Revision of wind loading code and introduction of ground research plan of NSFC

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ABSTRACT: As a country report of wind loading codes in China during 2007 and 2009, this paper presents recent action on the revision of wind loading codes and one major event in wind engineering research. The current legal specification of wind loading code for building structures has been recalled, and followed by recent amendment action in the first part of the paper. As a major event, the Ground Research Project of Natural Science Foundation of China, "Dynamic Hazard Evolution of Major Engineering Structures", has been briefly introduced.

KEYWORDS: wind loading code, main revision, ground research plan, highrise building, long span bridge, large space structure.

1 INTRODUCTION

The series of Workshops on Regional Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (APEC-WW) provide a stimulating and constructive forum for researchers and engineers specializing in the problems of wind loading and wind environment. In the 1st APEC-WW initiated by the 21st Century COE Program of Tokyo Polytechnic University in Atsugi Japan in 2004, Chinese country report presented the current specifications and the recent research results of wind loading for buildings and bridges in China. As the country report of China in the 2nd APEC-WW held in Hong Kong China in 2005, the amendment of wind loading code for building structures was introduced. During the 3rd APEC-WW in New Delhi India in 2006, Chinese delegates made the presentation on Peak Wind Loading for Cladding instead of country report. As the 4th APEC-WW's Chinese report, recent development of wind loading codes and their related activities in China were presented. For this new APEC-WW, Chinese report presents recent action on the revision of wind loading code and introduction of the Ground Research Plan of the Natural Science Foundation of China (NSFC), "Dynamic Hazard Evolution of Major Engineering Structures".

2 THE REVISION OF WIND LOADING CODE

2.1 *The position of wind loading code in the system of Chinese design code for building structures*

It is an urgent and strategic mission for Chinese government and authority to build an integrative and comprehensive technical standard system to cope with the situation of economic globalization. Accompanying by a new round of revision of design code which has been completed and put into practice in early 2002, a framework of standard system in building construction has been established. A guideline book 'Standard system in engineering construction (part of: planning and of cities and rural, construction of cities and towns, buildings)' compiled by the Construction Ministry of People's Republic of China was published in 2003, in which all standards and codes concerning the planning, design, construction and quality control are clearly assigned in a appropriated position in the system.

The levels of the system for Chinese construction standard can be illustrated by a hill-like figure (Fig. 1) by means of restriction. According to the applicable range and promulgation authority, Chinese technical standards and codes can also be divided into 4 grades: national, trade, local and enterprise (Fig. 2). Figure 3 layouts the detailed system of code for design of building structures.

Wind load code is a part of Load code for the design of building structures (GB50009-)' which include mainly live load of floors and roofs, crane load, snow load, wind load and load effect combination etc.. So, the position of wind load code can be located clearly. It is a Chinese National Standard and a Common Standard, and undoubtedly is a very important code for the design of building structures.

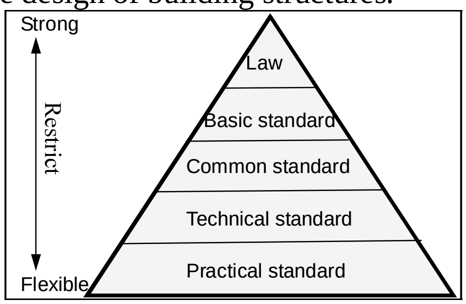

Fig. 1 Level of system

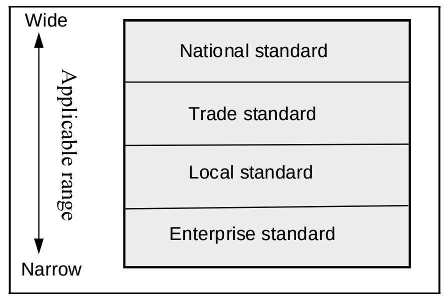

Fig. 2 Grades of standard

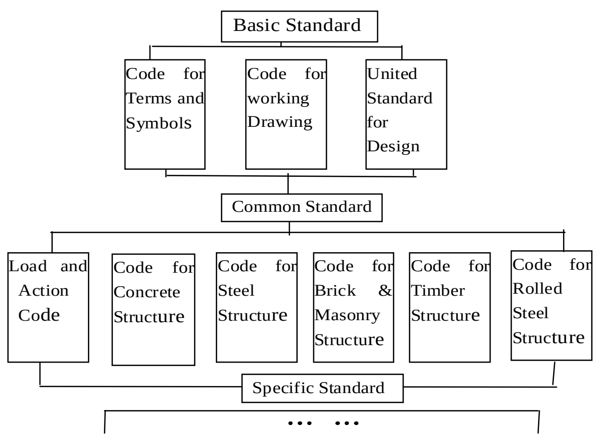

Fig. 3 The system of codes for design of building structures

2.2 *The versions of Chinese wind load code*

At the beginning of 1950s, when the government of People's Republic of China were established, almost all technical codes were introduced from foreign country mainly from the former Soviet Union. In the practice of the code, some national or local data corresponding to loads and materials were added into the design code gradually. A set of introduced Chinese design code were formed during the period of 50～60 decades. The original load code was formed in 1954 named 'templar requirement of loads (JI GUI 1-54)' and was revised in 1958 as the version of (JI GUI 1-58). A main frame of Chinese codes for the design of building structure was formed at the beginning of 1970's. 7 codes were included covering load, soil and foundation and 5 various material codes. In the version of 'load code for the design of industrial and civil building structures (TJ 9-74)', integrated and comprehensive provisions of wind load were given as a chapter of the code[1].

To harmonize the concepts of structural reliability and to unify the safety level and methods in material design code, a tremendous research project called 'structure safety and load combination' was launched at the end of 1970's, which was chaired by CABR and joined by about 100 units involving universities and design companies. Vast investigation had been done on the basic data of loads, materials and geometry of members. Take the wind load as an example, the climate data of wind velocity over more than 150 stations along south east coast of China were investigated elaborately to get the statistical parameters of basic wind load. The theories and methodology of structural safety and probability based limit state design were also learned and studied comprehensively. One of the notable achievements of the project was the drafting and issuing of the Chinese national standard 'Unified Standard for the Design of Building Structures (GBJ 68-84)' in 1984 which were similar to ISO 2394 in contents. All codes concerning building structure design were revised consequently according to the principles and rules of GBJ 64-84. It was a quite new generation of Chinese design code, which included the former version of 'Load code for the design of building structures (GBJ 9-87)' and were approved and practised at the end of 1980's[1].

2.3 *Recent activities in Chinese design code for building structures*

'Unified standard for reliability design of engineering structures (GB 50153-2008)' is a predominant code in China which is issued and applicable in 2008. This code is ranked at the top of all design standards in the case for technical control. The reliability principle and probability-based design method will be adopted in the design of all civil engineering structures covering building, railway, highway, dam, port and dock. Along with the issue of GB 50153-2008 and following the approximately revising interval of Chinese technical code, revision work of a new generation design code for building structures has been originated. All common standards (Fig. 3), plus 'Code for design of building foundation' and 'Code for seismic design of building' will be prior revised. The revision planning of 'Load code for the design of building structure (GB 50009-2001)' has been approved and released by the Ministry of Housing and Urban-Rural Development of P. R. China, and is going to be completed in the end of 2011. The revision of wind load is one the main tasks of the planning[2].

2.4 *Main aspects of wind load revision*

2.4.1 *Basic wind pressure*

Tow problems are raised concerning basic wind pressure with the quickly progressing of urbanization in China. One is that more and more basic wind pressure data for boomtowns are required because there will be many large-scale residential and industrial buildings occurred in such area. It is expected to solve the problem by encouraging developing more local codes authorized by local government of province.

Another problem is the changing of grand roughness around weather stations wrapped by buildings. It has been defined that the basic wind velocity should be taken from the flat and open terrain which is referenced to category B in the code. Though a great number of stations located in a large city of China have been moved toward suburban, it could not catch the step of city expanding. A decreasing trend for basic wind velocity has occurred in the wind data statistics in the last revision. It is necessary to investigate the circumstance and to calibrate the record data of wind velocity in the updating of basic wind pressure[3].

2.4.2 *Aerodynamic Pressure Coefficient*

External pressure coefficients of more than 30 typical buildings and structures are given out in the code, which came mainly from the wind tunnel test carried out by CABR in 1970s and partly from foreign code. Test data and literatures for external pressure coefficients are rich and available on the view of worldwide, and more elaborate and detailed provisions are required for the design of rich and colorful buildings. The dimensional factors, such as *h/d* and *d/b* ratio, are expected to be considered primarily.

For internal pressure coefficients, only one case of impermeable was prescribed in present version of the code. The building permeability and dominant opening should be considered to suit the condition of actual buildings[4].

2.4.3 *Dynamic response factor*

The simplified expression for along-wind dynamic response factor in the code is taken as:

$$\beta_z = 1 + \frac{\xi \nu \varphi_z}{\mu_z} \qquad (4.1)$$

Where ξ is a magnification factor depending mainly on the power spectrum of wind and the properties of structure vibration, ν is a influence factor considering wind turbulence and spatial correlation, and φ_z is the mode shape factor of structure.

The theories and methodology used in the calculating the values of factor are almost the same as the one adopted in other advanced codes abroad, in which both background response and resonant response are considered. For the convenience of application and comparison, it is a possible choice for the new version of code to adopt the more popular expression with the background and resonant response factors as follows:

$$\beta_i = 1 + 2gI_i\sqrt{B_D + R_D}$$

The provisions of cross-wind dynamic response factor for regular rectangular section buildings are required imminently. The torsional response factor and the interference factor of tall building are also considered to be added[5].

3 GROUND RESEARCH PLAN OF NSFC

3.1 *Introduction of the plan*

The Natural Science Foundation Committee of China did approve an eight-year ground research plan, namely, “Dynamic Hazard Evolution of Major Engineering Structures”, as the first and the largest research plan in civil engineering in China, in April 2007.

Major Engineering Structures are referring to the infrastructure, mainly the super civil and water conservancy engineering structures, which are closely related to the national economy and the people’s livelihood. In this ground research plan, the Major Engineering Structures are particularly referring to long or major bridges, large scale structures including super high-rise buildings, large space structures and urban underground structures, and high dams. Dynamic Hazards are involved in natural or manmade disasters with time-dependent actions, such as earthquake, wind, wave, collision, spray flow, vehicular or train action, terrorist attack and so on. The Dynamic Hazards in this ground research plan are specifically related to dynamic excitations induced by severe earthquake and strong wind or typhoon[6].

The Ground Research Plan of Dynamic Hazard Evolution of Major Engineering Structures aims to investigate the damage evolution process of major engineering structures under the dynamic excitations induced by severe earthquake fields and strong wind or typhoon fields, to explore the damage sources and collapse mechanisms of major engineering structures, to establish the refined simulation systems of the dynamic hazard evolution process of major engineering structures, and to develop the technologies of whole-process hazard mitigation and reduction for major engineering structures compliant to the economy and society of China. It will provide scientific and technical support for ensuring the safe construction and operation of major engineering structures[7].

3.2 *Main research content*

3.2.1 *Scientific objectives*

The scientific objectives of this ground research plan are: utilizing theoretical analysis, model testing, site measurement and numerical simulation for the study of major engineering structures, namely, long or major bridges, large scale structures (including super high-rise buildings, large space structures, urban underground structures) and high dams; analyzing the damage evolution of major engineering structures under the dynamic excitations of severe earthquake motion field and strong wind or typhoon field, with the help of creations from inter-disciplines of engineering science, material science, earth science, mathematical and physical science and information science; exploring the damage sources and collapse mechanisms of major engineering structures; setting up the simulation systems of dynamic hazard evolution of major engineering structures; upgrading the study of severe earthquake motion field and strong wind or typhoon field from the experiential or statistical deduction to the combination of statistical and theoretical predictions, and the analysis of dynamic hazard evolution of major engineering structures from the evaluation of simple effects to the whole process simulation of coupling multiple effects; improving the original creativity in the fundamental research of hazard mitigation and reduction of major engineering structures; providing supports to the safe construction and management of super large-scale major engineering structures (1000m long-span bridges, 500m super high-rise buildings, 300m high dams, and etc.); training creative talents for the hazard mitigation and reduction of major engineering structures in China; making China the big country of constructing major engineering structures and understanding and solving major relative scientific problems[6].

3.2.2 *Key scientific problems*

There are basically two key scientific problems to be solved in this ground research plan, concerning the damage evolution of major engineering structures under the dynamic excitations of severe earthquake motion field and strong wind or typhoon field, which are described as follows[6].

(1) Characteristics and laws of severe earthquake field and strong wind or typhoon field

- The relation between the propagation, decay and spatial distribution and its source mechanics and field conditions, the theoretical prediction model, and the damage characteristics, formation mechanisms and distribution laws of severe earthquake motion field.
- The laws of movement, decay and spatial distribution, the topography and physiognomy effects, and the 3-D time-space characteristics and spatial distribution model of strong wind or typhoon field.

(2) Process and mechanisms of dynamic hazard evolution of major engineering structures

- The nonlinear mechanical behavior of material and element damage under complex loading conditions.
- The modeling theory and analysis method of the structure-environment coupling effect under the excitations of severe earthquake motion field and strong wind or typhoon field.
- The damage evolution and the damage and collapse mechanisms of major engineering structures excited by severe earthquake motion field and strong wind or typhoon field.

3.2.3 *Main research topics*

To investigate the above two major scientific problems, the following four main research topics, including twelve sub-topics, will be carried out in this ground research plan[6].

(1) Modeling and prediction of severe earthquake field and strong wind or typhoon field

- Damage characteristics, theoretical modeling and prediction method of severe earthquake field: Study on the modeling theory and method of severe earthquake field considering epicenter outburst mechanism and propagation effect; Establishment of the theoretical prediction model and numerical computation method considering epicenter mechanism, propagation path and local site conditions that satisfy the requirement of earthquake response analysis of major engineering structures; and Revealing the damage characteristics (including field effects), formation mechanisms and distribution laws of severe earthquake motion field.
- Distribution characteristics, time-space modeling and prediction method of strong wind or typhoon field: Field measurement of strong wind or typhoon such as landing typhoons, thunderstorm wind, tornado, and etc.; Study on spatial characteristics of horizontal and vertical distribution and stationary and non-stationary time behaviors of strong wind or typhoon; Establishment of the theoretical models of mean wind and

corresponding fluctuating wind with high time-space resolution; Investigation on the effect of local topography and physiognomy on strong wind or typhoon field; and Development of numerical prediction method for the strong wind or typhoon field in the costal area of China.

(2) Key effects of dynamic damage and failure of major engineering structures

- Nonlinear dynamics of material, element and structure: Study on dynamic behavior and theoretical description of complex physical or geographical nonlinearity of material, element and structure under complex loading condition, using physical and numerical models as well as their combination, based on macro and micro as well as multi-scale theory and method; Investigation of non-linear dynamic effects, including material softening, stiffness degradation, size effect, loading rates and interface characteristics; and Development of refined modeling theory and method for nonlinear dynamic damage of major engineering structures under severe earthquake and strong wind or typhoon.
- Dynamic coupling of structure and environmental media: Investigation on dynamic coupling effects between structure and environmental media, including dynamic soil-structure interaction under severe earthquake and dynamic fluid-solid interaction under strong wind or typhoon; and Development of the modeling theory and method of continuous and discontinuous, contactable and non-contactable, and linear and nonlinear coupling of structure and environmental media.
- Spatial dynamics of structure: Study on the spatial dynamic load effect on major engineering structures under multi-dimensional, multi-points and non-stationary severe earthquake and strong wind or typhoon.
- Energy transformation and dissipation within a structure and between structure and environmental media: Investigation on the energy transformation, dissipation and radiation within a structure and between structure and environmental media under the excitations of severe earthquake motion field and strong wind or typhoon field.

(3) Whole process analysis of dynamic damage to failure of major engineering structures

- Modeling and numerical computation of dynamic damage to failure: Study on fast modeling theory for complex major engineering structural system considering strong nonlinearity, multi-media coupling, energy transformation and dissipation effects; Establishment of high-efficiency numerical simulation method for dynamic damage evolution of major engineering structures under severe earthquake and strong wind or typhoon; and Development of high-efficiency visualization technology based on feature analysis and extraction of multi-dimension dynamic data field.
- Damage evolution laws and collapse mechanisms: Study on the damage accumulation and evolution laws of major engineering structures under the excitations of severe earthquake and strong wind or typhoon; Revealing damage effects and failure mechanism of major engineering structures; Establishment of failure criteria for dynamic hazard evolution of major engineering structures; and Study on the relationship among element failure, substructure failure and global structure failure of major engineering structures under severe earthquake and strong wind or typhoon.
- Process control of dynamic hazard evolution: Development of failure modes and high efficiency analysis method for major engineering structures; Establishment of theory and method for optimizing failure modes and improving seismic resistance and wind resistance capacity of major engineering structures; and Revealing damage mechanism and collapse control principle for dynamic hazard evolution of major engineering structures.

(4) Integration and validation of simulation system of major engineering structures

- System integration method: Development of simulation software theory and method considering 3-D geometry modeling, numerical solution, virtual demonstration, analysis and prediction of structural damage and failure; Development of parallel computation techniques based on finite element grids; Study on the integration methodology of numerical simulation, prototype monitoring and model testing; and Establishment of the integration method for the platform software of numerical simulation with the existing application software systems.

- Integration system for simulating structures under severe earthquake action: Development of software and hardware platforms for simulating damage and failure process of major engineering structures including major bridges, large-scale buildings and high dams under severe earthquake action; Effective and reliable verification of the software through shaking-table model testing and prototype monitoring case study; and Reproduction of the damage and failure process of major engineering structures under severe earthquake action.
- Integration system for simulating structures under strong wind or typhoon action: Development of software and hardware platforms for simulating damage and failure process of major engineering structures including long-span bridges, super high-rise buildings and large space structures under strong wind or typhoon action; Effective and reliable verification of the software through wind-tunnel model testing and prototype monitoring case study; and Reproduction of the damage and failure process of major engineering structures under strong wind or typhoon action.

3.2.4 *Expected achievements*

To investigate the above two major scientific problems, the following four main research topics, including twelve sub-topics, will be carried out in this ground research plan[6].

(1) Theoretical prediction model of severe earthquake motion field and strong wind or typhoon field. Establish the theoretical prediction model of severe earthquake motion field and strong wind or typhoon field, with the following objectives[6]:

- Establishment of the theoretical model for the simulation of near field severe earthquake, with range of 100km and seismic wave propagation frequency of 0.1 to 3.0Hz.
- Establishment of the theoretical models of mean wind and corresponding fluctuation wind, with high time-space resolution of 1000 to 500m horizontal and 50 to 20m vertical.

(2) Modeling theory and implementation method of whole process simulation of dynamic hazard evolution of major engineering structures. Develop systematic and refined analysis theory and numerical implementation method of dynamic damage and failure process of major engineering structures, considering high nonlinearity, multi-media coupling, energy transformation and dissipation, and etc., and explore the damage evolution laws and collapse mechanisms of major engineering structures under the excitations of severe earthquake and strong wind or typhoon. The respective goals are as follows[6]:

- Development of the analysis theory and numerical implementation method of the whole process simulation, from local cracks till global collapse through damage evolution, of major bridges, large scale structures and high dams, under the excitations of severe earthquake motion field.
- Development of the analysis theory and numerical implementation method of the whole process simulation of long-span bridges, super high-rise buildings and large space structures under the excitations of strong wind or typhoon field.

(3) Integration systems for simulating dynamic hazard evolution of major engineering structures. Establish the integration systems for simulating dynamic hazard evolution of major engineering structures, including the simulations of both the key effects and the process of dynamic hazard evolution of major engineering structures. The respective goals are as follows[6]:

- Establishment of the verified integration systems for simulating the highly nonlinear damage and the whole damage process of major bridges, large scale structures and high dams under severe earthquake action.
- Establishment of the verified integration systems for simulating the highly nonlinear damage and the whole damage process of long-span bridges, super high-rise buildings and large space structures under strong wind or typhoon action.

3.3 *Schedule and budget*

3.3.1 *Implementation duration*

The implementation duration for the ground research plan on Dynamic Hazard Evolution of Major Engineering Structures is eight years[6].

The initial five years is for program establishment, where in the first three years funds will be offered in the projects of General Training Program and Key Supporting Program (representing the differences in the funds and the objectives), based on the creativity, research value and contribution to the ground research plan, and in the next 2 years, continuous proposals that develop integrated creative research and are crucial to the realization of the expected objectives and achievements of the plan, based on the impacts of the preliminary General Training Program and Key Supporting Program, will be awarded with continuous funds by Major Integration Program projects.

The last 3 years is the integration and validation stage for theory, method and system as well as program projects and achievements.

The progress evaluation will be arranged at the end of the 3rd year or the beginning of the 4th year. According to the evaluation results, the schemes of the ground research plan will be properly adjusted, in order to lay the foundations for the integration of all program projects.

3.3.2 *Funding distribution*

The funding of the ground research plan totals at 150 million RMB, of which, 137.5 million is allocated for research and 12.5 million is for academic exchange activities. In the first three years of the implementation, the total funding of 30 million RMB will be for 60 General Training Program projects with intensity of 0.5 million RMB per project and 62.5 million RMB for 25 Key Supporting Program projects with 2.5 million RMB per project. A total of 45 million RMB will be split among 3 Major Integration Program projects in the next 2 years. Funding distributions for different projects are shown in Table 1[7,8].

Table 1. Funding distributions for program projects

Contents	General Training			Key Supporting			Major Integr.	
	2008	2009	2010	2008	2009	2010	2011	2012
Modeling and prediction of severe earthquake field and strong wind or typhoon field	3	1	2	2	1	1		
Key effects of dynamic damage and failure of major engineering structures	4	6	2	2	1			
Whole process analysis of dynamic damage to failure of major engineering structures	19	12	4	6	9	1		
Integration and validation of simulation system of major engineering structures	4	1	2	2	0		2	1
Annual number of projects	30	20	10	12	11	2	2	1
Total number of projects		60			25		3	

3.4 *Wind-induced hazard related projects*

3.4.1 *General information*

The ground research plan of Dynamic Hazard Evolution of Major Engineering Structures launched 3 and 4 General Training Program projects and 3 and 4 Key Supporting Program projects, related to wind-induced hazard in 2008 and 2009, respectively, and will start 3 more General Training Program projects in 2010. The title of 10 General Training Program projects and 7 Key Supporting Program projects are listed in Table 2[7,8].

Table 1. Wind-induced hazard related projects

No.	Grant No.	Project Title	Program Type	Name Affiliation

Modeling and Prediction of Strong Wind or Typhoon Field				
1	90715031	Wind flow field and structural damage characteristics of landing Typhoons	Key	Lili Song Guangzhou Tropical Oceanic Meteorological Research Institute
2	90815028	Numerical simulation and theoretical analysis on three dimensional wind field of landing Typhoons	Key	Xudong Liang Shanghai Typhoon Research Institute
3	90915715	Field measurement and simulation of inland strong wind and its effects	General	Jianxin Liu Changan University
4	90915737	Surface layer wind field of typhoon under complicated terrain and its effects on flexible structure vibration	General	Yiyong Cai Fujian Meteorology Research Institute
Long Span Bridges under the Excitation Strong Wind or Typhoon				
5	90715039	Key effects and process control of wind-induced hazards for super long-span bridges	Key	Yaojun Ge Tongji University
6	90815022	Field measurement and prototype validation of wind dynamic hazard evolution of long-span bridges	Key	Hui Li Haerbin Institute of Technology
7	90715015	Refinements on wind and rain induced vibration of stay cables of long span cable-stayed bridges	General	Fengchen Li Haerbin Institute of Technology
8	90815016	Nonlinear flutter of long span bridges under nonlinear self-excited aerodynamic forces	General	Haili Liao Southwest Jiaotong University
9	90915718	Multi-scale models wind tunnel study on spatial and time characteristics of wind field in deep valley bridge site	General	Yongle Li Southwest Jiaotong University
Super Highrise Buildings under the Excitation Strong Wind or Typhoon				
10	90715040	Wind loading, wind-induced effects and control of super highrise buildings	Key	Ming Gu Tongji University
11	90815030	Field measurement and theoretical analysis of super highrise buildings under strong wind excitation	Key	Zhengnong Li Hunan University
12	90715023	Error and modification on wind loading simulation of super highrise buildings based on wind tunnel testing	General	Shuguo Liang Wuhan University
13	90715024	Hilly terrain wind field model and the response of super tall buildings	General	Zhengliang Li Chongqing University
14	90815015	Bending and torsional coupled wind-induced vibration of complicated highrise buildings based on wind tunnel testing	General	Xinyang Jin China Academy of Building Research
Large Space Structures under the Excitation Strong Wind or Typhoon				
15	90815021	Key effects and hazard evolution of large space structures under strong wind excitation	Key	Qinshan Yang Beijing Jiaotong University
16	90715025	Field measurement and wind tunnel testing of wind induced vibration of large space structures	General	Jiyang Fu Jinan University
17	90815003	Theoretical analysis and numerical simulation of wind induced hazard of membrane structures	General	Qilin Zhang Tongji University

3.4.2 *Key supporting program projects*

There are totally 7 Key Supporting Program projects related to wind-induced hazard, which are briefly introduced in the following sections.

(1) Wind flow field and structural damage characteristics of landing Typhoons[9]:

- The key scientific problem of this project is the laws of movement, decay and spatial distribution, the topography and physiognomy effects, and the 3-D time-space characteristics and spatial distribution model of strong wind or typhoon field.
- The main research content of this project is distribution characteristics, time-space modeling and prediction method of landing typhoon field.
- The research achievements of this project can be expected to establish the theoretical models of mean wind and corresponding fluctuation wind with high time-space resolution of 1000 to 500m horizontal and 50 to 20m vertical.

(2) Numerical simulation and theoretical analysis on three dimensional wind field of landing Typhoons[8]:

This project in 2009 focuses on the same key scientific problem as the first project mentioned in the above section, but on more general research content including not only landing typhoons but also other strong winds. In particular, the 3-D time-space characteristics and spatial distribution model of strong wind or typhoon field will be emphasized for the application in wind resistant design of major engineering structures.

(3) Key effects and process control of wind-induced hazards for super long-span bridges[10]:

- The key scientific problem of this project is the process and mechanisms of dynamic hazard evolution of super long-span bridges (cable-stayed bridges with a main span over 800m and suspension bridges with a main span over 1500m) including nonlinear mechanical behavior, structure and environmental media coupling effect and the damage and collapse mechanisms.
- The main research content of this project is the spatial dynamics of structure, dynamic coupling of structure and environmental media, modeling and numerical computation of aerodynamic damage to failure, damage evolution laws and collapse mechanisms and process control of aerodynamic hazard evolution of super long-span bridges under the excitation of strong wind or typhoon.
- The research achievements of this project can be expected to develop systematic and refined analysis theory and numerical implementation method of aerodynamic damage and failure process of super long-span bridges, considering high nonlinearity, multi-media coupling, energy transformation and dissipation, and etc., and explore the damage evolution laws and collapse mechanisms of super long-span bridges under the excitation of strong wind or typhoon.

(4) Field measurement and prototype validation of dynamic hazard evolution of long-span bridges[8]:

With the topic of field measurement and prototype validation of dynamic hazard evolution, this project in 2009 could be awarded to either wind-induced hazard or seismic hazard. Fortunately, wind-induced hazard topic has win because prototype validation of wind-induced hazard is much easier than that of seismic hazard based on the fact that fewer earthquakes occur in 2009.

(5) Wind loading, wind-induced effects and control of super highrise buildings[11]:

- The key scientific problem of this project is the process and mechanisms of dynamic hazard evolution of super highrise buildings including nonlinear mechanical behavior, structure and environmental media coupling effect and the damage and collapse mechanisms.
- The main research content of this project is the spatial dynamics of structure, dynamic coupling of structure and environmental media, modeling and numerical computation of aerodynamic damage to failure, damage evolution laws and collapse mechanisms and process control of aerodynamic hazard evolution of super high-rise buildings under the excitation of strong wind or typhoon.

- The research achievements of this project can be expected to develop systematic and refined analysis theory and numerical implementation method of dynamic damage of super high-rise buildings, considering non-steady wind loading, multi-media coupling and etc., and explore the damage evolution laws and collapse mechanisms of super highrise buildings under the excitations of strong wind or typhoon.

(6) Field measurement and theoretical analysis of super highrise buildings under strong wind excitation[8]:

Although the fifth project mentioned in the above section is also involved in super highrise buildings under the excitation of strong wind and typhoon, this project will more concentrate at field measurement, especially at several case studies of super high-rise building, in order to make the comparison with wind tunnel testing. As a main research topic, the validation of simulation system of major engineering structures is very important for the whole Ground Research Plan.

(7) Key effects and hazard evolution of large space structures under strong wind excitation[8]:

As defined at the beginning of this paper, Major Engineering Structures are specifically related to long or major bridges, super high-rise buildings and large space structures due to aerodynamic hazard evolution. Since the Key Supporting Program projects for long span bridges and super high-rise buildings under the excitation of strong wind or typhoon have been awarded in 2008, the rest Key Supporting Program project referring aerodynamic hazard should be solely involved in large space structures in 2009.

4 CONCLUDING REMARKS

The action of the revision for wind resistant design for building structures in China is briefly mentioned, and the further step for this revision will be introduced next year. Although there is not any immediate action on wind loading codes recently in China, the Ground Research Project of NSFC have been introduced thereafter. The first and largest research plan in civil engineering history of China, entitled "Dynamic Hazard Evolution of Major Engineering Structures", is launched at investigating the damage effects and failure process of major engineering structures including super long bridges, super high-rise buildings, large-space structures, major urban underground structures and high dams, under the dynamic actions from strong earthquakes and typhoons. The total of 17 wind induced hazard related projects have been listed and 7 Key Supporting Program projects have been introduced.

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