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Disaster Reduction News

State Key Laboratory for Disaster Reduction in Civil Engineering , Tongji University

CONTENTS

Academic Exchange Activities

1. “On Aerodynamic Limit to Suspension Bridges”, written by Prof.s XIANG Haifan and GE Yaojun, was selected as the first class excellent paper of the 7th China Civil Engineering Society Excellent Paper Award in January 2007.

2. On 11 - 13 Feb. 2007, Prof. XIANG Haifan attended the NSFC seminar on the key research plan of Dynamic Reduction of Major Engineering Works and made a keynote presentation entitled “Tomorrow’s Challenge of Bridge and Structural Wind Engineering” in Beijing.

3. Prof. XIANG Haifan attended the technical expert’s meeting of Sutong Bridge and made a presentation of “Towards Great Nation of Self Innovation” in Suzhou on March 28 - 30, 2007

4. Prof. XIANG Haifan attended the Executive Committee Meeting of IABSE in Zurich, Switzerland on April 25 to 30, 2007.

5. The China-Japan Joint Seminar on Steel and Composite Bridges was held at Tongji University on January 16, 2007. It was hosted by the Department of Bridge Engineering at Tongji University and Institution of Bridge and Structural Engineering of CCES. On behalf of Chinese group of the

joint seminar, Prof. GE Yaojun made a keynote presentation, titled “Longest Chinese Steel Bridges under Construction”.

6. The Ground Research Plan, “Dynamic Disaster Reduction of Major Engineering Works”, from 2008-2015 with total funds of 150 million CNY, was approved by the Committee of Natural Science Foundation of China on April 2, 2007. Prof. XIANG Haifan has been selected as one of seven members of Expert Committee of this plan project, and Prof. LI Jie and GE Yaojun are on the list of the Drafting Committee with 13 members.

7. Prof. GE Yaojun attended the Global Chinese Wind Engineering Forum held in Taiwan, China on April 2-5, 2007, and made a presentation, “Wind-Induced Vibration and Aerodynamic Mitigation of Long-Span Bridges”.

8. The Key Laboratory for Wind Resistance Research of Bridge Structures was approved by the Ministry of Communications in April 2007, and Prof. GE Yaojun was appointed as the first director of this laboratory.

9. From March 28 to April 3, 2007, Prof. SHEN Zuyan was invited by Prof. Davide Bigoni, Head of Institute of Structural Engineering, University of Trento, Italy as foreign expert to attend a Ph.D. thesis defense meeting held on April 1, 2007.

10. From April 21 to 24, Prof. SHEN Zuyan was invited to attend the 4th Cross-strait Conf. on Structural and Geotechnical Engineering held in Zhejiang University, and gave a keynote speech entitled “Ultimate Load-carrying Capacity of Spatial Steel Structures ”.

11. From May 19 to 21, 2007, Prof. Yukio Tamura, President of Japan Association of Wind Engineering, was invited by Prof. SHEN Zuyan to attend the centenary celebration of Tongji University, and gave a lecture on “Universal Equivalent Static Wind Load Distributions and Recent Activities in the COE Program of Tokyo Polytechnic University”.

12. The International Symposium on Integrated Life-Cycle& Management of Infrastructures (ILDMI) was held in Tongji University Shanghai on May 16–18, 2007. Prof. FAN Lichu Fan is Co-Chair of the symposium, and Prof. CHEN Airong, Prof. SUN Limin and Dr. SUN Zhi were the secretaries who made a great contribution to the organization of this symposium.

    There were eight keynote speakers and about fifty authors from China mainland, HKSAR, Chinese Taipei, North America, Europe and other parts of the world attended the symposium. Their contributions raised new thinkings on some of the important issues relating to the integrated life-cycle design and management of infrastructures

13. Prof. SUN Limin attended the China-Japan workshop on Steel Bridge Technology held in Shanghai, on January 16-17, 2007, and made a presentation entitled "Dynamic Behaviors and Vibration Control of Steel Tower of Large Span Cable-Stayed Bridge under Construction".

14. Prof. Dan Frangopol, President of Inter. Association of Life-Cycle Civil Engineering, President of Inter. Association for Bridge Maintenance and Safety, Fazlur Rahman Khan Endowed Chair of Structural Engrg. and Architecture Depart. of Civil and Environmental Engrg. Lehigh University, USA, was invited by Prof. SUN Limin Sun and DR. DAN Danhui to visit Tongji University and gave a seminar entitled "Integrated Life-Cycle Monitoring -Maintenance-Management of Civil Infrastructure", on May 14th, 2007.

15. Prof. SUN Limin attended ILDMI and gave a keynote speech entitled "Health Monitoring System for Long Span Bridges in China". Dr. Zhi Sun, Dr. Danhui Dan and Dr. Hongwei Huang also attended this symposium and made presentations on different topics.

16. The start-up meeting of the 863 project, "Hazard and Vibration Mitigation of Cable Stayed Bridge System with Length of Main Span over 1,000 Meter", was held successfully on February 5th, 2007 at the Depart. of Bridge Engrg. TJU. This project is supported by the Ministry of Science and Technology of China. In this meeting, all the PIs and Co-PIs were present, and topics on the project organization and management were discussed. A follow-up meeting was later held on June 15th, 2007, where the details on the setup, the working schedule and the expected results of each research item were finalized.

17. The start-up meeting of a 863 project, "Structural Dynamic Response Analysis and Condition Assessment on New-Type Bridges", was held successfully on March 19th, 2007 at the Depart. of Bridge Engrg. Tongji University. This project is supported by the Ministry of Science and Technology of China. In this meeting, topics on the project organization and management, and details on the setup and the expected results of each research item were discussed.

18. The start-up meeting of the project, "Key Technology on Structural Health Monitoring and On-line Assessment of Large-Scale Complex Bridges", was held successfully on

February 2nd, 2007. This project is supported by the Science and Technology Committee in Shanghai, China.

19. Dr. SUN Zhi, Dr. DAN Danhui and Dr. HUANG Hongwei attended the World Conf. on Smart Materials and Smart Structures Technology held in Chongqing and Nanjing, on May 22-27, 2007 and made presentations regarding structural health monitoring.

20. The half-year meeting of the project "Evaluation System of the Safety and Durability of Bridge Stay Cable and Its Maintenance Techniques" was held successfully on April 14th, 2007, at Liuzhou. This project is supported by the Western Communication and Construction Technology Project.

21. Prof. Roger Ghanem, Chairman of Probabilistic Methods Committee ASCE Engineering Mechanics Division, and Prof. Sami Masri, both from University of Southern California, were invited by Prof. LI Jie to visit Tongji from Jan. 14– 19, 2007. During their visit, a research collaboration agreement was signed between University of Southern California and Civil College of Tongji University, and they also gave presentations regarding their recent research works.

22. Prof. LU Xilin attended the Second World Forum on Collaborative Research in Earthquake Engineering, held on March 26-27, 2007 in Ispra, Italy. He gave a presentation entitled "Progress on Networked Structural Laboratories in China". There were 90 people attending the forum.

23. Prof. LU Xilin attended the International Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, held on June 11-19, 2007 in Greece. He gave a presentation entitled "Elasto-plastic Time History Analysis of a High-rise CFRT Frame Structure with Dampers". There were 450 people attending the conference.

Research and development

1. Prof. XIANG Hai-Fan and his colleagues obtained the second class award of Shanghai Science and Technology Award with the project "Theory and Application Software for Structural Design and Analysis of Long-span Bridges"

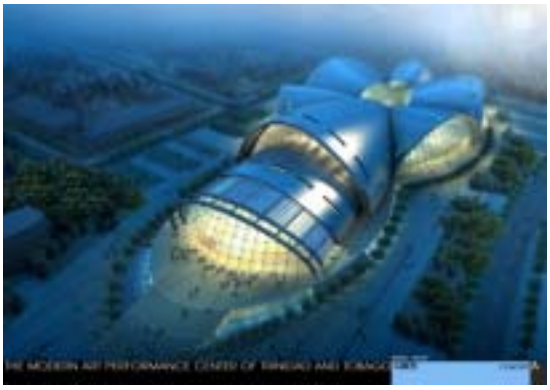
2. Prof. SHEN Zuyan and his term recently finished several important projects, such as:

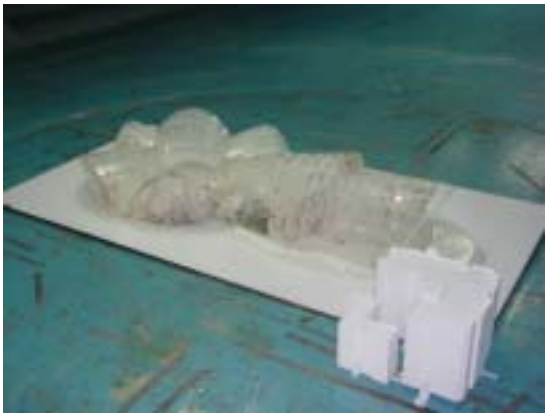
   (1) Compilation of several important design standards related to steel structures were in charge by Prof. SHEN Zuyan, including "Technical Specification for Low-rise Cold-formed Steel Building Structures" commissioned by Ministry of Construction of China, "Specification for Structural Design of Tall Steel Building Structures" and "Technical Specification for Light Steel Structures" commissioned by Shanghai General Administration of the Market for Construction and Construction Materials.

   (2) Reliability Analysis and Design methods of 550MPa High-strength Cold-formed Thin-walled Steel Structures. This project are commissioned by National Standard Management Committee for Technical Code of Cold-formed Thin-walled Steel Structures, and Light Steel Structure Committee of China Association for Engineering Construction Standardization (CECS), and cooperated with BlueScope Steel (Shanghai) Co. Ltd. The main purposes were to offer the suitable design method and determine reasonable design strength based on design reliability analysis for 550MPa High-strength Cold-formed Thin-walled Steel Sections, which are widely used in US and Australia but out of the provisions in current Technical Code of Cold-formed Thin-walled Steel Structures, GB50018. A series of research works have been conducted for load-carrying capacity design for basic members with deferent sections, typical connections and wall systems, and aseismic behaviors. On June 20, 2007, an appraisal meeting with seven experts in this area was held by National Standard Management Committee for Technical Code of Cold-formed Thin-walled Steel Structures in Tongji University, and a positive appraisal was given to the research group for the excellent findings in the project.

(3) Wind Tunnel Test and Wind Load Analysis for Modern Art Performance Center of Trinidad & Tobago. This project are commissioned by Shanghai Construction Group General Co. Overseas Business Division and cooperated with Prof. GE Yaojun. Based on wind tunnel test in TJ-3 wind tunnel of Tongji University, the mean

and fluctuating wind pressure coefficients for wind-resistant design of this single-layer reticulated shell with complex shape, as shown in the following picture was offered, time-history analysis of the shell subjected to wind load based on wind tunnel test results has been further conducted for suggesting the suitable wind-induced vibration coefficients in structural design.





3. HSBC Building -Shanghai International Financial Center (Shanghai IFC), located in Pudong District of Shanghai, has a height of 250m. The central RC tube and peripheral SRC frame with two outrigger trusses are designed to resist vertical and lateral loads. According to the Chinese seismic codes and standards, the height of Shanghai IFC clearly exceeds the upper limit height of a composite structure (190m). Thus, Prof. LU Xilin and his team designed and constructed a 1:30 scale model of Shanghai IFC in the Shaking Table Testing Division of SLDRCE. A series of earthquake simulation test were carried out on the shaking table with different waves and earthquake levels. The dynamic properties, responses of acceleration and displacement under different levels were studied, which showed that the structural system is a good solution for the building to resist earthquake of intensity seven.

4. New-built Famen Temple is one of the famous tourist sites in Shanxi Province. The building has a palm-type elevation with a structural height of 147m, which is classified as vertically irregular building according to the Chinese seismic codes. Thus, Prof. LU

Xilin and his team designed and constructed a 1:35 scale model of Famen Temple to study its seismic performance. The model was tested on the shaking table under different waves and earthquake levels. The weak position of the structure was found based on the experimental results.

5. Prof. GE Yaojun and his team recently finished several important projects as follows.

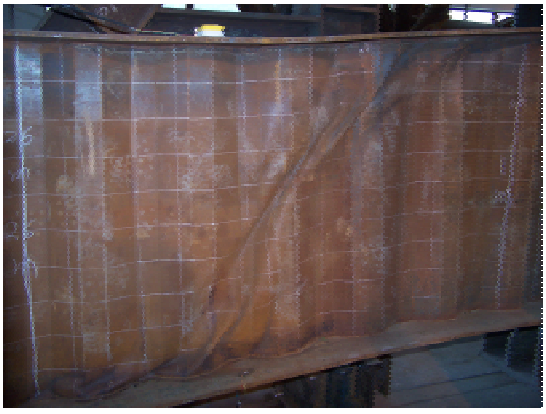
   (1) The consulting project of Numerical Wind Tunnel Study on Ningbo Bridge was checked and accepted by the Expert Committee invited by the owner on January 30, 2007. Ningbo Bridge is a twin-deck cable-stayed bridge with the main span of 460m, the longest twin-deck cable-stayed bridge in the world. Through this project, two alternative pylon types and three alternative deck schemes proposed by the design team have been compared and contrasted in structural dynamic properties and flutter instability limits, which greatly help the owner to make the final decision on the bridge scheme.

   (2) The Study on Wind Resistance Performance of Shanghai Yangtze River Bridge was checked and accepted by the Expert Committee invited by the owner on April 17, 2007. Shanghai Yangtze River Bridge is a steel cable-stayed bridge with the central span of 730m, the longest bridge in Shanghai. The wind resistance study has approved the design scheme in longitudinal arrangement and deck cross section of the bridge, but wind/rain induced stay cable vibration should be carefully treated with dimples on cable surface and dampers at the lower ends of cables.

   (3) The Wind Tunnel Study on Cooling Towers of Haining Power Plant was checked and accepted by the Expert Committee invited by the owner on May 2007. This is the first time that aeroelastic model wind tunnel testing of cooling tower is carried out in our laboratory after force balance and surface pressure tests are conducted in this project. The size of the cooling towers is within normal magnitude, but wind environment is quite sever, for which not only normal wind profile but also Typhoon condition have been simulated in wind tunnel testing.

6. Prof. LI Guoqiang and his team conducted experimental research on novel steel structural members. A group of buckling-restrained braces were studied. The specimens were designed in the form of a core element restrained by a steel tube. Both the core element and the tube were made of

Q235B steel. Up to now, two 1/3 scale substructures each with a diagonal BRB specimen under horizontal loading and a full scale BRB specimen under axial loading have been tested after standard cyclic load scheme. The behavior of the full scale one was satisfactory while the other two failed in premature buckling, being a result of large construction errors in such small specimens. Two specimens of I steel beams, sectional heights of which were 1m and 0.5m, with trapezoidal web corrugations were tested under monotonic loading. Both exhibited ultimate global failure in shear, while their failure initiated from elastic and elasto-plastic buckling of their web, respectively



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7. Prof. LI Guoqiang and his team conducted experiments on research of the mechanical property of fireproof paint, including compressive strength, tensile strength and shear strength Bonding performances between fireproof coatings and steel members both in the normal and tangential directions have also been investigated through experiments.

8. Prof. LI Jie and his team has conducted a series shaking table experiments on seismic capacity of underground infrastructure with consideration of travelling effect of earthquake wave. A shear box, which might be the first of its kind in the world, was designed and manufactured for the test. With full support for Chongqing Communications Research& Design Institutes (CCRDI), more than 400 test cases had been carried out for considering effect of different kind of excitation situations. Data processing and

analysis works are on-going and corresponding theoretical analysis are carried out as well.

9. The paper written by Dr. CHEN JB and Prof. LI Jie, which is titled "The extreme value distribution and dynamic reliability analysis of nonlinear structures with uncertain parameters" (published in Structural Safety Vol. 29 No. 2:77-93, 2007) , is ranked No. 1 in the top 25 hottest articles of the Journal Structural Safety during January-March 2007 and is ranked No. 10 in the top 25 hottest articles of the Journal Structural Safety during April to June 2007.

10. The paper written by Prof. LI Jie, Dr. CHEN JB and Mr. FAN WL "The equivalent extreme-value and evaluation of the structural system reliability" (published in Structural Safety, Vol. 29, No. 2: 112-131 2007) is ranked No. 4 in the top 25 hottest articles of the Journal Structural Safety during January-March 2007 and is ranked No.12 in the top 25 hottest articles of the Journal Structural Safety during April – June 2007.

International Publications (Abstract)

1. **Wind-induced Damages to a Three-span, Continuous, Concrete Arch Bridge under Construction**

(Published in *Structure Engineering International*, 17(2): 141-150,2007)

Wind-induced Damages to a Three-span, Continuous, Concrete Arch Bridge under Construct

GE Yaojun, YANG Yongxin, PANG Jiabin, XIANG Haifan

Abstract: The second Yibin bridge is a three-span, continuous, reinforced concrete arch bridge with equal span lengths of 160 m. After two reinforced concrete (RC) ribs were constructed through all three spans, during the night of June 7, 1997, the central span and the side span near Zigong city were found to have collapsed into the river on its own. The remaining side span near Yibin City collapsed later on its own, on August 29, 1997. The aeroelastic and aerodynamic investigations, including definition of design wind speed, determination of aeroelastic and aero- dynamic wind loading, testing of wind-induced vibrations, evaluation of RC arch rib strength, were conducted to identify the reason for the collapse. It was finally concluded that aerodynamic instability, flutter or galloping, should be excluded in these two accidents, and the direct reason was the ultimate resistance of the cross-sections at the arch bases being less than the total load responses under the joint action of structural dead loads and wind-induced loads including aerody- namic wind loading, aeroelastic wind loading and the loading based on P-Δ effects which were not considered in the design of the bridge under construction.

2. **Seismic analysis of Steel Structures Considering Damage Cumulation**

Published in *Frontiers of Architecture and Civil Engineering in China-Selected Publications from Chinese Universities*, 1(1): 1-11, 2007

Seismic analysis of Steel Structures Considering Damage Cumulation

SHEN Zuyan and WU Aihui

Abstract: The research on the development of a reliable analytical model for seismic analysis of steel structures is presented. The non-linear damage cumulation hysteretic model incorporating the deterioration of stiffness, strength and strain hardening for structural steel is proposed and validated. The complete loading history, energy dissipation and the effect of the maximum plastic strain are taken into account in the model. The constants in the model are determined from regression analysis of experimental results of simple standard tensile and cyclic tests. Finite element formulations for beam and structural solid element considering the damage cumulation are derived. A computer program capable of calculating the hysteretic model of steel members, predicting the damage state and crack initiation, and carrying out non-linear time history seismic analysis of steel structures is developed. Solutions obtained from the model are in good agreement with experimental results. It was demonstrated that the damage cumulation effect is considerable and important in structural seismic analysis

3. **Analysis and Design Reliability of Axially Compressed Members with High-strength Cold-formed Thin-walled Steel**

Published in *Thin-Walled Structures*, 45:473-492, 2007

Analysis and Design Reliability of Axially Compressed Members with High-strength Cold-formed Thin-walled Steel

LI Yuan-Qi, SHEN Zu-Yan, WANG Lei, WANG Yanmin and XU Hongwei

Abstract: High-strength cold-formed thin-walled steel has been widely used in developed countries in the last several years. However, the application and popularization of the new materials in China is still very limited, and there are no related provisions in current design codes for reference in engineering practice. In this paper, considering the effects of the variations from material strength in structural members, geometrical parameters of sections, analysis methods for limit load-carrying capacity and external loadings, the second-order moment probability method was used for conducting the design reliability analysis of 550 MPa high-strength cold-formed thin-walled steel structures, from which the reasonable target reliability index, the corresponding resistance partial coefficient and the design strength values were discussed and proposed. Existing experimental data related have been collected and used to demonstrate the suitability and reasonability of the proposed results, which shows that, with reasonable determination of the design strength value of 550 MPa high-strength cold-formed thin-walled steel sections, the effective width-to-thickness ratio method considering coupling stability of plates recommended by "Technical Code of Cold-formed Thin-Walled Steel Structures (GB50018-2002)" can be efficiently used to estimate the load-carrying capacities of the axially compressed elements of high-strength cold-formed thin-walled steel structures, and well satisfy the target reliability index in structural design

4. **Stability Analysis of Semi-rigid Composite Frames**

Published in *Steel and Composite Structures*, 7(2):119-134, 2007

Stability Analysis of Semi-rigid Composite Frames

WANG Jingfeng and LI Guoqiang

Abstract: Based on stability theory of current rigid steel frames and using three-column subassemblage model, the governing equations for determining the effective length factor (μ-factor) of the columns in semi-rigid composite frames are derived. The effects of the nonlinear moment-rotation characteristics of beam-to-column connections and composite action of slab are considered. Furthermore using a two-bay three-storey composite frame with semi-rigid connections as an example, the effects of the non-linear moment-rotation characteristics of connections and load value on the μ-factor are numerically studied and the μ-factors obtained by the proposed method and Baraket-Chen's method are compared with those obtained by the exact finite element method. It was found that the proposed method has good accuracy and can be used in stability analysis of semi-rigid composite composite frames.

5. **Spline Finite Element Methods for Analysis of Axially Restrained Steel Beams Subjected to Elevated Temperatures in Fire**

Published in *Advances in Structural Engineering,* 10(2): 111-120, 2007

Spline Finite Element Methods for Analysis of Axially Restrained Steel Beams Subjected to Elevated Temperatures in Fire

LI Guoqiang and WANG Peijun

Abstract: A spline finite beam element for analysis of axially restrained steel beams subjected to elevated temperatures in fire is presented. Both geometric nonlinearity and material nonlinearity are integrated in the proposed method. Governing equations of the beam are established according to the internal-force and external-force equilibriums at each node of the elements representing the beam, and the nonlinear equations system is solved by the Newton-Continuation method. This strategy can avoid the building of the element and globe stiffness matrix, which may be complex when involves the second-order effect of axial force and elastic-plasticity of steel at elevated temperatures. Numerical examples of using the method proposed are presented. The influence of non-uniform temperature distributions is discussed. The structural responses, includes the deflection, axial force and moment at middle-span of the example beam, are calculated using both the presented spline finite element method (SFEM) and general finite element method (FEM) with shell elements. Comparisons of the results show that the spline finite beam element method is computationally economical and precise.

6. **Modeling of Membrane Action in Floor Slabs Subjected to Fire**

Published in *Engineering Structure,* 29(6):880-887, 2007

Modeling of Membrane Action in Floor Slabs Subjected to Fire

LI Guoqiang, GUO Shixiong, ZHOU Haossheng

Abstract: Through observations from experiments and fire-caused damages in real buildings, it is found that membrane action plays an important role in enhancing the fire-resistant capacity of floor slabs. Considering the mechanism of the membrane action in slabs subjected to fire, an explicit theoretical model is proposed. Based on the force and moment equilibrium requirement on slabs in fire, formulas for calculating the ultimate load-bearing capacity of floor slabs in fire conditions considering the effects of membrane action are obtained. The effectiveness of the theory for modeling membrane action of floor slabs subjected to fire is verified through satisfactory comparison with results from experimental and different theoretical simulations.

7. **Shaking Table Model Test on Shanghai World Financial Center Tower**

Published in *Earthquake Engineering and Structural Dynamics*, 36(4):439-457, 2007

Shaking Table Model Test on Shanghai World Financial Center Tower

LU Xilin, ZOU Yun, LU Wensheng and ZHAO Bin

Abstract The height of 101-storey Shanghai World Financial Center Tower is 492m above ground making it possible the tallest building in the world when completed. Three parallel structural systems including mega-frame structure, reinforced concrete and braced steel services core and outrigger trusses, are combined to resist vertical and lateral loads. The building could be classified as a vertically irregular structure due to a number of stiffened and transfer stories in the building. Complexities related to structural system layout are mainly exhibited in the design of services core, mega-diagonals and outrigger trusses. According to Chinese Code, the height of the building clearly exceeds the stipulated maximum height of 190 m for a composite frame/reinforced concrete core building. The aspect ratio of height to width also exceeds the stipulated limit of 7 for seismic design intensity 7. A 1/50 scaled model is made and tested on shaking table under a series of one and two-dimensional base excitations with gradually increasing acceleration amplitudes. This paper presents the dynamic characteristics, the seismic responses and the failure mechanism of the structure. The test results demonstrate that the structural system is a good solution to withstand earthquakes. The inter-storey drift and the overall behavior meet the requirements of Chinese Design Code. Furthermore, weak positions under seldom-occurred earthquakes of seismic design intensity 8 are found based on the visible damages on the testing model, and some corresponding suggestions are proposed for the engineering design of the structure under extremely strong earthquake

8. **Modeling and Experimental Verification on Concrete-filled Steel Tubular Columns with L or T Section**

Published in *Frontiers of Architecture and Civil Engineering in China*, 1(2): 163-169, 2007

Modeling and Experimental Verification on Concrete-filled Steel Tubular Columns with L or T Section

LU Xilin, LI Xueping and WANG Dan

Abstract: Concrete-filled steel tubular columns with L or T sections were analyzed in this paper. According to the confining mechanism, the stress-strain constitutive model was put forward, and calculated results were compared with experimental records. After that, the hysteretic rules for the in-filled concrete were constructed, aiming at the analysis on the seismic behavior of composite members. The simulation analysis was performed by programming it in Fortran. The models in this paper can be applied in the program of time history analysis on tall buildings with concrete-filled steel tubular columns with L or T sections.

9. **Analysis of Seismic Response of Soil Layers with Deep Deposits**
Published in *Frontiers of Architecture and Civil Engineering in China*, 1(2):188-193, 2007

Analysis of Seismic Response of Soil Layers with Deep Deposits

LOU Menglin, LI Yucun, LI Nansheng

Abstract: Several typical problems in the seismic response analysis of soil layers with deep deposits have been studied according to the seismic response analysis of the soil layer in Shanghai region. The problems include the effect of the inclination of the bedrock under the soil layer on the seismic response of the soil layer, the rationality of the artificial horizontal bedrock boundary in soil layer, and the effect of the wave velocity of the bedrock and dynamic characteristics of the soil media on the seismic responses of the soil layer. Some results are obtained by numerical analysis. In the seismic responses analysis, the effect of inclination angle of the bedrock surface under the soil layer can be neglected if the angle is not more than two degrees. A significant error will be introduced in calculation when the artificial horizontal rock surface is assumed in the soil layer according to the shear velocity of the soil media. The elasticity of the solid rock has little influence on the seismic response of the deep soil layer. The field investigation on the soil dynamic property should be paid more attention.

10. **Shaking Table Model Test and Numerical Analysis of a Complex High-rise Building**
Published in *The Structural Design of Tall and Special Buildings*, 16(2):131-164, 2007

Shaking Table Model Test and Numerical Analysis of a Complex High-rise Building

LU Xilin, ZHOU Ying and LU Wensheng

Abstract: Owing to commercial or aesthetic considerations, the shapes of high-rise city buildings are becoming increasingly unique and complicated. This brings challenges to structural engineers in analyzing and predicting their dynamic responses, which are crucial to the safety of the buildings. For these buildings in China, a detailed study, sometimes including shaking table testing, is required to verify the safety and rationality of their design. This paper presents results of a study performed for a high-rise building with a large space in the ground floor and large openings in elevation. The maximum responses of acceleration and deformation were measured and evaluated, as well as the dynamic characteristics, cracking pattern and failure mechanism of the building. In addition, a 3D finite element analysis was carried out and the analytical results were compared with experimental ones to gain a better understanding of the structural behavior. Suggestions regarding the design of this type of structure were also derived from the test results.

11. **The number Theoretical Method in Response Analysis of Nonlinear Stochastic Structures**
Published in *Computational Mechanics,* 39(6):693-708, 2007

The number Theoretical Method in Response Analysis of Nonlinear Stochastic Structures

LI Jie and CHEN Jianbing

Abstract: Astrategy of determining representative point sets through the number theoretical method (NTM) in analysis of nonlinear stochastic structures is proposed. The newly developed probability density evolutionmethod, applicable to general nonlinear structures involving random parameters, is capable of capturing instantaneous probability density function. In the present paper, the NTM is employed to pick out the representative point sets in a hypercube, i.e., the multidimensional random parameters space. Further, a hyper-ball is imposed on the point sets to greatly reduce the number of the finally selected points. The accuracy of the proposed method is ensured in that the error estimate is proved. Numerical examples are studied to verify and validate the proposed method. The investigations indicate that the proposed method is of fair accuracy and efficiency, with the computational efforts of a problem involving multiple random parameters reduced to the level of that involving only one single random parameter

12. **Joint Probability Density Function of the Stochastic Response of Nonlinear Structures**
Published in *Earthquake Engineering and Engineering Vibration,* 6(1):35-47, 2007

Joint Probability Density Function of the Stochastic Response of Nonlinear Structures

CHEN Jianbing, LI Jie

Abstract: The joint probability density function (PDF) of different responses of structures is of paramount importance. In the present paper, the probability density evolution method, which is successfully developed to capture the instantaneous PDF of arbitrary single response of interest, is extended to evaluate the joint PDF of any two responses. A two-dimensional partial differential equation with respect to the joint PDF is established. The strategy of selecting representative points via Number Theoretical Method and sieved by a hyper-ellipsoid is outlined. The two-dimensional difference scheme is elaborated. As examples, a SDOF system is first studied to verify the proposed method, and then a frame structure exhibiting hysteresis subjected to stochastic ground motion is investigated as well. It is pointed out that the correlation of different responses results from the fact that randomness of different responses comes from the same set of basic random parameters involved. In other words, the essential of probabilistic correlation is physical correlation

13. **The Equivalent Extreme-value Event and Evaluation of the Structural System Reliability**
Published in *Structural Safety*, 29:112-131, 2007

The Equivalent Extreme-value Event and Evaluation of the Structural System Reliability

Jie Li, Jianbing Chen, Wenliang Fan

Abstract: The idea of equivalent extreme-value event and accordingly a new approach to evaluate the structural system reliability are elaborated. For any type of compound random event as combination of a set of random events represented by inequalities, an equivalent extreme-value event is defined. Elaborated investigations show that correlative information among the component random events is inherent in the equivalent extreme-value event. Since the probability density function of equivalent extreme value could be obtained through probability density evolution method, the idea of equivalent extreme-value event leads to a new uniform approach to evaluate structural system reliability for both static and dynamic problems. Particularly, the investigation points out that computation of the dynamic reliability essentially involves dealing with infinite-dimensional correlation information and that is why the widely-used out-crossing process theory could be only an approximate and somewhat empirical reliability evaluation rather than an exact approach. The proposed approach is discussed in detail on how to construct the equivalent extreme-value event and then implement the procedure numerically. Two examples, of which one deals with static problem comparing the results with exact solution, the other deals with a nonlinear frame structure subjected to stochastic ground motions, are illustrated to validate the proposed method. The investigations show that the proposed approach is of satisfactory accuracy and applicable to the structural reliability analysis of various structures

14. **Studies on Seismic Performance of Prestressed Egg-shaped Digester with Shaking Table Test**
Published in *Engineering Structures*, 29(4):552-566, 2007

Studies on Seismic Performance of Prestressed Egg-shaped Digester with Shaking Table Test

Jie Li, Huaming Chen, Jianbing Chen

Abstract: The seismic response and performance of a water-filled, prestressed concrete egg-shaped digester (ESD) subjected to various earthquake inputs are investigated by shaking table test. A 1:8 scaled model structure was tested. The tests involve three stages including the empty model digester (EMD1) subjected to accelerations of relatively small peak ground acceleration (PGA), the model digester filled with half volume of water (WMD) subjected to accelerations of medium PGA and the empty model digester with water taken out (EMD2) subjected to acceleration with PGA up to a large value. According to the site condition and seismic background, two scaled ground motion accelerations, the recorded El Centro acceleration (ELA) and the artificial acceleration adopted in Guangzhou (GZA), are employed as the seismic excitations. The natural frequency, seismic responses including the amplification factor of acceleration (AFA), the relative displacement and the strain and stress of the EMD1, WMD and EMD2, are investigated based on the test results. Some features are captured and discussed. The fluid–solid coupling effects on different responses are pointed out. Finite-element modeling computations are conducted. Comparison with the test counterparts shows a fair agreement on the whole, indicating the reasonability as an engineering model. However, detailed stochastic response analysis and reliability assessment are necessary to comprehensively capture seismic performances of the ESD. Some concluding remarks are made.

15. **The extreme Value Distribution and Dynamic Reliability Analysis of Nonlinear Structures with Uncertain Parameters**

Published in *Structural Safety*, 29:77-93, 2007

The Extreme Value Distribution and Dynamic Reliability Analysis of Nonlinear Structures with Uncertain Parameters

CHEN Jianbing and LI Jie

Abstract: A new approach for evaluation of the extreme value distribution and dynamic reliability assessment of nonlinear structures with uncertain parameters is proposed. The approach is established based on the thoughts of the newly developed probability density evolution method, which is capable of capturing the instantaneous probability density function (PDF) and its evolution of the responses of nonlinear stochastic structures. In the proposed method, a virtual stochastic process associated to the extreme value of the studied stochastic process is firstly constructed in such a way that the extreme value equals the value of the virtual stochastic process at a certain instant of time. The probability density evolution method is then employed to evaluate the instantaneous PDF of the virtual stochastic process. This will yield the PDF of the extreme value as a natural byproduct. After that, dynamic reliability could be evaluated from the extreme value distribution, instead of the level-crossing process theory. A simple integration in terms of the extreme value distribution over the safe domain will give the dynamic reliability, requiring neither the joint PDF of the response and its velocity, nor the assumptions on properties of the level-crossing events. Numerical algorithm is outlined. Two examples, of which one is to capture the extreme value distribution of the random sampling, the other is to evaluate the extreme value distribution and dynamic reliability of a nonlinear stochastic structure, are studied. Some features of the instantaneous PDF and its evolution, the extreme value distribution and the dynamic reliability are discussed. The investigations indicate that the proposed approach is of versatility, accuracy and efficiency

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