part of pedestrian level wind in the wind code at this stage and leave other further revisions in the next-time revision work.

Currently, the evaluation of pedestrian level winds is executed through wind tunnel tests. In Taiwan, ABRI and Wind Engineering Research Center at Tamkang University are the two main institutes carrying out wind tunnel tests. The appendix is the template report for the evaluation of pedestrian level winds based on the criteria proposed by Hunt et al. (1976).

THE FOUNDATION OF THE WIND ENGINEERING COMMITTEE IN THE CHINESE INSTITUTE OF CIVIL AND HYDRAULIC ENGINEERING

The Chinese Institute of Civil and Hydraulic Engineering (CICHE) was funded in 1936 and has been the largest society in the civil and hydraulic engineering field. The institute plays a vital consultant role for the government when national policies are forming. Under the organization frame of CICHE, administrative and technology committees have been set up with the missions providing professional advice to the government and organizing technology workshops on specific issues. The CICHE offers a communication platform between the public and the experts as well. The current technology committees include the water resource engineering committee, the concrete engineering committee, the steel structure engineering committee, the geotechnical engineering committee, and the other 15 technology committees.

In recent years, issues regarding extreme climate changes have been broadly addressed. Wind engineering-related problems attract more and more attention, especially the typhoon-prone area like Taiwan. Compared to the CICHE, TAWE is more of an academic society consisting of professors and researchers in the wind engineering field. To solidify mutual understanding and promote more cooperation in the future, the TAWE has decided to organize a technology committee under the CICHE organization providing more expertise assistance for wind-related engineering problems in the industrial fields. This committee will also play a communication role bridging the disaster prevention technology committee and the TAWE to collect information regarding wind-induced disasters in Taiwan.

PREPARING OF GUIDELINES FOR SITE INVESTIGATION AND STRUCTURAL DESIGN OF OFFSHORE WIND TURBINES

In Taiwan, increasing sustainable energy utilization such as wind energy is the most concerning national policy in recent years. To integrate the domestic industrial resources and the wind turbine technologies from the overseas wind turbine developers, the Ministry of Economic Affairs in Taiwan has announced implementation plans of developing design codes or guidelines for all construction and maintenance stages of offshore wind turbines. In 2021, the National Taipei University of Technology was assigned the mission to chair the implementation committee to develop the guidelines for site investigation and structural design of offshore wind turbines. The TAWE has been invited to provide professional knowledge in wind environmental investigations and the associated wind load assessment requirements. In 2022, the guideline will be announced and put into practice for all related parties. The main content of the guideline includes:

1. General – Introduce the application scope of the guideline and the target users, the nomenclature and definitions, the integration with construction and maintenance guidelines, the report format requirements.
2. Site investigation – Regulations on the site investigation of metocean and geotechnical information.
3. Performance requirement – Performance requirement of offshore wind turbine facilities and design scenarios of various turbine operation or non-operation status.
4. Environmental evaluation – Evaluations on environmental variables such as wind conditions, wave conditions, current conditions, seismic loadings, scouring of the seabed, sea creature attaching, corrosion, etc.
5. Design requirement – Design scope and analysis methodologies for the wind turbine, the substructure, and the foundation structure.

EDUCATIONAL ACTIVITIES OF TAIWAN ASSOCIATION FOR WIND ENGINEERING

For the past years, TAWE has organized regular domestic wind engineering conferences and workshops for the promotion of wind engineering education. Several publications (Figures 2-4) on wind-resistant design for engineers have been made. The Architecture and Building Research Institute (ABRI), Ministry of the Interior has announced many research projects to help the revision work of wind-resistant design code and has continuously provided educational activity funding for TAWE. The following list is the related activities of TAWE.

Publications relating to wind-resistant designs

Handbook of Wind Resistant Design on Buildings (Figure 2.)

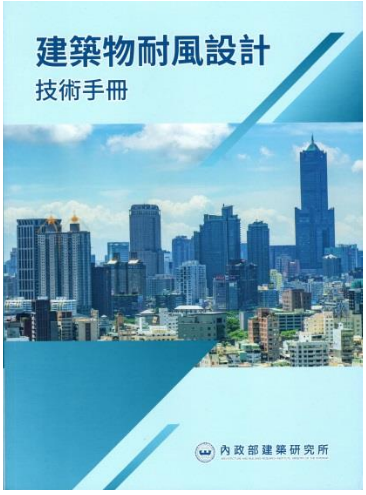


Figure 2. Book publication: Handbook of Wind Resistant Design on Buildings [2].

Theory and Applications of Wind Engineering (Published by TAWE, July 2016. See Figure 3.)

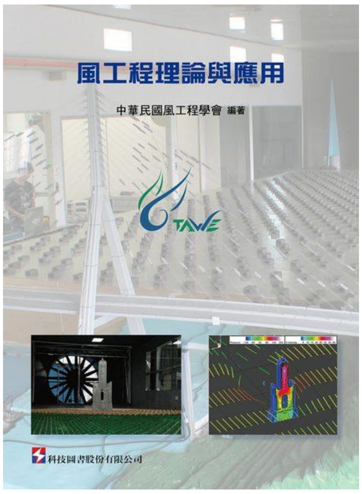


Figure 3. Book publication: Theory and Applications of Wind Engineering [3].

Handbook of Wind Resistant Design on Curtainwall (Published by ABRI, Jun 2020. See Figure 4.)

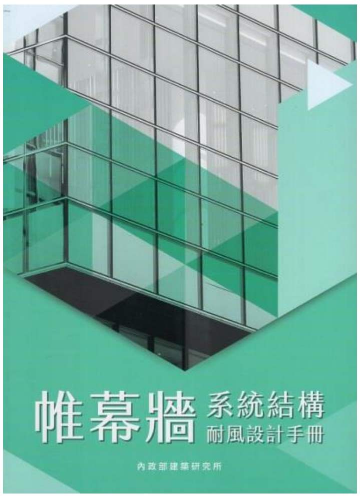


Figure 4. Book publication: Handbook of Wind Resistant Design on Curtainwall [4].

Workshops for wind-resistant design code promotion

TAWE has worked with two institutes to promote wind engineering education through workshop events (Table 1). The two institutes are Architecture and Building Research Institute (ABRI) and Taiwan Construction Research Institute (TCRI); the former is an official division of the central government while the latter is a civil organization, especially for educational purposes. Wind-related courses in the civil or architectural engineering departments in universities or colleges are not as common as earthquake engineering courses. Therefore, the workshop events are mostly based on the wind-resistant design code for most structural engineers in the industrial fields. The following table lists the workshop events held in recent years.

Table 1. Workshop events in recent years [5-8].

Activity name	Time	Location	Speakers	Organizers
Forum of Wind Resistance Design Specifications - 2nd Edition	Oct 2014	Taipei, Taiwan	TAWE members	The Construction and Planning Agency
Wind-resistant design code introduction and application examples	Jul 2015	Taipei, Taiwan	Dr. Chi-Ming Cheng Dr. Chia-Ren Chu Dr. Rwey-Hua Cherng Dr. Jenmu Wang	ABRI TAWE

Table 1. Workshop events in recent years [5-8] (cont.)

Activity name	Time	Location	Speakers	Organizers
CFD simulation using a high-accuracy numerical topographic model	Sep 2016	Taipei, Taiwan	Dr. Fuh-Min Fang Dr. Yi -Chao Li	ABRI TAWE
Wind-resistant design code introduction and application examples	Feb 2017	Taipei, Taiwan	Dr. Rou-Hwa Chen Dr. Yuan-Lung Lo	ABRI TAWE
Workshop of Buoyancy-driven Ventilation in Atrium with a cap	Sep 2018	Taipei, Taiwan	Dr. Chia-Ren Chu	ABRI
Wind-resistant design code introduction and application examples	May 2019	Taipei, Taiwan	Dr. Chi-Ming Cheng Dr. Yuan-Lung Lo Dr. Rwey-Hua Cherng Dr. Chung-Lin Fu	TCRI TAWE
Development of Wind Resistant Design Code for Solar Panel Systems	Jun 2019	Taichung, Taiwan	Dr. Rwey-Hua Cherng Dr. Chung-Lin Fu	TCRI TAWE
Wind-resistant design code introduction and application examples	Jul 2020	Taipei, Taiwan	Dr. Yuan-Lung Lo Dr. Rwey-Hua Cherng	TCRI TAWE
Workshop of Buildings on Wind-resistant Design Specifications: Solar photovoltaic system of Wind-resistant and Wind environment	Jul 2020	Taichung Taiwan	Dr. Yi -Chao Li Dr. Chung-Lin Fu	TCRI TAWE

Conferences and yearly research projects from ABRI for wind engineering research works

TAWE has regularly organized domestic wind engineering conferences every two years. The main organizers were changed by turns – 5th TCWE at National Central University (Host: Prof. Chia-Ren Chu) in 2014, 6th TCWE at Chienkuo Technology University (Host: Prof. Jwo-Hua Chen) in 2016, 7th TCWE at Tamkang University (Host: Prof. Cheng-Hsin Chang) in 2018, and 8th TCWE at National Taiwan University (Host: Prof. Rwey-Hua Cherng) in 2020. The 9th TCWE has been decided to be held at National Cheng-Kung University (Host: Prof. Yu-Ting Wu) in 2022.

Besides the domestic wind engineering conferences, two international events were held by Wind Engineering Research Center, Tamkang University (WERC-TKU) in Taipei. They are: (1) the International Wind Engineering Symposium and Advanced School in Wind Engineering in 2014, and (2) Symposium on Progress in Wind Engineering and Structural Dynamics in 2015. One special exhibition of wind engineering was held in Songshan Cultural and Creative Park in Taipei for the public by WERC-TKU and the Cheetah Industrial Aero-Dyna. Tech Co., Ltd. The latter is a private local company with expertise in wind tunnel testing. Figure 5 is the poster photo of the special exhibition event.

Figure 5. Poster of Wind Engineering Exhibition in Taipei [9].

For other domestic conferences, wind engineering is a regular presentation session for participants. Here such domestic conferences in recent years: 11th National Conference on Structural Engineering (Sep. 2012, Aug. 2014, Aug. 2016, Aug. 2018 and Sep. 2020).

EVALUATION REPORT FOR PEDESTRIAN LEVEL WIND COMFORT ASSESSMENT

This section presents the wind tunnel test results in assessing the pedestrian environment wind field around a target building, located in Daan District, Taipei, Taiwan. The studied case is hypothetical, which is assumed to be the CAARC building [A1], with a full-scale height of 183m and a plane dimension of $30.5\text{m} \times 45.7\text{m}$. The pedestrian wind fields are measured in three scenarios to see the effects of the presence of the target building and the uncomforted mitigation approach: (i) Before the construction of the target building, (ii) after construction of the target building, and (iii) trees planted around the constructed building. In particular, we present the updated summary of the results obtained from two different atmospheric boundary layer (ABL) wind tunnel (WT) facilities at (i) Architecture and Building Experiment Center (ABEC) and (ii) Tamkang University (TKU). These efforts try to understand the deviations resulted from different facilities. This work is also a part of the ongoing project 'Research on Wind Tunnel Test Technology and Report Evaluation Mechanism of Construction Engineering' in Taiwan.

SETUPS IN TWO WIND TUNNEL FACILITIES

The surroundings within 400 meters from the target building are included in the wind tunnel modeling, as shown in Figure A1a. In the area inside the range of 500m from the target building, most of the surrounding buildings are about 10m – 20m in height. According to the 'Wind-resistant design specifications' in Taiwan, the surroundings are classified as a moderately developed area. Therefore, the mean wind speed profile modeled in the wind tunnel should be consistent with the power-law with an exponent, $\alpha = 0.25$, and gradient height $z_g = 400\text{m}$. A total of 57 surface anemometers (i.e., the Irwin probe [A2]) were deployed in the pedestrian activity area around the building and nearby streets. The test starts with $\theta = 0°$ wind direction, which is parallel to the true north of the studied area (Figure A1a). The turntable is then rotated by 10 degrees for the next testing orientation. As a result, a total of 36 wind directions are considered in the testing. The equivalent full-scale sample duration is 1 hour. The common setup parameters for simulations at both wind tunnel facilities are summarized in Table 2 [10-12].

Table 2. Common setup parameters for both ABEC and TKU wind tunnels.

Model dimension (Full scale)	W x B x H = 45.7m x 30.5m x 183m
Radial distance of surroundings included (Full scale)	400 m
Total number of surface anemometers	57
Equivalent sample duration (Full scale)	1 hour
Tested wind directions	$\theta = 0°$(North) → 350°; Increment, $\Delta\theta = 10°$; Total 36 directions.
Upstream terrain condition	Exposure B defined in Taiwan's Code: Power law exponent, $\alpha = 0.25$; gradient height, $z_g = 400\text{m}$;

The differences in the wind tunnel setups are summarized in Table A2. Because of the larger test section, the ABEC WT allows for a larger geometric scale, i.e., 1/250, as compared to the 1/400 scale used in TKU WT. Partly due to different geometric scales, the full-scale height of the surface anemometers deployed in the ABEC WT can be 0.2m closer to the ground. The information of the model scale sampling rate, sampling duration, and roof height mean wind speeds are also noted in Table 3. The example of the testing setups is given in Figure 6 [13-14].

Table 3. Differences in setup parameters in the two wind tunnel facilities.

Wind tunnel capacity		
	ABEC WT	TKU WT
Tunnel Type	Closed circuit	Open straight
Test section dimension (Width x Height x Length)	4m x 2.6m x 36.5m	2.2m x 1.8m x 15m
Geometry scale for model	1/250	1/400
Pedestrian level velocity measurement		
	ABEC WT	TKU WT
Probe height	Model scale: 0.72 cm Full scale: 1.8m	Model scale: 0.5 cm Full scale: 2m
Sampling rate (Model scale)	256 Hz	200 Hz
Sample duration (Model scale)	75 sec	57 sec
Roof height wind speed	11.7 m/s	10.9 m/s

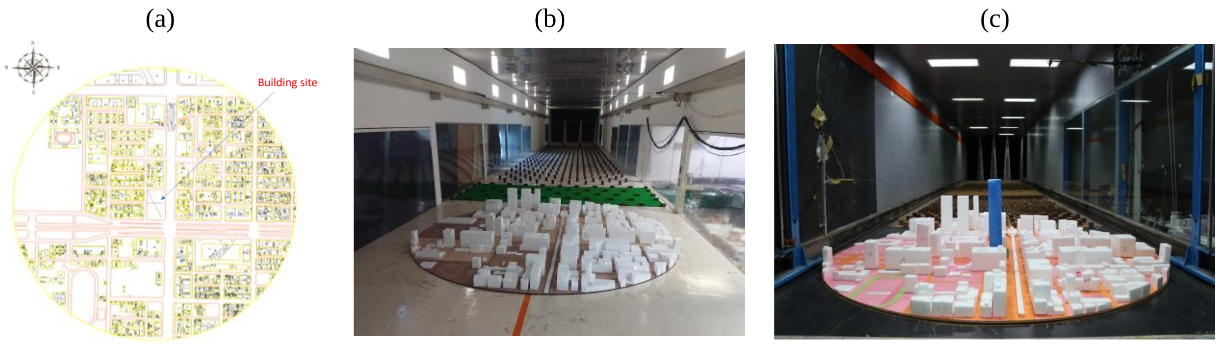


Figure 6. Setup for pedestrian wind field tests: (a) Planar layout of the construction site. (b) ABEC WT, without target building. (c) TKU WT, with target building painted blue.

Before the models are placed in the wind tunnel [15-17], the vertical profiles of the mean velocities and the turbulence intensities were measured and shown in Figure 7. The distribution of the mean wind speeds obtained from the two facilities are consistent and match quite well with the power law of exponent, $\alpha = 0.25$, and gradient height, $\delta = 400$m (full scale), as can be seen in Figure A1a. For the turbulence intensities, Iu, shown in Figure A2b, TKU WT produces lower turbulence by about ΔIu $= 0.02$ below the roof height and above $0.15\ \delta$. Above the building height, TKU WT produces higher turbulence.

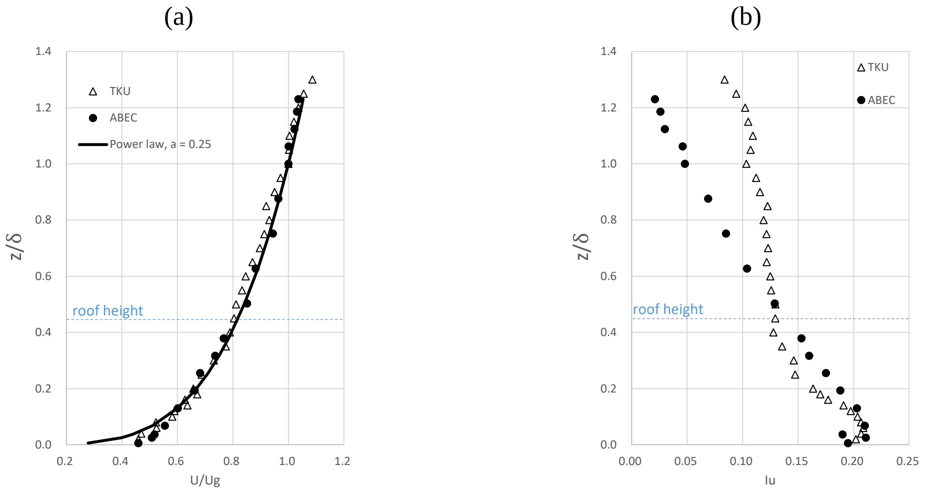


Figure 7. Vertical time-averaged wind profiles measured from the two wind tunnel facilities: (a) Mean wind speed U normalized by gradient velocity, Ug. (b) Turbulence intensity, Iu.

PEDESTRIAN WIND COMFORT ASSESSMENT

In the current analyses, the assessment of the pedestrian level wind comfort is based on the criteria proposed by Hunt et al. [18]. Basically, the criteria specifies an equivalent wind speed, u_e, that should not be exceeded for a given percentage of the time, i.e.,

$$\text{The chances that} \quad u_e = \bar{u} + \lambda\sigma_u > u_{\text{thr}} \quad \text{should be less than some specified probability, } P. \tag{1}$$

Here, λ denotes some positive constants; $\bar{u}$ and σ_u denotes the mean and rms of the pedestrian level wind speed, respectively. As shown in Table 4, the definition of the first three levels of comfort utilizes $\lambda = 3$, while the last comfort level use only the mean speed. The threshold wind speed, u_{thr}, are 6m/s and 9 m/s.

Table 4. Pedestrian level wind criteria proposed by Hunt et al. [18].

Activity	Location	Criteria	Probability condition, *P*
Sitting/Standing long	Outdoor dinning area, patio	$\overline{U} + 3U_{rms} > 6$ m/s	< 10%
Sitting/Standing short	Public parks or squares	$\overline{U} + 3U_{rms} > 9$ m/s	< 10%
Walking	Sidewalks	$\overline{U} + 3U_{rms} > 9$ m/s	> 10%
Uncomfortable		$\overline{U} > 9$	> 1%

The statistics of the pedestrian level wind speeds are measured from the wind tunnel tests for a duration equivalent to 1 hr in full scale (see Table A1). To define the probability of exceedance, u_{thr} needs to be projected to its equivalent value as measured at the nearby weather station, $u_{\mathrm{thr}}^{(s)}$, i.e.,

$$u_{\mathrm{thr}}^{(s)} = u_{\mathrm{thr}} \left(\frac{u_g}{u_e}\right)\left(\frac{z_s}{\delta}\right)^{\alpha} \tag{2}$$

Here, the velocity ratio (u_g/u_e) is used to transform the wind speed at the pedestrian level to the gradient height. In the wind tunnel tests, the gradient velocity, u_g, can be measured together with the pedestrian level velocity u_e. This gradient height wind speed is further transformed to the wind speed at the height of the weather station, z_s, using the power law, $(z_s/\delta)^{\alpha}$, with the exponent α characterizing the terrain condition at the weather station. By assuming that the meteorological data of the hourly wind speed can be expressed by the Weibull distribution, the probability of exceedance, $P(u_e > u_{\mathrm{thr}})$, can be expressed as

$$P(u_e > u_{\mathrm{thr}}) = \exp\left[-\left(u_{\mathrm{thr}}^{(s)}/c\right)^{k}\right], \tag{3}$$

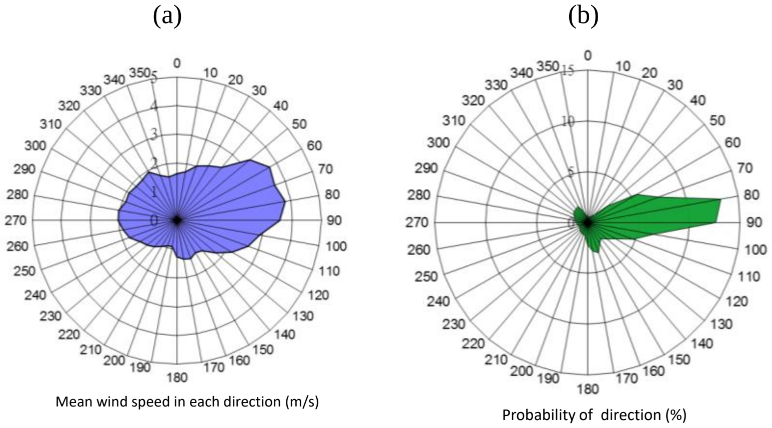
where c and k are the scale and shape parameters of the Weibull distribution. The right-hand-side of Eq. (E3) is in fact the probability that the wind speed, $u_{\mathrm{thr}}^{(s)}$, being exceeded at the weather station.

The process in identifying the probability of exceedance, i.e., Eqs (E2) and (E3), is repeated for every tested wind direction, θ_i. If $A(\theta_i)$ is used to represent the probability of wind directions measured at the weather station, the total probability of exceedance can be obtained by summing the probability of exceedance in each wind direction, i.e.,

$$P(u_e > u_{\mathrm{thr}}) = \sum_i \exp\left[-\left(u_{\mathrm{thr}}^{(s)}(\theta_i)/c(\theta_i)\right)^{k(\theta_i)}\right]. \tag{4}$$

METEOROLOGICAL DATA

The statistics of the hourly wind speeds, measured from the year 2000 to 2017, are obtained from the closest weather station for the studied building site – the Taipei weather station. The mean wind speeds and the probability of occurrence, as a function of the wind directions, are shown in Figures 8a and 8b-c, respectively. It can be seen that the strong wind speeds and dominant directions coincide at $\theta = 60° – 90°$. By fitting the historical data of the hourly wind speed, the Weibull parameters, $c(\theta)$ and $\mathrm{k}(\theta)$, are obtained. The results associated with dominant wind directions are shown in Figure A3c, where k ranges from 2.1 to 2.5 and c ranges from 3.6 to 4.2.


(a)

(b)

(c)

θ	$\mathrm{k}(\theta)$	$c(\theta)$
50	2.10	3.58
60	2.35	4.00
70	2.44	3.95
80	2.53	4.24
90	2.41	3.92
100	2.03	3.27

Figure 8. Statistics of hourly mean wind speed at Taipei weather station measured from 2000 – 2017: (a) Mean wind speed in each wind direction. (b) Probability of wind directions. (c) Weibull parameters k and c for wind directions $\theta = 50° - 100°$.

SUMMARY

The assessment results of the pedestrian comfort obtained from the two wind tunnel facilities are shown in Figures 9(a-f) for the site before construction, after construction, and after trees planted around the constructed building. Generally, the construction of the building increases the wind speeds at the pedestrian level around the building. Planting trees on the sidewalks around the constructed building has limited effects in mitigating the high wind speeds, since only about two locations where the level of uncomfortableness is reduced.

Both wind tunnel facilities give consistent assessments for the case before construction. For the cases when the building is constructed, including the planted tree scenario, the assessments obtained from the ABEC WT raise the discomfort level by one for locations near the building. The exact causes of these differences are not clear at this point and are worth further investigation.

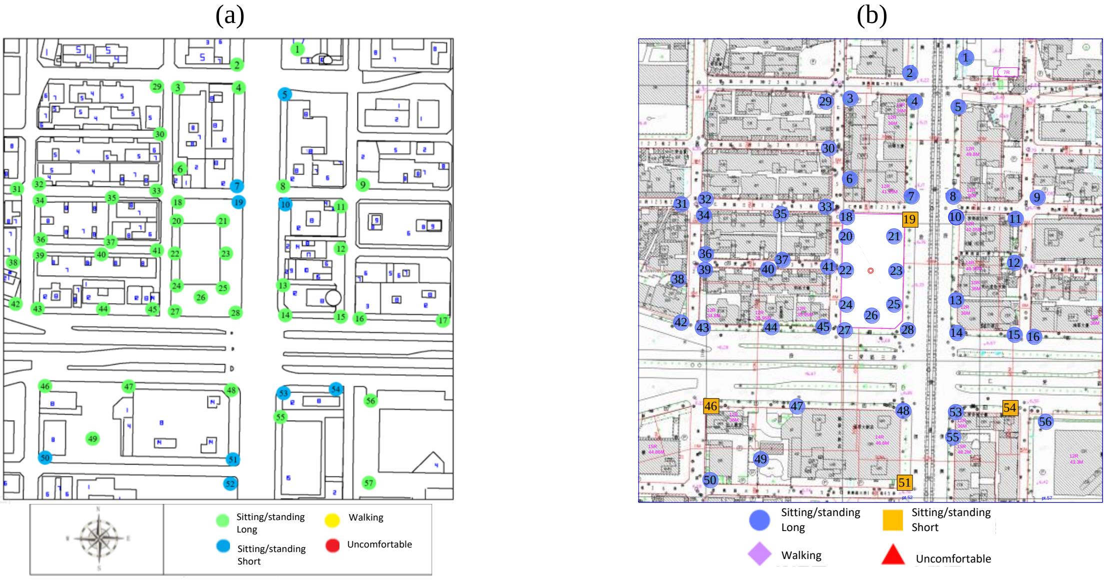


Figure A4. Pedestrian comfort assessment results before construction: (a) ABEC WT (b) TKU WT.

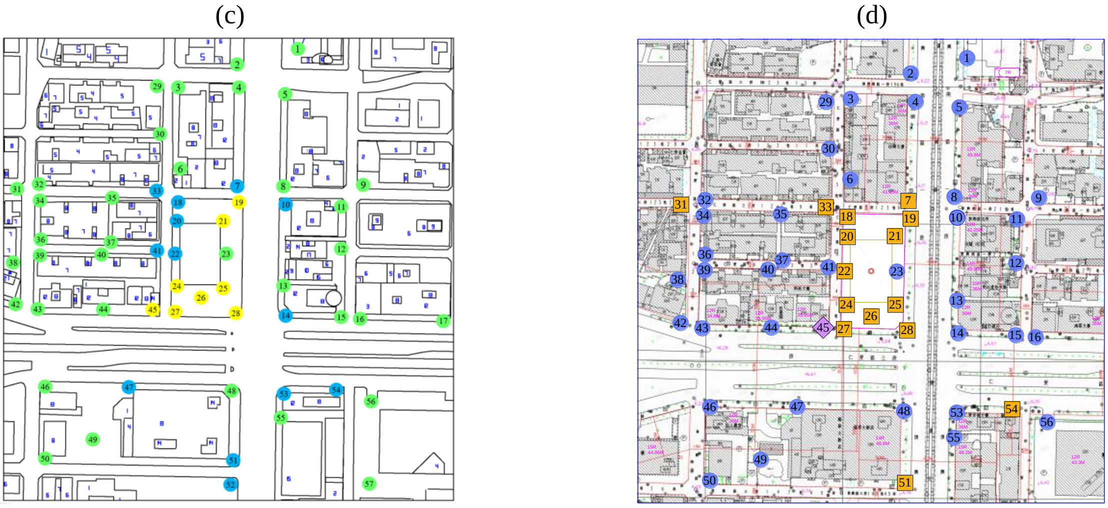


Figure A5. Pedestrian comfort assessment results after construction of the tall building: (a) ABEC WT (b) TKU WT. (Same legend as in Figure A4).

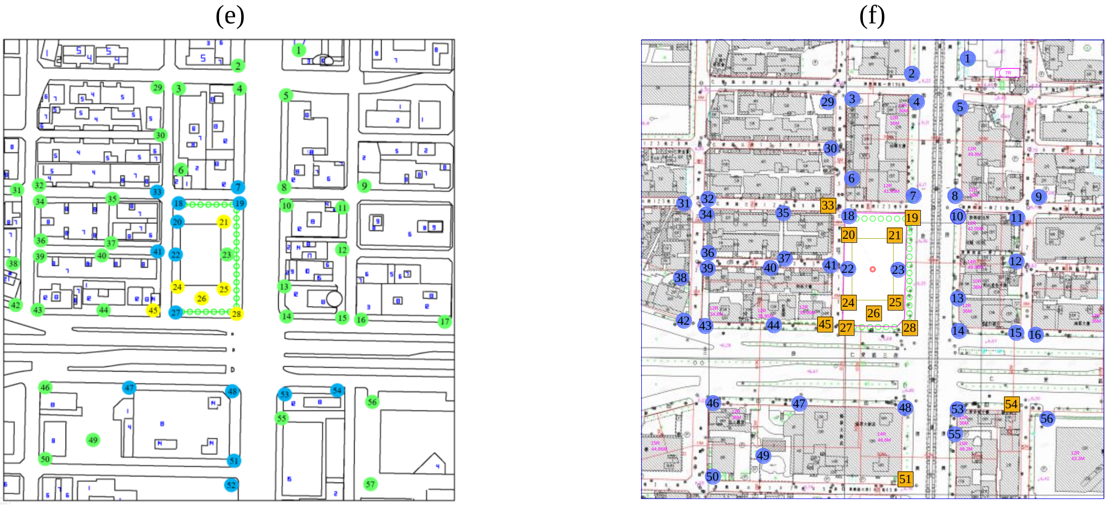


Figure 9. Pedestrian comfort assessment results after trees being planted around the tall building: (a) ABEC WT (b) TKU WT. (Same legend as in Figure A4).

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