APEC-WW2009 Economy Report: Chinese Taipei

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ABSTRACT: Taiwan lies in the path of severe tropical cyclones known in East Asia as typhoons. With their violent winds and extremely heavy rainfall, these storms often cause severe damages. Also, dense populated urban areas and numerous ongoing economic activities have caused serious environmental problems, especially the air pollution problems. Most Asia-Pacific Economics face the same problems as Taiwan. This paper provides the information of wind structural loading codes and wind environmental problem overviews of Taiwan as references for neighborhood countries to improve individual standard/specification and to harmonize the wind load and wind environmental specifications in APEC.

KEYWORDS: building wind code, design wind load, indoor air quality standard, wind disaster loss, Typhoon Morakot

INTRODUCTION

Wind and earthquake loads are two important lateral loadings for buildings in Taiwan. Unfortunately, the effect of high wind is overshadowed by strong earthquake among both general public and professional engineers. As the result, Taiwan used to have a obsolete building wind code. In 2003, after more than 20 years overdue, a wind code working team was assembled to update the wind load provisions to meet the recent development in wind engineering. The new draft of wind load provisions for Taiwan building code and the *Specifications for Building Wind Resistant Design*, has been submitted to the Building Code Review Committee in 2004 for ratification. The revised wind code has received its final approval in 2006 and formally becomes part of the official building code in January 1st, 2007. Since these was very little wind code related research in Taiwan, the now building wind code is not a result of local wind engineering investigation. In stead, it is a combined transformation from USA and Japan wind code, i.e., ASCE7-02 and AIJ-96. The framework of the newly announced building wind code is briefly stated (detail can be found in the APEC-WW 2004 report). This article will discuss the possible shortcoming due to such direct adoption of foreign wind code and the ongoing research for the future amendment.

According to the historical data from 1990 to 2008, there were at least three land typhoon warnings issued every year, and the average numbers of typhoons to land were three. The data from 2002 to 2008 shows that the average of insurance indemnity for wind disaster losses were all below 7%, average was 3%, amongst the engineering disaster losses in a year, except in 2002, the insurance indemnity was 12%. Typhoon Morakot wrought catastrophic damage in Taiwan, leaving 609 people dead and 154 others missing. The storm produced copious amounts of rainfall, peaking at 3,079 mm (121.2 in). The extreme amount of rain triggered enormous mudslides and severe flooding throughout southern Taiwan.

1 CURRENT STATUS AND FUTURE DEVELOPMENT OF TAIWAN BUILDING WIND CODE

1.1 *Taiwan building wind code*

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). The Taiwan building wind code, "*Specifications for Building Wind Resistant Design*", 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 [4]. The 10-minute wind speed with return period of 50 years, at 10m height in open country is used as the basic design wind speed. Due to lacking of sufficient typhoon data, the directionality is not to be considered on the basic design wind speed unless authority approves the statistical and/or simulation method. However, a directional reduction factor of 0.85 is applied to the wind load factor for the limit state design approach.

1.2 *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. A few wind code provisions are currently under investigation for the future revision.

1.2.1 *Wind profile characteristics*

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. Currently, there are two ongoing field measurement projects to collect wind profile data. The first one is a stationary monitoring project, in which, a 100 m mast was instrumented with ultrasonic anemometers at five levels to study the characteristics of atmospheric boundary layer. The second one is to deploy LiDAR unit (Light Detection And Ranging) to locations near the expected typhoon route. Hopefully, giving time, sufficient wind data will be collected for the next revision of Taiwan building wind code.

1.2.2 *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 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 $H/\sqrt{BD}$ =2, 3, 4, 5, 6, 7; side ratios D/B= 1/5, 1/4, 1/3, 1/2, 1/1, 2/1, 3/1, 4/1, 5/1. For model with aspect ratio of 7, 380 pressure taps were installed on 15 levels along the model height. The sampling rate was 200Hz and the sample length was 287 seconds. 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.

1.3 *Proposed wind code revisions*

1.3.1 *Wind load combination*

Since Taiwan building wind code is a combination and compromise of ASCE7 and AIJ recommendations, certain uncoordinated situation would be inevitable. It was found that, for certain building geometry, mainly buildings with low aspect ratio, the acrosswind/ torsional design wind loads and wind load combination are not well defined. Therefore, the ASCE7-05 article 6.5.12.3, design wind load cases, is proposed for buildings with low aspect ratio.

1.3.2 *External pressure coefficients*

A relatively simple version of external pressure/force coefficients was adopted in the current Taiwan wind code. Reference to a few national wind codes, a more comprehensive version of external pressure/force coefficients is proposed to replace the current one.

1.3.3 *Comfort criteria*

For most of the building design in Taiwan, the design lateral loads for main structural systems are generally dominated by seismic loads. Wind loads become the dominant design lateral loading largely due to the serviceability concern instead of structural strength. The current building wind code specifies that the peak lateral acceleration at corner of a building's highest inhabited story should not exceed a flat number 0.05 m/s^2 under six months return period wind speed. This article has caused some controversy among building designers for the comfort criteria check-up is mandatory for all buildings whilst most of cases are known to be satisfactory. Therefore, it is proposed that a regular shaped building with height less than 50 meters shall be exempt from conducting the comfort criteria check.

2 WIND ENVIRONMENTAL PROBLEMS IN TAIWAN

2.1 *Air Quality Overview in TAIWAN*

2.1.1 *Air quality trend analysis of Taiwan*

The major weather type of Taiwan area in spring is stationary front and eastward Hua-Nan cloud rain band. If stationary frontal linger around Taiwan area, it will cause continuous precipitation, then air quality will be good everywhere. If stationary front linger around East China Sea, pressure gradient will be weak. Taiwan will be situated in a warm and low wind speed area, hence air quality will be worse.

In summer and at the beginning of fall, Taiwan area is mainly affected by Pacific Ocean subtropical High and southwest monsoon. There is higher wind speed because of southwest monsoon in south area, and afternoon convection is more active, the air quality is also better commonly. But for north and northeastern area, there is worse air quality result in the terrain block effect. As to the influence of Pacific Ocean subtropical High, because of the downdraft, it will follow more stable air and lower humidity, then causes entire area is in disadvantageous of pollutant dispersion, the influence depends on the strength of subtropical High and position of Rodge. In addition, weather is often affected by typhoon in this season. When typhoon attacks Taiwan, wind speed increases in each place and air quality is better. If typhoon not directly lands, only receives the influence by outer circulation of typhoon, then the air quality on each area in Taiwan will vary on different position related to typhoon, ozone concentration will vary greatly especially. In the end of fall and winter, Taiwan area is mainly influenced by frontal and northeast monsoon, air quality in the north and eastern is generally better. Because middle and south area are located within the leeward side of the Central Mountain Range, the wind speed is weak and the sunshine is stronger, and temperature inversion near ground will be set up easily in early morning being disadvantage pollutant dispersion, the air quality is worse. In addition, Under weather condition with high pressure moving to the sea from land, wind in synoptic scale has more east-west component, because of being obstructed by the Central Mountain Range, the concentration of pollutant in western area is accumulated easily, particularly in the middle and Yunlin and Jiayi area, high pollutant concentration appears easily.

2.1.2 *2008 Air quality best in past five years*

EPA of Taiwan statistics for recent years show that in 2006 the percentage of poor air quality days (Pollution Standards Index＞100) was 3.72%, falling to 3.68% in 2007. This figure fell further still to 2.87% in 2008, an improvement of 22%. Of all of the pollutants measured in the index, ozone showed the greatest reduction, falling from 2.97% in 2007 to 1.77% in 2008, an improvement of 40%.

The EPA of Taiwan gives a number of reasons for the great improvement in air quality over the last 2 years. These include:

· Planning air pollution reduction measures and total quantity controls in the Central Taiwan, Yunlin-Chiayi-Tainan, and Kaohsiung-Pingtung Air Quality Zones

· continuing to collect air pollution prevention fees from stationary pollution sources and revising the Stationary Pollution Source Air Pollution Prevention Fee Rates

· fixing a special rate for sources of nitrous oxides in order to give operators an extra incentive to reduce nitrous oxide emissions

· increasing the number of standards that govern restrictions on VOC emissions from stationary pollution sources according to type of industry

· Formulating measures for the management of air pollution prevention facilities that prevent fugitive particle pollutants from escaping from stationary pollution sources

· providing subsidies for businesses and government agencies that run LPG vehicles

· raising emission standards for new vehicles and other mobile pollution sources

2.1.3 *The indoor air quality management act approved in 2008*

The EPA of Taiwan indicates that most people in Taiwan spend about 90% of their time indoors. The indoor air quality therefore has a direct influence on human health. In recent years more people have come to place more importance on indoor air pollution. To further protect citizens' health and improve indoor air quality, the EPA drafted the Indoor Air Quality Management Act .Indoor environments range from closed to semi-closed spaces such as offices, theatres, restaurants, department stores, hospitals, and even cars, boats, and planes. Many different pollution sources are continuously or intermittently emitted in both indoor and outdoor environments. Poor air circulation causes pollutants to accumulate in closed spaces and harm human health.

Research in recent years points to the following problems in domestic indoor air quality:

1. Public premises where employees work indoors are too closed off, air conditioning equipment is inadequate and air is not adequately circulated. These factors contribute to poor circulation resulting in excessive levels of CO_2.

2. Excessive interior decoration of indoor spaces leads to exposure of VOCs in materials such as glues. This is exacerbated in buildings with poor air circulation and causes increased concentrations of indoor volatile pollutants, especially formaldehyde and TVOC.

3. Taiwan’s subtropical climate has an average humidity of over 80%. The external environment is therefore a hotbed for the development of biological pollutants and shows consistently high concentrations of organic pollutants such as bacteria and fungi.

The EPA indicates that in order to get public premises to take indoor air quality seriously and make effective improvements, the draft Indoor Air Quality Management Act approved by the Executive Yuan stipulates indoor air quality standards for premises designated by the EPA. Environmental agencies can conduct unscheduled inspections and request those not abiding by standards to make improvements before a given deadline. Failure to make improvements will result in a fine ranging from NT$50,000 to NT$250,000.

While making improvements, public premises will be required to let people know about air quality by posting a notice in a conspicuous place near the entrance announcing that indoor air quality does not accord with standards and is currently undergoing improvements. For large public buildings that contain many people, have a high rate of use, or have particular air quality requirements, automatic monitoring equipment must be installed to continuously monitor indoor air quality. Monitoring results should be instantly displayed in an conspicuous location at the entrance of the building.

2.2 *Status of wind disaster and loss in Taiwan*

Taiwan lies in the path of severe tropical cyclones known in East Asia as typhoons. With their violent winds and extremely heavy rainfall, these storms often cause severe damages in Taiwan. According to the historical data from 1990 to 2008, there were at least three land typhoon warnings issued every year, and the average numbers of typhoons to land were three. The statistics also showed that the typhoons caused the most severe casualties were Toraji and Nari in 2001, which caused 225 people dead, 129 people missing and 585 people injured. Moreover, according to the data from 2002 to 2008, the average of insurance indemnity for wind disaster losses were all below 7%, average was 3%, amongst the engineering disaster losses in a year, except in 2002, the insurance indemnity was 12%. Therefore, it can be seen that the losses caused by wind disaster were not the major ones in Taiwan every year. Most of the losses were flood caused by heavy rainfall in days of typhoon. The reason of the wind disaster losses were less than other disasters is because that wind and earthquake loads are two primary lateral loadings for land based structures and buildings in Taiwan. Taiwan locates at an area that both effects are severe. For resisting of earthquake, almost all residential buildings are in the form of reinforced concrete, which is generally sturdy for the wind loads. Figure 1 show the residential buildings and damages of trees and advertising signs by typhoon.

Figure 1 Residential buildings and damages of trees and advertising signs by typhoon.

3 TYPHOON MORAKOT DISASTER

Typhoon Morakot (International designation: 0908, JTWC designation: 09W, PAGASA name: Kiko) was the deadliest typhoon to impact Taiwan in recorded history. It formed early on August 2, 2009 as an unnamed tropical depression. During that day the depression gradually developed before being upgraded to a tropical storm and assigned the name Morakot, by the Japan Meteorological Agency late on August 3. The large system gradually intensified as it tracked westward towards Taiwan. By August 5, the JMA and JTWC upgraded Morakot to a typhoon. Due to the size of the typhoon, the barometric pressure steadily decreased; however, maximum winds only increased slightly. Early on August 7, the storm attained its peak intensity with winds of 150 km/h (90 mph 10-minute sustained) according to the JMA. The JTWC reported the storm to be slightly stronger, with winds peaking at 155 km/h (100 mph 1-minute sustained), the equivalent of a Category 2 hurricane on the Saffir–Simpson Hurricane Scale. Morakot weakened slightly before making landfall in central Taiwan later that day. Roughly 24 hours later, the storm emerged back over water into the Taiwan Strait and weakened to a severe tropical storm before making landfall in China on August 9. The storm gradually weakened as it continued to slowly track inland. The remnants of the typhoon eventually dissipated on August 11.

Typhoon Morakot wrought catastrophic damage in Taiwan, leaving 609 people dead and 154 others missing, most of whom are feared dead and roughly NT$164 billion ($4.9 billion USD) in damages. The storm produced copious amounts of rainfall, peaking at 3,079 mm (121.2 in), surpassing the previous record of 1,736 mm (68.35 in) set by Typhoon Herb in 1996 in Taiwan. Table 1 list the amounts of rainfall at county of southern of Taiwan by Typhoon Morakot. The extreme amount of rain triggered enormous mudslides and severe flooding throughout southern Taiwan. Figure 2 shows the picture of the amounts of rainfall from August 5th to 10th 2009 by Typhoon Morakot. Figure 3 shows the severe flooding in Pingpung county by Typhoon Morakot. One mudslide buried the entire town of Shiao Lin, killing an estimated 500 people in the village alone. Figure 3 shows the picture of changes after Typhoon Morakot of Shiao Lin village. The slow moving storm also caused widespread damage in China, leaving eight people dead and causing $1.4 billion (USD) in damages. Nearly 2,000 homes were destroyed in the country and 136,000 more were reported to have sustained damage. The storm also caused severe flooding in the northern Philippines that killed 26 people.

County	**8/6 (unit:)**	**8/7 (unit:mm)**	**8/8 (unit:mm)**	**8/9 (unit:mm)**	**8/10 (unit:mm)**	**Amount (unit:mm)**
Nantou	64	169.5	716	904.5	133.5	1987.5
Chiayi	68	465	1161.5	1166.5	218	3079
Tainan	88	424	975	432.5	66.5	1986
Kaohsiung	57	235	1301.5	721.5	423	2738
Pingtung	37	1003.5	1403	393.5	332	3169
Taitung	0.5	239	985	382	32	1638.5

Table 1 The amounts of rainfall at county of southern of Taiwan by Typhoon Morakot.

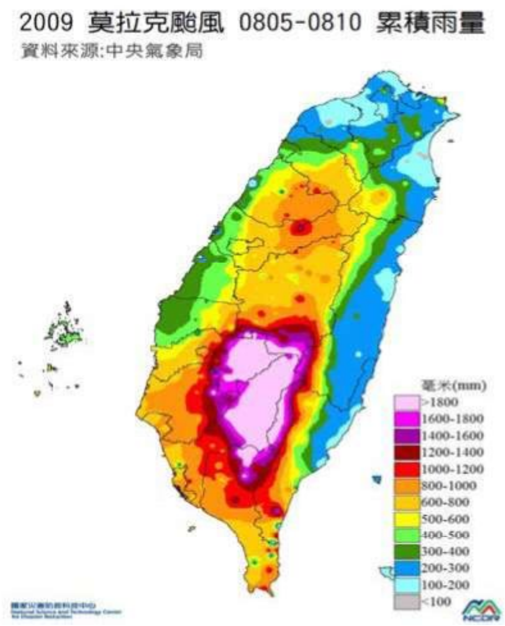

Figure 2 the amounts of rainfall from August 5th to 10th 2009 by Typhoon Morakot.

Figure 3 severe flooding in Pingpung county on August 5th 2009 by Typhoon Morakot.

Figure 4 the changes after Typhoon Morakot of Shiao Lin village. 資料來源:國立成功大學

4 CONCLUSIONS

1. Field monitoring project for wind profile characteristics and a tall building aerodynamic database project are ongoing to collect data for the future wind code revision.
2. Some modification and upgrading on wind load combination, external pressure/force coefficients and the applicability of comfort criterion have been proposed.
3. Air quality gets improvement in Taiwan gradually. Air quality of 2008 was best in past five years.
4. The indoor air quality management act approved in 2008 by the EPA of Taiwan. The new measure covers CO_2, CO, HCHO, TVOCs, bacteria, fungi, PM_{10}, $PM_{2.5}$, O_3 and temperature.
5. The losses caused by wind disaster were not the major ones. Most of the losses were flood caused by heavy rainfall in days of typhoon. In 2009, Typhoon Morakot wrought catastrophic damage in Taiwan, leaving 609 people dead and 154 others missing.

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