Post Proceedings of

ACECC TC-8

2nd Workshop on Harmonization of Design Codes in the Asian Region - Direction of Future Design Code -

Venue: Tohoku University, Kawauchi North Campus
Multimedia Education and Research Complex
Date: Wednesday, 11th September, 2008
Time: 9:00-16:00

Sponsor: Japan Society of Civil Engineers
Asian Civil Engineering Coordinating Council
TC-8 "Harmonization of design codes in the Asian region"
Co-Sponsor: Kajima Foundation

"2nd Workshop on Harmonization of Design Codes in the Asian Region - Direction of Future Design Code –" is supported by the International Scientific Exchange Fund, JSCE, and the Kajima Foundation.

第２回アジア域内における設計基準の調和に関するワークショップ『将来の設計コードの方向性』は、公益信託土木学会学術交流基金および鹿島学術振興財団の助成を受け開催されております。

Contents

Introduction

Introduction of the ACECC Activities and the Workshop

Introduction of the ACECC Activities and the Workshop

Yusuke HONJO, Ph.D.
Chair of ACECC TC-8
Professor, Gifu University, Japan
Kenichi HORIKOSHI, Ph.D.
Secretary of ACECC TC-8, Chair, Committee on ACECC, JSCE
Senior Research Engineer, Taisei Corporation, Japan

1. About ACECC

The Asian Civil Engineering Coordinating Council (ACECC) is an organization which was established in 1999, and now consists of the nine civil engineering societies/institutions:

ASCE	American Society of Civil Engineers,
CICHE	Chinese Institute of Civil and Hydraulic Engineering
EA	Engineers Australia
HAKI	Indonesian Society of Civil and Structural Engineers
JSCE	Japan Society of Civil Engineers,
KSCE	Korean Society of Civil Engineers
MACE	Mongolian Association of Civil Engineers
PICE	Philippine Institute of Civil Engineers
VIFCA	Vietnam Federation of Civil Engineering Associations

ACECC is now trying to invite other Asian countries.

ACECC organizes a conference that is called the Civil Engineering Conference in the Asian Region (CECAR) once in three years, in order to provide all the experts in the civil engineering profession an opportunity to discover some of the most important innovations in civil engineering technology and R&D, and advance integrated discussions on the infrastructure development in the Asian region. The CECAR conferences were held in Manila in 1998, Tokyo in 2001, Seoul in 2004 and Taipei in 2007. Over 1,000 engineers from all over the world participated in the Taipei Conference (4th CECAR). The next 5th CECAR is going to be held in Sydney from 8 - 12 August 2010.

Information about ACECC：http://www.acecc.net/index.php (now under revision)

Information about 5th CECAR: http://www.cecar5.com/

2. The outline of the 2nd Workshop

As part of activities of the above-mentioned ACECC, the importance of mutual coordination on creating codes to be used in common in Asia has been discussed, and JSCE has been taking initiative for working on the possible measures. While codes like ISO and Eurocodes are being formulated from a global perspective, a lot of codes such as in the fields of concrete, geotechnical and seismic engineering are being transmitted to the world from Asian countries. Under these circumstances, we held the "1st Workshop on Harmonization of Design Codes in the Asian Region" in Taipei in 2006, and significant discussions were made as the first step toward the code harmonization in the Asian region.

After that, the new ACECC Technical Committee (TC-8) on “Harmonization of Design Codes in the Asian Region” was approved to be established at the ACECC Executive Committee Meeting on June 25, 2007. Terms of references of the new TC are as follows;

1) Create and strengthen human network on code development through continuous discussions.
2) Provide the latest information on design code in the Asian region, and make it public on the website.
3) Create the glossary of terminology for basis of design, which will be based on a new concept such as performance based design.

The objectives of the 2nd workshop are considered as follows;

1) This second workshop shall be continuation of the last special forum at the 4th CECAR which is held on June, 2007. The TC-8 was officially approved by the ACECC Executive Committee Meeting.
2) This second workshop shall be the first occasion where the members of ACECC TC-8 (Harmonization of design codes in the Asian Regions) give presentations and take part in the discussions.
3) A new ACECC member has joined since the last workshop, therefore the latest information on the code development in these new members shall be reported.
4) This workshop shall make up the first TC-8 meeting, which corresponds to the sessions in the afternoon. Not only the opinions and discussions by the TC-8 members but also those from the audience shall be incorporated for the planning of future activities.
5) At this stage, we recognize that harmonization of terminology in the new design concept will be one of the most important issues. The chair of the committee, Prof. Honjo, shall provide the basic idea of this.

Now, as we are stepping forward on these issues, we would like to hold the **“2nd Workshop on Harmonization of Design Codes in the Asian Region”** for the purpose of mutually sharing the information and having discussions on international strategy by the engineers/researchers who are working on code formulation in different areas in civil engineering assembled in one place. We position the 2nd workshop as the workshop for “Direction of Future Design Code “, then shall start discussions toward mutual understanding of the terminology for basis of design, which will be based on a new concept such as performance based design. Since new members might participate in the workshop, the 2nd workshop also will provide~~s~~ them a place to share the information on their activities and strategies for formulating design code. The outline of the 2nd workshop at the present stage is as follows;

3. Photo

Welcome address by Dr. Sumiyoshi

Presentation by Prof. Honjo

Presentation by Dr. Koo

Lecturers of WS

Lecturers and Participants

4. Workshop Program

Time table	Sessions	Speakers
09:00-09:10	**Opening**	Prof. Yusuke Honjo, Chair, ACECC TC-8
09:10-09:25	**Introduction** Introduction of the ACECC Activities and the Workshop	Dr. Kenichi Horikoshi, Secretary of ACECC TC-8
09:25-10:00	**Special Lecture 1** Outlines of the Revision of "Standard Specifications for Concrete Structures [Design], JSCE – 2007 Version"	Prof. Junichiro Niwa, Tokyo Institute of Technology
10:00-10:10	**Coffee Break**	
10:10-10:20	**Welcome Address**	Dr. Yukihiko Sumiyoshi, JSCE Representative to ACECC Dr. Hiroshi Okada, Former President of ACECC, Former President of JSCE
10:10-10:45	**Special Lecture 2** New Technical Standards for Port and Harbor Facilities (New TSPHF)	Dr. Yoshiaki Kikuchi, Port & Airport Research Institute
10:45-11:20	**Special Lecture 3** Development of Design Codes and Standard Specifications in Korea	Dr. Koo, Jai-Dong, Korea Institute of construction technology
11:20-11:30	**Coffee Break**	
11:30-11:50	**Presentation from TC-8 members** Status of Design Codes in Taiwan	Prof. Shyh-Jiann Hwang, National Taiwan University
11:50-12:10	Recent Aspect of Mongolian Code for Building and Construction	Prof. Duinkherjav Yagaanbuyant, Mongolian University of Science and Technology
12:10-13:00	**Lunch**	
13:00-13:20	**Presentation from other representatives** Introduction of 'Asian Concrete Model Code (ACMC)'	Dr. Yoshitaka Kato, Institute of Industrial Science, the University of Tokyo
13:20-13:40	Seismic Design Specifications for Highway Bridges in Japan	Dr. Zhang Guangfeng, Public Works Research Institute
13:40-14:00	The Necessity of Design Codes for Cambodia	Dr. Vong Seng Institute of Technology of Cambodia
14:00-14:20	Structural Steel Design Specifications in Thailand	Dr. Taweep Chaisomphob Engineering Institute of Thailand
14:20-14:30	**Coffee Break**	
14:30-15:50	**Panel Discussion (1st TC-8 Meeting)** ・ Forming opinions from each country ・ Direction of future design code ・ TC-8 activity plan hereafter First Draft of 'Glossary of Terminologies for Design Code.' **Summary Report**	Chair: Prof. Yusuke Honjo With all the participants of workshop.
15:50-16:00	**Closing Remarks**	Dr. Kenichi Horikoshi Secretary of ACECC TC-8

5. List of Participants

TC-8 members (including speakers):

Japan Prof. Yusuke Honjo (Chair of TC-8, Gifu University)
Prof. Eiki Yamaguchi (Kyushu Institute of Technology)
Dr. Kenichi Horikoshi (Secretary of TC-8, Taisei Corporation)
Taiwan Prof. Shyh-Jiann Hwang (National Taiwan University)
Mongolia Prof. Duinkher Yagaanbuyant (Mongolian University of Science and Technology)

Others (including speakers):

Japan Prof. Junichiro Niwa(Tokyo Institute of Technology)
Dr. Yoshiaki Kikuchi (Port & Airport Research Institute)
Dr. Yoshitaka Kato (Institute of Industrial Science, the University of Tokyo)
Dr. Zhang Guangfeng (Public Works Research Institute)
Korea Dr. Koo, Jai-Dong (Korean Institute of Construction Technology)
Cambodia Dr. Vong Seng (Institute of Technology of Cambodia)
Thailand Dr. Taweep Chaisomphob(Engineering Institute of Thailand)

Organizing Members:

Mr. Masayuki Torii (Secretary General, Committee on ACECC, JSCE
Nishimatsu Construction Co., Ltd)
Mr. Masaaki Nakano (Secretary, Committee on ACECC, JSCE, Nippon Koei Co., Ltd)
Mr. Hiroyuki Yanagawa (International Affairs Section, JSCE)

Special Lecture

ACECC TC-8 2nd Workshop on Harmonization of Design Codes in the Asian Region
Sep. 11, 2008, Sendai, Japan

Outlines of the Revision of "Standard Specifications for Concrete Structures [Design], JSCE – 2007 Version"

Junichiro Niwa
Secretary General, Subcommittee on the Revision of Standard Specifications, Design Group, Concrete Committee of JSCE
Professor, Tokyo Institute of Technology, Tokyo, Japan

Outlines of the Revision of “Standard Specifications for Concrete Structures [Design], JSCE – 2007 Version”

Sept. 11, 2008

Concrete Committee of JSCE

Subcommittee on the Revision of Standard Specifications, Design Group

Junichiro Niwa (Tokyo Institute of Technology)

Standard Specifications for Concrete Structures [Design], JSCE (2007 Version) have been published in March 2008.

1. Introduction

(1) Standard Specifications of Concrete Structures were originally published in 1931.

(2) The specifications showed the ideal figure for planning, design, construction, and maintenance of concrete structures.

(3) In 1986, the concept of the limit state design method was introduced.

(4) In 2002, the concept of the performance based-design was introduced.

(5) In 2007, the latest version has been published.

2. Features of the Standard Specifications – 2002 Version

(1)Extension to high strength materials (concrete and reinforcement)

(2) Introduction of findings of Fracture Mechanics (Size effect, nonlinear analysis, etc.)

(3) Revision of the predicting equation for flexural crack width

(4) Introduction of “Strut-and-Tie Model” (for D regions)

3. Outlines of the Revision of Standard Specifications [Design] – 2007 Version

(1) The Specifications [Design] have been divided into three parts, such as the main documents, the standards, and the reference materials.

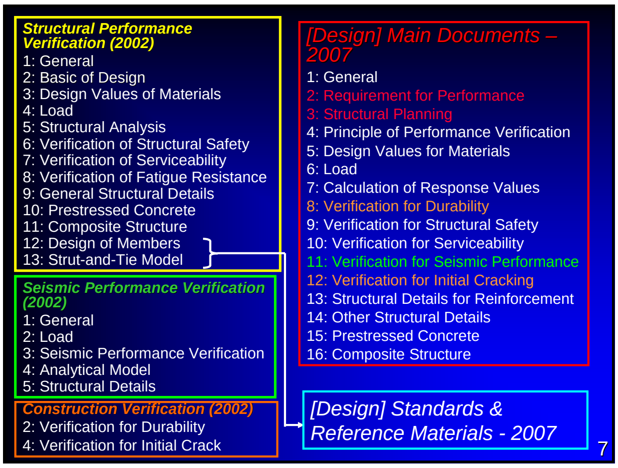
(2) The main documents maintain the style of text and comment. They present the general way for the performance verification.

(3) The standards show the simplified way to meet the performance verification within the limited conditions.

(4) The reference materials give the explanation or examples to understand the main documents.

3. Outlines of the Revision of Standard Specifications [Design] – 2007 Version

(5) The Specifications [Design] - 2007 have merged “Structural Performance Verification (2002)” and “Seismic Performance Verification (2002)” into one, and have taken “Chapter 2: Verification for Durability” and “Chapter 4: Verification for Initial Crack” from the Standard Specifications of “Construction Performance Verification (2002)”.



[Design] Standards & Reference Materials

[Design: Standards]

- 1: Structural Analysis of Members
- 2: Seismic Design
- 3: Durability Design
- 4: Thermal Stress Analysis
- 5: Details of Reinforcements
- 6: Strut-and-Tie Model

[Design: Reference Materials]

- 1: Examples of Structural Planning
- 2: Examples of Structural Analysis
- 3: Nonlinear Structural Analysis
- 4: Examples of Seismic Design

8

3. Outlines of the Revision of Standard Specifications [Design] – 2007 Version

(6) Since the structural planning is the most important work in the design stage, "Chapter 3: Structural Planning" has been newly drawn up.

9

3. Outlines of the Revision of Standard Specifications [Design] – 2007 Version

(7) "Chapter 12: Design of Members" of 2002 version has been moved to the Reference Materials, because the contents are related to linear structural analysis.
(8) The items related to "Nonlinear analysis" are explained in the Reference Materials.
(9) "Chapter 13: Strut-and-Tie Model" of 2002 version has been moved to the Standards, because it is the simplified design method within the limited conditions.
(10) "Allowable stress design method" in the appendix of 2002 version has been deleted, because the contents are not examined.

10

3. Outlines of the Revision of Standard Specifications [Design] – 2007 Version

(11) "The Standards" such as "Seismic Design" or "Durability Design" have been newly drawn up to promote the Specifications to practical engineers.
(12) Since "design drawings" can be considered as an interface between the design and the construction, material details which are thought in the design stage have to be clearly exhibited in design drawings.
(13) To pay attention to excessively large shrinkage of concrete, the predicted value by the conventional design equation has been increased by 1.5 times.

11

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 1: General

Design is the action to set the required performance for a concrete structure related to the durability, safety, serviceability, restorability, environmental aspect and aesthetic viewpoint, etc.

12

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 2: Required Structural Performance

(1) Durability, safety, serviceability, restorability, environmental aspects and aesthetic viewpoint are treated as the required structural performance.

(2) Since the seismic performance is the combined performance, it is considered to be different from others. However, to take the continuity from 2002 version, the seismic performance is treated as the required performance in Chapter 11.

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 3: Structural Planning

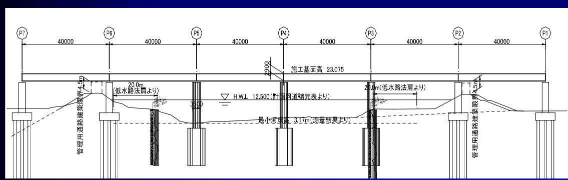
(1) Newly drawn up in 2007.

(2) The basic ideas are described in selecting structural forms. The viewpoints of required performance, construction, maintenance, environment and economic viewpoint are considered.

Example of Structural Planning of Railway Bridge

- The bridge length is 240 m. It passes over a river having the width around 160 m (HWL).
- Plan 1 6-span PC simple girder bridge 40 m × 6=240 m.
- Plan 2 6-span continuous PC box girder bridge 40 m × 6=240 m.
- Plan 3 4-span continuous extradosed PC girder bridge 40m+80m+80m+40m=240m.
- Plan 4 4-span continuous PC cable-stayed bridge 40m+80m+80m+40m=240m.
- Plan 1: 6-span PC simple girder bridge, is adopted from the economical viewpoint.

Example of Structural Planning of Railway Bridge

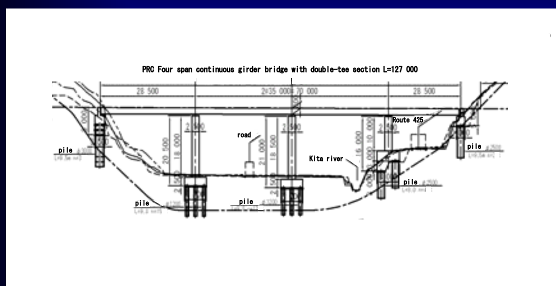


(Adopted plan) 6-span PC simple girder bridge 40m × 6=240 m.

Example of Structural Planning of Highway Bridge

- The bridge length is 130m. It passes over a small-sized river and 2 roads.
- Plan 1 5-span continuous PRC double girder bridge 25m+4@25.5m=127m.
- Plan 2 4-span continuous PRC double girder bridge 28.5m+2@35m+28.5m=127m.
- Plan 2, 4-span continuous PRC double girder bridge, is adopted from the economical viewpoint and the harmonization with environment.

Example of Structural Planning of Highway Bridge



(Adopted Plan) 4-span continuous PRC double girder bridge

Chapter 4: Principle of Performance Verification

(1) The limit state corresponding to the required performances shall be established.

(2) It shall be confirmed that the structure does not reach the limit state.

(3) The current limit state design method is adopted.

(4) Verification shall be performed by Eq. (4.3.1).

$$\gamma_i \cdot S_d / R_d \leqq 1.0 \qquad (4.3.1)$$

where, S_d : Design response value
R_d : Design limit state value
γ_i : Structure factor

4.5 Safety Factor

Table C4.5.2 Recommended Safety Factor

Required Performance (Limit state) \ Safety factor		Material factor γ_m: Concrete γ_c	Material factor γ_m: Steel γ_s	Member factor γ_b	Structural analysis factor γ_a	Load factor γ_f	Structure factor γ_i
Safety (Section failure)*1		1.3	1.0 or 1.05	1.1～1.3	1.0	1.0～1.2	1.0～1.2
Safety (Section failure・Collapse)*2 Seismic performance Ⅱ・Ⅲ *2	Response value	1.0	1.0	—	1.0～1.2	1.0～1.2	1.0～1.2
	Limit state value	1.3	1.0 or 1.05	1.0, 1.1～1.3	—	—	
Safety (Fatigue failure)*1		1.3	1.05	1.0～1.1	1.0	1.0	1.0～1.1
Serviceability *1 Seismic performance Ⅰ *1		1.0	1.0	1.0	1.0	1.0	1.0

Note) ＊1: Linear analyses ＊2: Nonlinear analyses

4.8 Design Drawings

Outlines:

(1) Design drawings are the interface between the design and construction, and the design and maintenance.

(2) Items which should be written in the design drawings are prescribed in detail.

4.8 Design Drawings

(1) The basic points of design calculation and the conditions of construction and maintenance shall be clarified in the design drawings.

① Design service life, environmental condition
② Characteristic value of loads and combination of design loads
③ Safety factor
④ Required performance and result of verification
⑤ Characteristic value of materials (concrete and steel), such as shrinkage of concrete

4.8 Design Drawings

⑥ Types and quality of steel
⑦ Cover of steel and construction error in all parts
⑧ Types and locations of the joint and the portion where the joint can be arranged.
⑨ Tension force at the end, the elongation and tensioning sequence of PC steel
⑩ Required items in construction and maintenance
⑪ Name and location of the structure
⑫ Signature of the responsible engineer
⑬ The date of design
⑭ Scale, dimension and unit
⑮ Name of applied specifications

4.8 Design Drawings

Following items shall be described as the reference values.

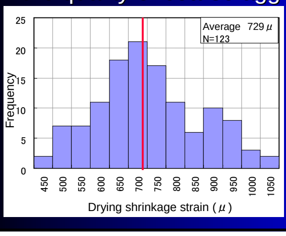
⑯ Types of cement
⑰ Maximum size of coarse aggregate
⑱ Unit cement content
⑲ Slump or slump flow of concrete
⑳ Water-cement ratio
㉑ Air content

Although ⑯～㉑ are reference values, it shall be confirmed in the design stage that these values are fully realistic.

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 5: Design Values for Materials

Outlines: The shrinkage strain of concrete is increasing year by year due to the degradation of the quality of coarse aggregates.



According to JIS test, the average shrinkage strain of concrete is 730 μ.

The shrinkage strain is sometimes more than 1000 μ.

25

Prediction of shrinkage strain of concrete

(1) If the data of real-size test or JIS test are available, the data can be used for the design.

(2) When the test data is not available, the predicted value by the conventional design equation has to be increased by 1.5 times.

(3) The maximum value by the conventional design equation is around 800μ. The maximum value of JIS test (7 days ~ 6 months) is around 1000 μ. If the sum of the autogeneous shrinkage before 7 days and the shrinkage after 6 months is estimated as 200μ, the maximum total shrinkage becomes around 1200μ. Therefore, the predicted value has to be increased by 1.5 times.

26

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 6: Load

(1) “Seismic loading” has been taken from the “Specifications of Seismic Performance Verification – 2002”.

(2) Earth pressure is determined by considering the interaction between the ground and the structure and the change with age.

27

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 7: Calculation of Response Values

(1) The calculation of response values by nonlinear analysis has been taken from the “Seismic Performance Verification – 2002”.

(2) Calculation methods for section force, deflection, stress, strain, crack width, etc. are prescribed in Chapter 7.

(3) The information on nonlinear structural analysis has been newly drawn up in the Reference Materials.

28

7.4.4 Calculation of Flexural Crack Width

The method of calculation of flexural crack width is the same as that in 2002.

$$w = 1.1k_1k_2k_3\{4c + 0.7(c_s - \phi)\}\left[\frac{\sigma_{se}}{E_s}\left(\text{or } \frac{\sigma_{pe}}{E_p}\right) + \varepsilon'_{csd}\right]$$

ε'_{csd} : The value to consider the influence of shrinkage and creep.
It is determined depending on the verification, such as the durability of steel corrosion, or the appearance of surface cracks.

29

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 8: Verification for Durability

(1) Chapter 8 has been newly drawn up by merging "Chapter 7 Verification of Serviceability" (2002) and “Chapter 2 Verification for Durability” (2002).

(2) In the verification for the chloride attack, the concentration of chloride ions at the concrete surface C_o is updated according to the location of the structure and its distance from the shoreline.

(3) The difference of C_o between Japan sea side and Pacific ocean side has been taken into account.

30

8.2 Environmental Action

Fig. C8.2.2 Concentration of chloride ions at the concrete surface C_o (kg/m³)

		splash zone	distance from shoreline (km)				
			close to shoreline	0.1	0.25	0.5	1.0
The area with high blown chloride contents	Hokkaido,To-hoku, Hokuriku, Okinawa	13.0	9.0	4.5	3.0	2.0	1.5
The area with low blown chloride contents	Kanto,Tokai, Kinki, Chugoku, Sikoku, Kyusyu		4.5	2.5	2.0	1.5	1.0

The values corresponding to the area with low blown chloride contents have been updated.

31

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 9: Verification for Structural Safety

(1) The cross-sectional failure of a member, fatigue failure, and the stability of a structure are taken into account as a main target.

(2) In the shear capacity of RC deep beams, a new calculation method which can consider the effect of shear reinforcement has been prescribed.

32

9.2.2.2(5)[Commentary] Design shear capacity of linear members

Eq. (C9.2.4)

$$V_{dd} = (\beta_d \cdot \beta_n + \beta_w)\beta_p \cdot \beta_a \cdot f_{dd} \cdot b_w \cdot d / \gamma_b$$

where, $\beta_w = 4.2\sqrt[3]{100 p_w} \cdot (a/d - 0.75) / \sqrt{f'_{cd}}$

if $\beta_w < 0$, $\beta_w = 0$.

(1) The parameter β_w has been introduced to consider the effect of shear reinforcement.

(2) The accuracy of the estimation for shear capacity of RC deep beams is almost same as that of the existing design equation.

33

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 10: Verification for Serviceability

(1) The verification of the appearance of structures, water-tightness, and fire resistance has been newly prescribed.

(2) The limit of crack width for the appearance of structures is determined as 0.3mm based on past records and experience.

(3) The flexural crack width can be evaluated by the following equation.

$$w = 1.1 k_1 k_2 k_3 \{4c + 0.7(c_s - \phi)\}\left[\frac{\sigma_{se}}{E_s}\left(\text{or } \frac{\sigma_{pe}}{E_p}\right) + \varepsilon'_{csd}\right]$$

34

10.3.2 Flexural Crack

ε'_{csd} should be determined to assume construction works for the structure concerned such as concrete casting and removal of formwork and support. The test value of ε'_{csd} and the age of concrete when the crack initiates should be taken into account.

When the shrinkage strain obtained by JIS test method is not more than 1000μ, the following values are recommended as ε'_{csd}.

Table 10.1 Recommended value of ε'_{csd} for calculating flexure crack on surface

Material age of crack initiation	ε'_{csd}
30 days	450×10^{-6}
100 days	350×10^{-6}
more than 200 days	300×10^{-6}

35

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 11: Verification for Seismic Performance

(1) Chapter 11 has been newly drawn up based on the "Seismic Performance Verification – 2002".

(2) To avoid the decrease in shear capacity due to large deformation cyclic loading and maintain the safety against the input of excessive seismic loading, sufficient shear reinforcement shall be provided so that the ratio between shear and flexure capacities should exceed 2.0.

36

The Standards

Chapter 2: Design of Seismic Coefficient Method

2.4.3 Shear Reinforcement in the Plastic Region

Deformation ability shall be maintained by the following relationship, which is the prerequisite to make the design yield seismic coefficient spectrum.

$V_{yd} / V_{mu} \geq 2.0$

where, V_{yd} : Design shear capacity
V_{mu} : Shear force at the end of a member when the member reaches flexural capacity, $V_{mu}=M_u / L_a$

37

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 11: Verification for Seismic Performance

(1) In addition to Chapter 11 of the Main Documents, Chapter 2 of the Standards "Seismic Design" and Chapter 4 of the Reference Materials "Examples of Seismic Design" have been drawn up.

(2) In the Standards, the design yield seismic coefficient spectrum is given as a result of the numerous calculation for modeled ground and structures.

38

Seismic Design

- Main Documents

  Time history response analysis by a one-dimensional continuous model or a finite element model.

- Standards

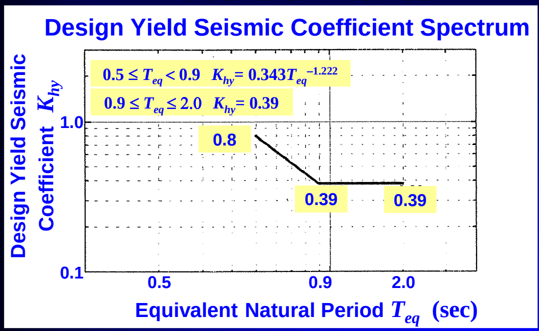
  Following simplified static analyses can be used.

  (1) Static linear analysis by the design yield seismic coefficient spectrum.

  (2) Static nonlinear analysis by the nonlinear seismic coefficient spectrum.

39

Chapter 2: Design of Seismic Coefficient Method



Natural Period of Ground (∼0.25 sec)

40

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 12: Verification for Initial Cracking

(1) Chapter 12 has been newly drawn up based on the Chapter 4 Verification for Initial Crack of "Construction Performance Verification (2002)".

(2) The simplified method to verify the performance of the structure by cracking due to the hydration heat of cement has been newly introduced in Chapter 4: Thermal Stress Analysis in the Standards.

41

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 13: Structural Details for Reinforcement

Chapter 14: Other Structural Details

(1) Structural details are classified into two categories. One is the structural details with quantitative provisions, and the other is the structural details with only qualitative explanation.

(2) In the Standards, "Chapter 5: Details of Reinforcements" has been newly drawn up to prescribe the cover of reinforcements, the dimension and shape of hooks, the anchorage length, etc. in the form of Tables.

42

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

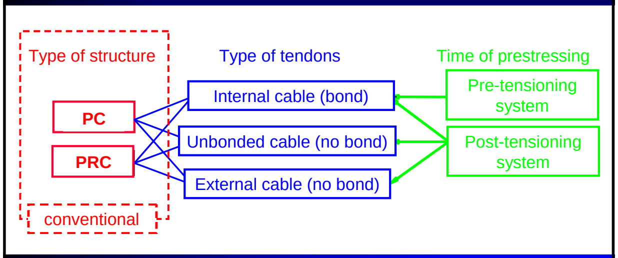
Chapter 15: Prestressed Concrete

(1) The description for the stress calculation and the problem of shrinkage in PRC structures has been modified and increased.

(2) The calculation method for prestressing forces and ultimate flexural capacities in internal and external PC members has been shown in detail.

(3) The prestressing tendons have been classified into three categories, such as internal, unbonded and external tendons.

Fig. C15.2.1 Type of Prestressed Concrete Structures



4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 15: Prestressed Concrete

(4) When PRC structures are used in corrosive or severely corrosive environment, a plastic sheath to have the shielding effect against corrosive materials shall be used in principle.

4. Characteristics of Each Chapter of the Standard Specifications [Design] – 2007

Chapter 16: Composite Structure

(1) The technical terms in the Standard Specifications [Design] – 2007 have been unified with the guidelines of composite structures, JSCE.

5. Conclusions

(1) The Specifications [Design] - 2007 have merged "Structural Performance Verification (2002)" and "Seismic Performance Verification (2002)" into one.

(2) The Specifications [Design] - 2007 have three parts, such as the Main Documents, Standards, and Reference Materials.

(3) The Specifications try to make the sophisticated verification technique possible and also present the simplified design method as well.

(4) "Structural Planning" and "Design Drawings" are the most important issues in this revision.

Thank you very much

for your attention !

ACECC TC-8 2nd Workshop on Harmonization of Design Codes in the Asian Region
Sep. 11, 2008, Sendai, Japan

New Technical Standards for Port and Harbor Facilities

Yoshiaki Kikuchi
Port & Airport Research Institute, Japan

New Technical Standards for Port and Harbor Facilities (New TSPHF)

2nd Workshop on Harmonization of Design Codes in the Asian Region
- Direction of Future Design Code -
ACECC TC8 2008.9.11

Yoshiaki Kikuchi
Port & Airport Research Institute

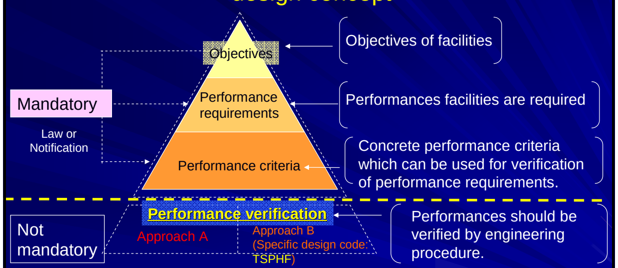
Table of contents

Difference of the former and new TSPHF

Example of provisions in former TSPHF - Breakwater or Protective facilities -

	Contents	Provisions in former TSPHF
Objectives and performance requirements	Function	Protective facilities for harbors should be maintained its function under every natural situations such as geography, meteorology, marine phenomena and others. (Law Article 7)
	Safety	Protective facilities should be safe against self weight, water pressure, wave force, earth pressure, earthquake force and so on. (Law Article 7)
Performance verification (They are also written in notification)	Calculation of forces	The wave force acting on a structure shall be determined using appropriate hydraulic model experiments or design methods in the following procedure. (Notification Article 5)
	Safety verification of members	Examination of the safety of the members of the rein forced concrete structures shall be conducted as standard by the limit state design method. (Notification Article 34)
	Stability check	Examination of the stability of upright section of gravity type breakwater shall be based on the design procedures using the safety factors against failures. (Notification Article 48)

Technical standard system under performance based design concept



- Performance verification: Designers can select the approach for verification.
  - Approach A: Designers should prove the verification of the performance requirements under an appropriate reliability. Verification results will be checked by an accredited organization or a authorized committee.
  - Approach B: Designers should prove the verification of the performance requirements in accordance with technical codes prepared by the authorities
    >> Guidelines which present the standard procedure of verification are prepared for reference.

Concept of performance based design system in new TSPHF

Level	Definition	Mandatory situation	Example for break water
Objectives	The reason why the facility is needed.	Mandatory (Port and Harbor Law)	Law Article 14 Calmness of navigation channels and basin should be kept in order to navigate and moor ships safely and in order to handle cargo smoothly and in order to safely maintain buildings and other facilities located in port
Performance requirements	Performances which facilities are required	Mandatory (Port and Harbor Law)	Law Article 14 - Serviceability requirement- Damages by the actions of self weight, wave, Level 1 earthquake should not affect the objectives of the break water and the continuous usage of it.
Performance criteria	Concrete performance criteria which represent performance requirements	Mandatory (Notification)	- Notification Article 35 - 1st Danger of the possibility of the sliding failure of the ground under the persistent situation in which main action is self weight should be lower than limit level. 2nd Danger of the possibility of the sliding and rotation failure of the gravity structure and of the failure of the ground by in short of bearing capacity under the variable situation in which main actions are wave or Level 1 earthquake should be lower than limit level.
Performance verification	Performances should be verified by engineering procedure.	Not Mandatory (Guidelines are presented for references)	(Guidelines present standard procedure of performance verification for reference)

Performance considered in former TSPHF

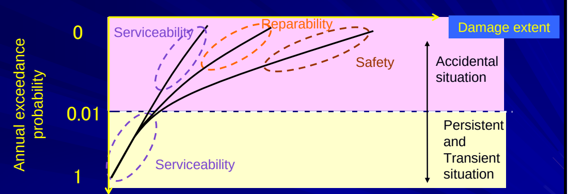
Design situation	Definition	Performance Requirement
Ordinary Situation	Permanent actions (self weight, earth pressures) are major actions	Safety factors against failure shall be larger than prescribed value.
Extraordinary Situation	Variable actions (wave, Level 1 earthquake) are major actions	
Large earthquake	Level 2 earthquake is major action	Safety factors against failure shall be larger than prescribed value.

This design situation is applied only on earthquake proofed structures.

Performance matrix considered in new TSPHF

Design situation	Definition	Performance Requirement
Persistent Situation	Permanent actions (self weight, earth pressures) are major actions	Serviceability (Possibility of damage is low or the functions of the facility would be recovered with minor repairs.) ・Serviceability is required for all facilities ・If serviceability is satisfied, reparability and safety are automatically satisfied.
Transient Situation	Variable actions (wave, Level1 earthquake) are major actions	
Accidental Situation	Accidental actions (Tsunami, Level 2 earthquake) are major actions	・Levels of the performance requirements will be changed by the importance of the facilities. - Serviceability - Reparability: The function of the facility would be recovered in relatively short period after some repairs. - Safety: Significant damage would take place. However, the damage would not cause any lives loss or serious economic damages to hinterland.

Relation between design situation and performance requirement in new TSPHF



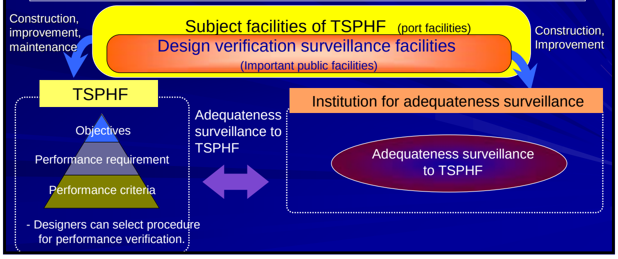
Note) Accidental and transient situation are separated by the annual exceedance probability of 0.01 for the descriptive purpose.

Level 1 & 2 earthquake

- For the verification of earthquake resistance of public structures, two types of seismic motions shall be applied such as Level1 earthquake and Level 2 earthquake.
  - Level 1 earthquake: is the intensity of seismic motion which structures will encounter 1 or 2 times during its service period. This level of earthquake is the almost equivalent seismic motion as that used for the external force against conventional seismic design.
  - Level 2 earthquake: is the intensity of seismic motion of which event probability is quit low. Large scale plate boundary earthquakes occurred near land or inland earthquakes will be this kind of earthquakes.

Introduction of the institution for adequateness surveillance to TSPHF

- Although a large variety of design verification methods can be applied by introduction of performance based design code, high level of engineering knowledge is required for adequateness surveillance.
- To adequately maintain the safety of important public facilities, designs of those facilities shall be surveyed by government of accredited organization. Accredited organizations shall be nominated by government.



Advantage of new TSPHF

- Advantage of new TSPHF shall be summarized as follows;
  - Performance of facilities are clearly presented to users.
    - fully performance based design code is introduced.
  - Designers can utilize their decision and can exercise their ingenuity.
    - Designers can propose new design method or new type of structures.
  - Building cost reduction is anticipated with ingenuity.
- In order to employ above advantages appropriately, it is required for designers and promoters to understand the thoughts and technical contents of the TSPHF correctly.
- And to guarantee to users that new technology has satisfied the demand of TSPHF, the system for checking the adequateness of proposed design to TSPHF is founded.

Changed Important technical points

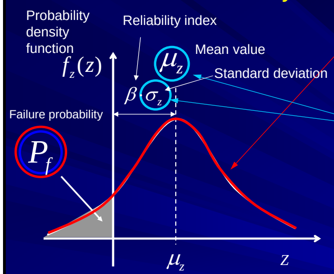
- Introduction of performance based design method
  - Reliability based design method is fully introduced.
- Change of calculation procedure for the input earthquake force for design (L1 & L2)
  - Observed seismic motions in each port are utilized for the calculation of input earthquake force for design
- New seismic coefficient method (L1) with new seismic coefficient for design
  - New concept of seismic coefficient compatible with existing seismic coefficient method
    > Damage of the mooring facilities after L1 level earthquake is considered to decide the seismic coefficient.

Changed Important technical points

- Introduction of performance based design method
  - Reliability based design method is fully introduced.
- Change of calculation procedure for the input earthquake force for design (L1 & L2)
  - Observed seismic motions in each port are utilized for the calculation of input earthquake force for design
- New seismic coefficient method (L1) with new seismic coefficient for design
  - New concept of seismic coefficient compatible with existing seismic coefficient method
    > Damage of the mooring facilities after L1 level earthquake is considered to decide the seismic coefficient.

Reliability based design method in new TSPHF

Levels of Reliability based design method



(1) Level 3 PBD
- Failure probability is directly evaluated (P_f: Probability of performance function Z<0)

(2) Level 2 PBD
- Distance between mean value μ_z and failure condition is evaluated with reliability index β.
- Indirectly considering the probability distribution form. β and σ_z are considered for evaluating failure probability.

(3) Level 1 PBD
- Partial factors are used for considering the distance between mean value and failure condition.
- Partial factors are decided from Level 2 PBD calculation.

Performance function: Resistance, Action

$$Z = R - S$$
$$= (\gamma_R R_k - \gamma_S S_k)$$

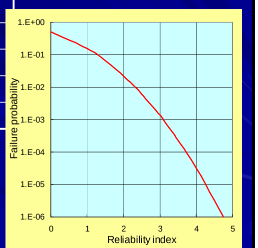
Partial factor　Partial factor

$$\gamma_i = \left(1 - \alpha_i \beta_T \frac{\sigma_i}{\mu_i}\right)\frac{\mu_i}{x_{ki}}$$

Reliability index and failure probability

If performance function Z and R and S are assumed to be normal probability variables. Relationship between Pf and β are as follows.

Failure probability P_f	Reliability Index β
10^{-1}	1.29
10^{-2}	2.32
10^{-3}	3.09
10^{-4}	3.72
10^{-5}	4.27
10^{-6}	4.75



Relationship between traditional design method and reliability based design method

Traditional design method (Safety Factor Method)

Deterministic
- Safety factor
- Allowable stress method

* Actions and resistances are deterministically defined.

Code calibration

- Experience of traditional method is emphasized.
- Failure probability is explicitly considered.

RBD method

Probabilistic
- Partial factors
- Limit state of materials

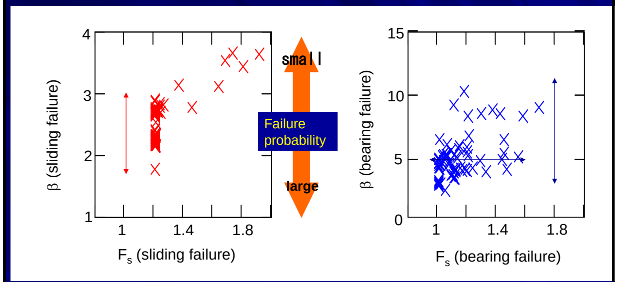
* Probabilities of action and resistances are taken into consideration.

Difficult ↕ simple

RBD Level	Performance criteria	Evaluation parameter
Level 3	$P_{fT} > P_f$	Failure probability
Level 2	$\beta_T > \beta$	Reliability index
Level 1	$R_d > S_d$ ($\gamma_R R_k > \gamma_S S_k$)	Partial factor

Safety factor method and RBD method

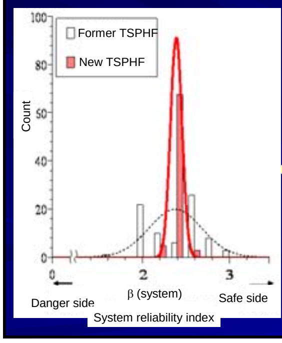
Safety factor cannot explain failure probability.

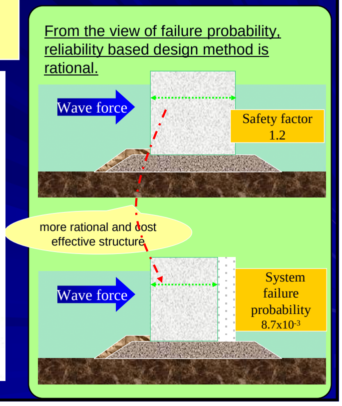


- Difference between safety factor and failure probability:
  - Large safety factor <=> Small failure probability
  - Failure probability has some variance even in the same safety factor is used.
- Failure probability cannot be presented in the traditional design method.

Effect of introduction of reliability based design to design results

Variance of system reliability index - combination of three mode of failure such as sliding, turnover, and loss of bearing capacity - is minimized in new TSPHF.





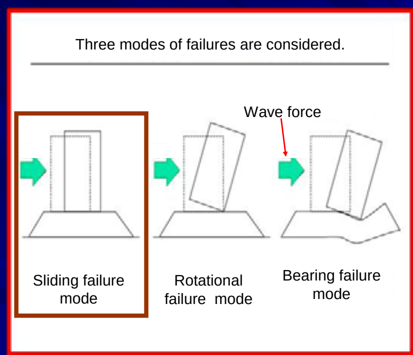
Performance based design in new TSPHF (in guideline)

- Reliability based design (Partial factor method)
  - Performance levels are categorized mainly by importance of the structures.
- Not only static analysis such as seismic coefficient method but also dynamic response analysis is introduced especially in the case of important structures.
  - Performance of quay wall is indicated by displacement or deformation. To evaluate those, analytical method to predict the deformation of the structure is needed.
- Importance of model tests or field experiments are emphasized to include design verification procedure.

Traditional safety factor method are still used for some types of structures. In those cases, partial factors are formally used.

Design verification of gravity type of breakwater

Design verification method used in new TSPHF is explained using the verification of gravity type of breakwater for example.

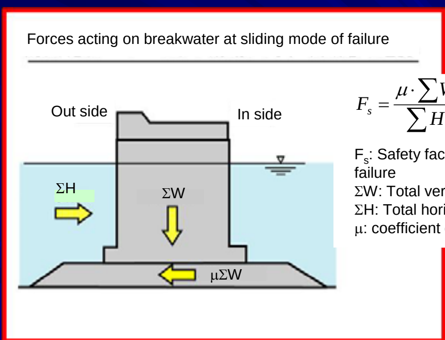


Verification of sliding mode of failure is presented.

Design situation is transient situation at which wave force is the major action.

Design verification of gravity type of breakwater

Traditional method



$$F_s = \frac{\mu \cdot \sum W}{\sum H}$$

F_s: Safety factor for sliding failure
ΣW: Total vertical force
ΣH: Total horizontal force
μ: coefficient of friction

Difference in statements between former and new TSPHF

(Ex: Verification of the sliding stability of a gravity type of breakwater)

Former TSPHF

$$F_s \leq \frac{\mu \cdot (W_0 - U)}{P}$$

$F_s = 1.2$

F_s: Safety factor
μ : friction coefficient between the upright section and rubble mound
W_0: weight of the upright section in still water
U: uplift force
P: horizontal wave force

New TSPHF

$$\gamma_f f_k (\sum_i \gamma_{W_i} W_{ik} - P_{Bd} - \gamma_{P_U} P_{Uk}) \geq \gamma_{P_H} P_{Hk}$$

$P_f \leq 8.7 \times 10^{-3}$

γ: partial factor
k (suffix): characteristic value ,
d (suffix): design value
f: friction coefficient between the upright section and rubble mound
W_i: total weight of the upright section
P_B: buoyancy acting on the upright section in still water
P_U: uplift force acting
P_H: horizontal wave force

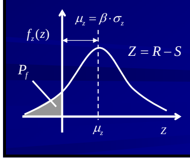
Evaluation of failure probability of existing structures

Deciding Target system failure probability

- Reliability indices of existing structures are calculated with first order reliability method (FORM) for understanding average failure probability of existing structures.
- About 40 cases were examined for each type of structures and design method.
  - * FORM method is categorized in level 2 of RBD.

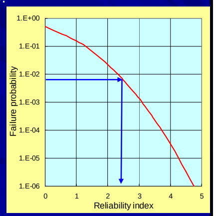
$P_f \leq 8.7 \times 10^{-3}$

Average system reliability index of existing caisson type breakwater is 2.38.



μ_z: mean value
σ_z: Standard deviation

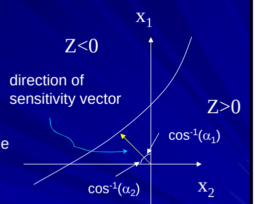
- Reliability index β



Determination procedure of partial factor

$$\gamma_i = \left(1 - \alpha_i \beta_T \frac{\sigma_i}{\mu_i}\right) \frac{\mu_i}{x_{ki}}$$

α_i: Sensitivity of the parameter
β_T: Target reliability index
μ_i: Mean value of the parameter
σ_i: Standard deviation of the parameter
x_{ki}: Characteristic value or nominal value



Design value and characteristic value

$$x_{di} = \gamma_i x_{ki}$$

Characteristic value is a value which represents a material property.

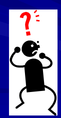
Statistic parameters of design parameters

	μ_i/x_{ki}	σ_i/μ_i
Wave force (PH,PU)		
Offshore wave height	1.00	0.10
Wave deformation calculation		
shallow slope	0.97	0.04
steep slope	1.06	0.08
Deformation after breaker	0.87	0.10
Calculation of wave force		
Caisson type	0.91	0.19
Caisson type covered with wave-dissipating concrete blocks	0.84	0.12
Tidal range		
γ_{wl}=1.5	1.00	0.20
γ_{wl}=2.0,2.5	1.00	0.40
Coefficient of friction	1.06	0.15
Unit weight		
Rein forced concrete	0.98	0.02
Concrete	1.02	0.02
Sand	1.02	0.04
Foundation ground	1.00	0.03
Strength parameters of the ground (c', tanϕ')	1.00	0.10

Note)
μ_i/x_{ki} : deviation of characteristic value (mean/characteristic value)

σ/μ_i :Coefficient of variance

r_{wl} : Ratio of highest water level ever recorded and mean monthly-highest water level



Very complicated !!!

Partial factors used in TSPHF

Partial factor $\gamma_i = \left(1 - \alpha_i \beta_T \frac{\sigma_i}{\mu_i}\right) \frac{\mu_i}{x_{ki}}$

Coefficient of variance V

Deviation of the characteristic value to mean value

Sensitivity

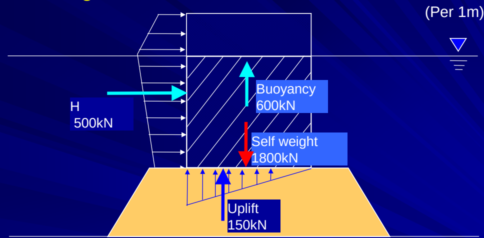
Target reliability index

Standard partial factor (Transient situation for wave)						
Target system reliability index β_T			2.38			
Target system failure probability P_{fT}			8.7 X 10^{-3}			
Target reliability used for partial factor **β_T'**			**2.40**			
			γ	α	μ/x_k	σ/μ
Sliding	γ_f	Coefficient of friction	**0.79**	0.689	1.060	0.150
	γ_{PH},γ_{PU}	steep slope	**1.04**	-0.704	0.740	0.239
		shallow slope	**1.17**		0.825	0.251
	γ_{wl}	r_{wl}=1.5	**1.03**	-0.059	1.000	0.200
		r_{wl}=2.0,2.5	**1.06**		1.000	0.400
		H.H.W.L.	**1**		-	-
	γ_{WRC}	Unit weight of RC	**0.98**	0.030	0.980	0.020
	γ_{WNC}	Unit weight of NC	**1.02**	0.025	1.020	0.020
	γ_{WSAND}	Unit weight of sand	**1.01**	0.150	1.020	0.040

Too much factors!!

Difference in former TSPHF and new TSPHF
Sliding failure verification in former TSPHF

(Per 1m)



(1) Calculation of safety factor by former TSPHF (Fs>1.2)

$$Fs = \frac{(1800-150-600)}{500} \times 0.6^{*} = 1.26 > 1.2 \quad \text{O.K}$$

* 0.6 is coefficient of friction between concrete and rubble mound

Difference in former TSPHF and new TSPHF
(Sliding failure verification in new TSPHF)

(2) Calculation of performance function on sliding failure (performance function Z>0)

1. Calculation of design values

Design value of the weight of a caisson

Parts	Characteristic value of weight (kN/m)	Partial factor	Design value of weight (kN/m)
Caisson	342.0	0.98	335.2
Concrete cap	61.2	1.02	62.4
Sand	1056.6	1.01	1067.2
Concrete crown	340.2	1.02	347.0
Total	1800.0		1811.8

- Design value of buoyancy
  600 X 1.03 = **618kN/m**
  (Partial factor)

- Design value of Horizontal wave force and uplift
  Horizontal force 500 X 1.04 = **520kN/m**
  Uplift 150 X 1.04 = **156kN/m**
  (Partial factor)

Difference in former TSPHF and new TSPHF (Sliding failure verification in new TSPHF) *(continue)*

2. Verification by performance function

Z= (1811.8 - 156 - 618) X (0.6 X 0.79) - 520 = **-28.1** **>>Out**

(Partial factor for coefficient of friction)

If weight of caisson is increased, Z will be positive. Then…

If Z>0, the breakwater designed is verified that sliding failure possibility of this caisson is less than 8.7×10^{-3} in TSPHF.

$$\gamma_f f_k \left(\sum_i \gamma_{W_i} W_{ik} - P_{Bd} - \gamma_{P_U} P_{Uk} \right) \geq \gamma_{P_H} P_{Hk}$$

From the new equation, design values shall be presented as follows.

$W_{0d} = \sum_i \gamma_{W_i} W_{ik} - P_{Bd}$ Design value of the weight of the upright section in still water

$U_d = \gamma_{P_U} P_{Uk}$ Design value of the uplift force acting on the upright section

$P_d = \gamma_{P_H} P_{Hk}$ Design value of the horizontal wave force acting on the upright section

$\mu_d = \gamma_f f_k$ Design value of the friction coefficient between the upright section and rubble mound foundation

New equation can be rewritten as follows;

$\mu_d (W_{0d} - U_d) \geq P_d$

$$1 \leq \frac{\mu_d (W_{0d} - U_d)}{P_d} \Longleftrightarrow F_s \leq \frac{\mu \cdot (W_0 - U)}{P}$$

It means there aren't any new idea for the physical model for calculating the safety. Introducing partial factors is to clarify the failure probability and to make clear the sensitivity of each factors.

SUMMARY

- Main points of this presentation are summarized in key words are as follows;
  - Performance based design (Expanding the alternatives in verification procedure)
  - Introduction of the institution of design verification surveillance (Checking the design by third party institution)
  - Introduction of reliability based design method (failure probability of the structure system is the rule) -- Partial factor design method is introduced.
  - Change of calculation procedure for the input earthquake force for design (L1 & L2)
    - Site dependent Seismic force
    - New seismic coefficient method (L1) with new seismic coefficient for design
      - New concept of seismic coefficient compatible with existing seismic coefficient method
      - Damage of the mooring facilities after L1 level earthquake is considered to decide the seismic coefficient.

ACECC 2nd Workshop on Harmonization of Design Codes in the Asian Region
September 11, 2008, Sendai, Japan

Development of Design Codes and Standard Specifications in Korea

Jai-Dong Koo and Tae-Song Kim
Construction Engineering and Management Division, Korea Institute of Construction Technology, Goyang, Korea
Ha-Won Song
School of Civil and Environmental Engineering, Yonsei University, Seoul, Korea

1 INTRODUCTION

According to the Agreement on Government Procurement of the World Trade Organization, each country realized the importance of the globalization of its design codes and development of performance-based design codes. For the past more than a decade, the Korean government has made many efforts to improve design codes and standard specifications. As a result of these efforts, uniformity of the design code and specification formats and the convenience of users have been partially obtained. Recently extensive researches on the development of the performance-based design codes and specifications in various sectors of the construction field in Korea are ongoing. In this paper the status of the recent development of design codes and specifications will be introduced and the future development direction of performance-based design codes and specifications will be also explained.

2 DESIGN CODES AND STANDARD SPECIFICATIONS IN KOREA

Major standards in Korea are controlled by Korean government. For example, in the field of construction, design codes and standard specifications had been administered by the Ministry of Land, Transport and Marine Affairs (previously the Ministry of Construction and Transportation), Korea. But such administrative operation and control fell short of professionalism and efficiency. Moreover, design codes and standard specifications were not established in unified manner. In particular, application of the construction codes and specifications called differently as 'standard specifications', 'codes', 'guidelines', 'handbooks', 'technical instructions', 'manual', etc. entailed many confusion. Furthermore, the problem of using different criteria in coding for the same engineering item or behaviour was experienced. Due to these reasons, the Ministry of Land, Transport and Marine Affairs delegated the management of construction codes and specifications to corresponding academic societies and associations from 1995 so that each responsible organization can establish and revise construction codes and specifications as shown in Table 1.

For construction codes and specifications, the codes were categorized into ‘Design Codes’, ‘Standard Specifications’, ‘Owner's Standard Specifications’ and ‘low-level technological criteria’. Then, ‘Design Codes’, ‘Standard Specifications’, and ‘Owner's Standard Specifications’ were stipulated by the law to be subject to the deliberation of the Central Construction Technology Deliberation Committee. And the ‘low-level technological criteria’ is controlled by the academic societies, associations and owners (Fig. 1). Since the Design Codes and Standard Specifications are national codes and specifications, government subsidies are granted to each responsible organization for development or revision of Design Codes and Standard Specifications. In addition, Design Codes and Standard Specifications play a role of high-level criteria of the other construction codes and specifications as well as the ‘low-level technology criteria’. Moreover, there are construction codes for facilities, such as the Road Act and the Building Act, and construction criteria Stipulated as the Guidelines, the Public Notifications as low-level regulation.

Table 1. Standard specifications and design codes in Korea

Responsible Organizations	Standard Specifications	Design Codes
Korean Society of Civil Engineers	·General Standard Specification for Civil Works ·Standard Specification for Urban Railroad (metro) Works·	
Korea Concrete Institute	·Standard Concrete Construction Specification	·Concrete Structure Design Code
Architectural Institute of Korea	·Architectural Standard Specification	·Korean Building Codes
Korean Geotechnical Society		·Structural Foundation Design Codes
Korean Institute of Landscape Architecture	·Standard Specification for Landscaping Works	·Landscape architecture Design Codes
Korea Road & Transportation Association	·Standard Specification for Road Works ·Standard Specification for Construction of Bridges on Road Projects	·Road Design Codes ·Bridge Design Code on Road Projects
Korean Tunnelling Association	·Standard Specification for Tunnelling	·Tunnel Design Codes
Korea Water Resources Association	·Standard Specification for Construction of River	·River Design Codes ·Dam Design Codes
The Korean Institute of Illuminating & Electrical Installation Engineers	·Standard Specification for Building Electrical Installations Works	·Building Electrical Installations Design Codes
The Society of Air-Conditioning & Refrigerating Engineers of Korea	·Standard Specification for Building Mechanical Equipments Works ·Standard Specification for Industrial/Environmental Equipments Works	·Building Mechanical Equipments Design Codes
Korean Society for Steel Construction		·Steel Structure Design Codes
Earthquake Engineering Society of Korea		·Earthquake-proof Design Codes
Construction Temporary Equipment Association of Korea	·Standard Specification for Temporary Works	
Korea Water & Wastewater Works Association	·Standard Specification for Water and Wastewater Works	·Water Supply Design Codes ·Wastewater Design Codes
Korea Port & Harbour Association	·Standard Specification for Construction of Ports and Harbours	·Port and Harbour Design Codes
Technical Safety Policy Officer	·Standard Specification for Construction Environment Control	
Korea Infrastructure Safety and Technology Corporation	·Standard Specification for Slopes	·Design Code for Slopes
Korea Rail Network Authority		·Railroad Design Code ·Express Railroad Design Code
Korea Rural Community & Agricultural Corporation	·Standard Specification for Agricultural Civil Works	·Plan and Design Codes for Improvement Projects of Agricultural Production Base

These Guidelines and Public Notifications are compulsory regulations. However, Design Codes, Standard Specifications and low-level technological criteria are not compulsory regulations. Therefore, if only the owners should choose these criteria as construction contract documents, that criteria may take effect as contract documents.

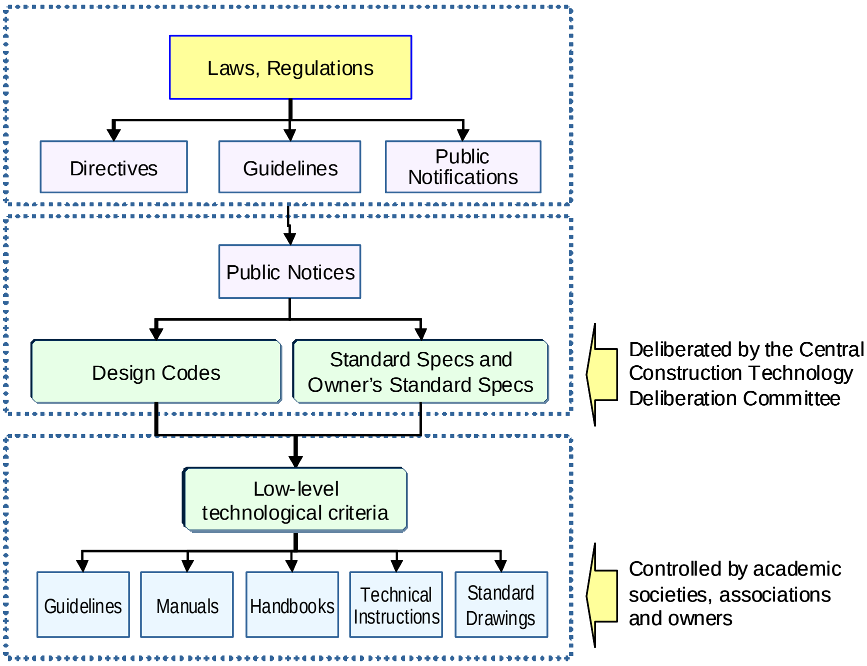


Figure 1. Design codes and standard specifications in Korea

As a result of these efforts, the problem of overlapping construction codes and specifications together with the problem of assigning different criteria for an identical item have been removed. However, even though these efforts served to obtain uniformity of the design code and specification system and the convenience of users, securing design engineering capability and advancement and globalization of design code and specification system remain to be desired.

3 NEEDS AND DIRECTION FOR HARMONIZED CODES AND SPECIFICATIONS IN KOREA

The Korean design codes and specifications is the prescriptive codes suggesting materials and design methods for achieving the objectives and functional requirements. These kinds of codes have an advantage of being able to be directly utilized by the designer and contractor. However, the enhancement of design engineering capabilities may be faced with bottlenecks due to limitation of designer's discretion. Therefore, it is considered to be necessary to move forward to the direction of performance-based design code and specification system by which designers and constructors are free to choose diversified design and construction methods.

According to the Agreement on Government Procurement of the World Trade Organization, technical specifications prescribed by procuring entities of each country shall be in terms of performance rather than design or descriptive characteristics, and shall be based on international standards, where such exist. Due to this reason, each country is exerting efforts to globalize its design codes. Therefore, design codes and standard specifications in Korea are also considered to be necessary to join in the performance-based globalization trend.

Depending on the types of facilities, not many performance-based design codes and specifications have been developed in Korea until recently. The status of performance-based design codes and specifications in various facility sectors in Korea are as follows.

3.1 Road Pavement Sector

Experiments and researches were conducted partially to examine road pavement performance. But technical development for evaluating road pavement performance was few.

3.2 Concrete Structure Sector

Fundamental research on the development of performance-based design technique is in its initial stages in the Korean academic communities. Both performance-based design code and standard specification is under development including durability design. But the performance of high performance concrete was not properly reflected in the design yet.

3.3 Steel Structure (Civil) Sector

Steel structural design is mostly limited to the Allowable Stress Design. Performance-based design is mainly concentrated on seismic design. Researches on the buildings that employ steel structures are being carried out. Researches on performance-based design, still, remain to be desired.

3.4 Architectural Building Sector

Efforts of introducing the performance concept in the architectural building design have long been implemented but any significant development has not been achieved so far. Since the 1990s, efforts of complying Korean Standards (KS) with an international standard like ISO has been made but full-scale performance design has not been realized. Recently, researches on performance-based design technique have been started mainly in the Korean academic communities. Relevant systems and regulations include the Building Energy Efficiency Rating System, the Green Building Certification System, regulation for floor impact sound in apartments, recommendation regulation for indoor air quality of newly built apartment and the Housing Performance Grade Indication System, etc..

3.5 Other Sectors

Researches on the area of foundation engineering have been carried out mainly in the deep foundation design based on reliability analysis. Researches on the evaluation of bearing capacity of piles and researches with a safety factor in prediction methods of bearing capacity of piles, based on reliability analysis have been performed. And researches on stochastical reliability analysis to nonlinear structures, development of reliability analysis algorithm of real structures, and reliability analysis of pile structures subject to biaxial loading have been carried out at the same time.

Among road subsidiaries, the criteria of safety barriers have been changed into performance criteria. Reflective performances of retro-reflectors are applied to delineation systems, pavement markings, road signs, re-boundable guideposts and etc.. But performance codes and specifications of road subsidiaries still remain to be desired.

In case of tunnels, the Tunnel Design Code remains mostly at material-oriented approaches. Up to now researches and introduction of technologies based on the performance in tunnel area remains to be lack.

In the area of landscaping, development of performance codes nearly has not been implemented so far but researches on the assessment of landscapes, thermal environments, rainwater storage and utilization and biological habitat have been performed.

In case of the building mechanical systems, certain levels of performance for the products and equipments are ensured by certification processes of the Korean Standards and certification systems of public institutions and academic communities. However, the maintenance of the systems is not sufficient and the criteria of high efficiency performance and durability have not been established.

In the building electrical systems, along with efforts of complying Korean Standards with IEC since the 1990s, efforts of complying Korean codes with international codes have been maintained sustainably but visible outcome is few so far. Performance evaluation system under implementation in Korea includes ultra-high speed telecommunication building certification system, intelligent building certification system, and etc..

3.6 Performance Warranty Contracting System

Researches to introduce international performance warranty contracting system for inducing improvement of facilities and the contractor’s technical innovation has not been performed.

Recently, breaking away from the bidding system of giving priority on price, introduction of an awarding system that can assess costs and technologies synthetically is under progress.

4 ONGOING DEVELOPMENT OF PERFORMANCE BASED DESIGN CODES AND SPECIFICAIONS

The project, "Master plans to develop performance-based construction codes and specifications" was carried out in 2007. This project is one of the Construction and Transportation Technology Research and Development Projects implemented by the Ministry of Land, Transport and Marine Affairs. This project is in line with the policy of "International standardization of design documents and performance-based improvement of design codes".

Through this project, master plans for developing performance based codes and specifications for about ten different materials/facilities covering road pavement, concrete structures, steel structures, and architectural buildings has been established. The manuals for developing performance based codes and specifications for each facility were prepared. In addition, as a subsequent development project, "Standardization of Construction Specifications and Design Criteria based on Performance - Focused on Pavements and Concrete Structures" commenced in September 2006 and will end in May 2011. The research roadmap is shown in Figure 2. The research goals of this project are as follows:

(1) To develop the performance warranty specification consists of the performance based standard, pay adjustment regulation and the performance warranty contract system in pavement area.

(2) To convert the prescriptive design code to the performance based design code for concrete structures and develop the performance based design code considered the environment, material, and technique level in Korea in concrete area.

(3) To prepare performance-based and globally standardized design and construction guidelines for steel structures, buildings, foundation structures, road subsidiary facilities, tunnels, landscaping facilities, building mechanical and electrical systems.

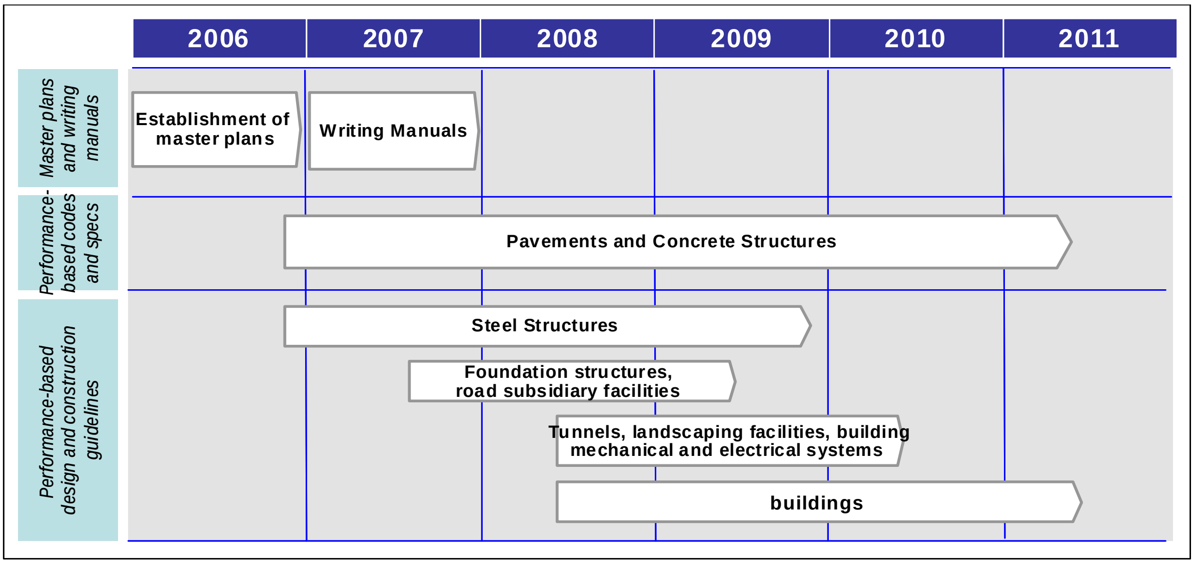


Figure 2. Roadmap to develop performance-based design codes and specifications (general)

In this project, status and plans for developing performance-based codes and specifications or the guidelines for performance based design of the main facilities are shown in Figures 3-6:

	2006~2007	2007~2008	2008~2009	2009~2010	2010~2011
Performance based standard	Case study of overseas performance specs and development of the logics	Draft preparation of performance specs and selection of pilot section for applying performance specs	Draft preparation of performance specs	Application plan preparation of performance specs	Evaluation of application effects of performance specs
Pay adjustment regulation	Survey of material property status and establishment of test plan	Preparation of pay adjustment regulation draft and selection of pilot section for applying pay adjustment regulation	Draft preparation of pay adjustment regulation	Development of serviceability model of pay adjustment regulation	Evaluation of pay adjustment regulation and application effects

Figure 3 Roadmap of performance based pavement work specifications and contracting system

	2006~2007	2007~2008	2008~2009	2009~2010	2010~2011
Code system	**Evaluation of structure design code status and establishment of introduction system**	**Definition of codes for limit states**	**Evaluation of reliability (basic variables)**	**Reliability analysis (failure probability/partial safety factor)**	**Completion of performance-based structure design code**
Material property	**Survey of material property status and establishment of test plan**	**Concrete stress-strain/compressive strength/autogenous shrinkage model**	Establishment of concrete tensile strength model, and drying shrinkage/ autogenous shrinkage model test	**Establishment of concrete material property model with age**	**Completion of performance-based structure design codes – material chapter**
Durability	Development of performance-based durability design principles and establishment of durability test plan	**Establishment of durability design model**	**Establishment of durability design and evaluation model**	**Establishment and verification of durability evaluation program**	**Preparation of performance-based standard specification – durability chapter**
Structural resistance	Suggestion of basic concept of performance-based design and establishment of test plan	**Development of element deformation/strength model**	**Development of members deformation/strength model**	**Development of members deformation/strength model**	**Preparation of performance-based standard specification – member design chapter**

Figure 4. Roadmap of performance-based design codes for concrete structures

2006~2007		2007~2008	2008~2009
Establish-ment of master plan to develop performance-based codes	Collection and analysis of performance-based design materials	Analysis of the performance hierarchy of steel structures	Development of a guideline of performance-oriented design for steel structures
		Establishment of the high level criteria for performance-oriented design	
	Establishment of Korean performance-oriented design process	Suggestion of performance capacity assessment methods	Proposal of a research project to develop performance-based Design Codes and Standard Specifications for steel structures

Figure 5 Roadmap of performance-based steel structure design guideline

	2008 ~ 2009		2009~2010		2010~2011
Architect-ural materials	**Survey/analysis of architectural material performance criteria and performance test method at Korea and abroad. Review of building performance classification method**		**Performance classification for each member(use) and development of performance assessment technologies**		**Preparation of performance-based architectural material design guideline**
			DB establishment of high temperature characteristics of structural materials		**Preparation of fire-resistance performance design guideline of structural members**
Steel structural buildings	**Understanding bottlenecks in case of converting descriptive design to performance-based design**	**Survey of performance levels and comparative analysis of performance-based design process of each country**	**Establishment of performance goal and level as per performance evaluation**	**Development of performance evaluation technologies**	**Preparation of performance-based structural design guideline of steel structural buildings**

Figure 6. Roadmap of performance-based building design guideline

According to the project, “Standardization of Construction Specifications and Design Criteria based on Performance: Focused on Pavements and Concrete Structures”, it is expected that the development of performance-based codes and specifications for pavements and concrete structures will be reflected in the Standard Specifications in near future. And also it is further expected that in case of other facilities including steel structures and architectural buildings, research and development projects for performance-based codes and specifications will be progressed on an urgent basis.

5 CONCLUSION

Since the establishment of the World Trade Organization, there is a possibility that there will be open international competition in design technologies among countries to comply with international standards based on the Agreement on Government Procurement in both domestic construction fields and foreign construction fields. In view of this trend, importance of development of harmonized performance-based improvement of design codes and specifications were realized recently in Korea. At this juncture, it seems to be encouraging to note that Asian countries are exerting their cooperative efforts for the harmonized design codes for each construction field. One of good example is that successful development of the Asian Concrete Model Code (ACMC) developed by the International Committee of Concrete Model Code (ICCMC). In Asian countries, information exchanges and mutual close cooperation for the harmonization in design codes including developing performance-based design codes in the field of civil engineering are very much necessary.

ACKNOWLEDGEMENT

The authors would like to acknowledge supports by the Construction & Transportation R&D Policy and Infrastructure Project on Standardization of Construction Specifications and Design Criteria based on Performance, the Ministry of Land, Transport and Marine Affairs, Korea.

Development of Design Codes and Standard Specifications in Korea

Jai-Dong Koo, Tae-Song Kim
And Ha-Won Song

CONTENTS

INTRODUCTION

- For the past more than a decade, the Korean government has made many efforts to improve design codes and standard specifications.
- Recently intensive researches on the development of the performance-based design codes and specifications in various sectors in Korea are ongoing.
- In this paper the status of the recent development of design codes and specifications will be introduced and the future development direction of performance-based design codes and specifications will be explained.

DESIGN CODES AND STANDARD SPECIFICATIONS IN KOREA

- Had been administered by government.
  - Fell short of professionalism and efficiency.
- Construction code and specification entailed many confusion
  - Standard specifications, codes, guidelines, handbooks, technical instructions, manual, etc.
- Was delegated to corresponding academic societies and associations from 1995.

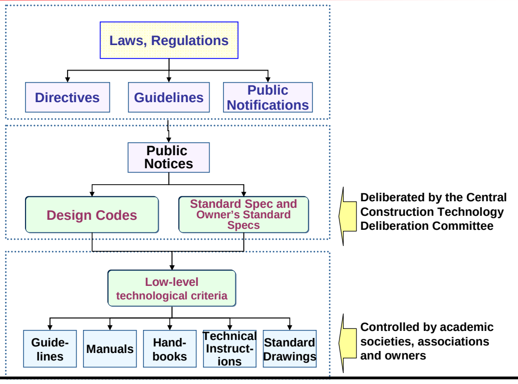
Example of Standard specifications and design codes

Responsible Organizations	Standard Specifications	Design Codes
Korean Society of Civil Engineers	▪General Standard Specification for Civil Works ▪Standard Specification for Urban Railroad (metro) Works·	
Korea Concrete Institute	▪Standard Concrete Construction Specification	▪Concrete Structure Design Code
Architectural Institute of Korea	▪Architectural Standard Specification	▪Korean Building Codes
Korean Geotechnical Society		▪Structural Foundation Design Codes
Korean Society for Steel Construction		▪Steel Structure Design Codes

DESIGN CODES AND STANDARD SPECIFICATIONS IN KOREA

- Construction codes and specifications were categorized into 'Design Codes', 'Standard Specifications', 'Owner's Standard Specifications' and 'low-level technological criteria'.
- Design Codes and Standard Specifications
  - National and high-level criteria.
  - Government subsidies are granted for the establishment or revision.
  - Subject to the deliberation of the Central Construction Technology Deliberation Committee.
  - Not compulsory regulations.
- Uniformity of the construction code and specification formats and the convenience of users were obtained.
- Securing design engineering capability and advancement and globalization of design codes and specification system remain to be desired.

DESIGN CODES AND STANDARD SPECIFICATIONS IN KOREA



NEEDS AND DIRECTION OF HARMONIZED CODES AND SPECIFICATIONS IN KOREA

- Korean design codes and specifications is the prescriptive codes.
  - Able to be utilized by the designer and contractor.
  - May be faced with bottlenecks due to limitation of designer's discretion.
- Necessary to move forward to performance-based design codes and specifications.
- Necessary to join in the performance-based globalization trend.

Development status of performance-based design codes and specifications

- Not many have been developed in until recently.

- **Road Pavement Sector**

- Experiments and researches were conducted partially to examine road pavement performance.
- Technical development for evaluating road pavement performance was few.

Development status of performance-based design codes and specifications

- **Concrete Structure Sector**

- Fundamental research on the development of performance-based design technique is in its initial stages in the Korean academic communities.
- Both performance-based design code and standard specification is under development including durability design.
- The performance of high performance concrete was not properly reflected in the design yet.

Development status of performance-based design codes and specifications

- **Steel Structure (Civil) Sector**

- Design is mostly limited to the Allowable Stress Design.
- Performance-based design is mainly concentrated on seismic design.
  - Especially on the buildings that employ steel structures.
- Researches on performance-based design, still, remain to be desired.

Development status of performance-based design codes and specifications

- **Architectural Building Sector**

- Any significant development performance concept in design has not been achieved.
- Full-scale performance design has not been realized.
- Recently, researches on performance-based design technique have been started mainly in the Korean academic communities.

Development status of performance-based design codes and specifications

- **Foundation structures Sector**
  - Researches have been carried out mainly in the deep foundation design based on reliability analysis.
  - Researches on the evaluation of bearing capacity of piles and researches with a safety factor in prediction methods of bearing capacity of piles, based on reliability analysis have been performed.
  - Researches on stochastical reliability analysis to nonlinear structures, development of reliability analysis algorithm of real structures, and reliability analysis of pile structures subject to biaxial loading have been carried out.

Development status of performance-based design codes and specifications

- **Road subsidiaries Sector**
  - The criteria of safety barriers have been changed into performance criteria.
  - Reflective performances of retro-reflectors are applied to delineation systems, pavement markings, road signs, re-boundable guideposts and etc., but performance codes and specifications of road subsidiaries still remain to be desired.

Development status of performance-based design codes and specifications

- **Tunnels Sector**
  - The Tunnel Design Code remains mostly at material-oriented approaches.
  - Researches and introduction of technologies based on the performance in tunnel area remains to be lack.
- **Landscaping Sector**
  - Development of performance codes nearly has not been implemented.
  - Researches on the assessment of landscapes, thermal environments, rainwater storage and utilization and biological habitats have been performed.

Development status of performance-based design codes and specifications

- **Building mechanical systems Sector**
  - Performance for the products and equipments are ensured by certification processes of the Korean Standards and certification systems of public institutions and academic communities.
    - However, the maintenance of the systems are not sufficient.
  - The criteria of high efficiency performance and durability have not been established.

Development status of performance-based design codes and specifications

- **Building electrical systems Sector**
  - Along with efforts of complying Korean Standards with IEC since the 1990s, efforts of complying Korean codes with international codes have been maintained sustainably but visible outcome is few.

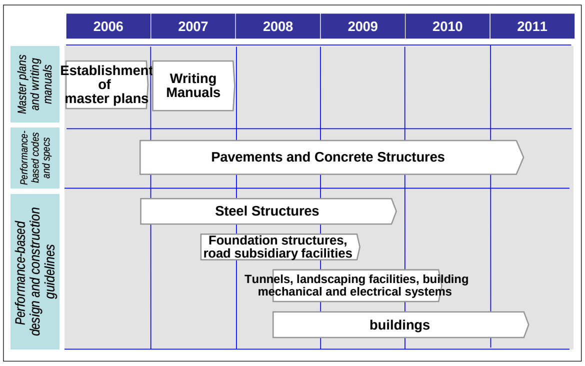
Development status of performance-based design codes and specifications

- **Performance Warranty Contracting System**
  - Researches to introduce international performance warranty contracting system has not been performed.
  - Recently, introduction of an awarding system that can assess costs and technologies synthetically is under progress.

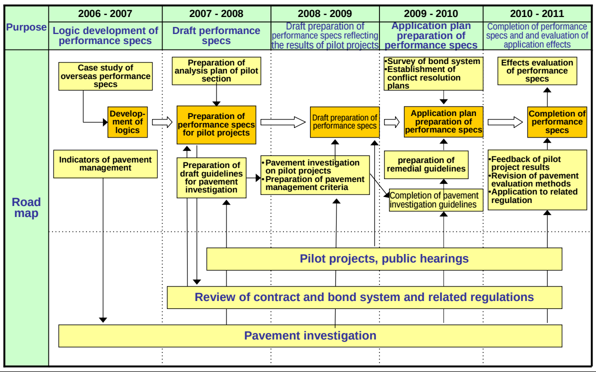
ONGOING DEVELOPMENT OF PERFORMANCE BASED DESIGN CODES AND SPECIFICAIONS

- According to the policy, "International standardization of design documents and performance-based improvement of design codes", the project, "Master plans to develop performance-based construction codes and specifications"(2007) had been carried out.
- The project, "Standardization of Construction Specifications and Design Criteria based on Performance - Focused on Pavements and Concrete Structures"(2006 ~ 2011) was commenced.

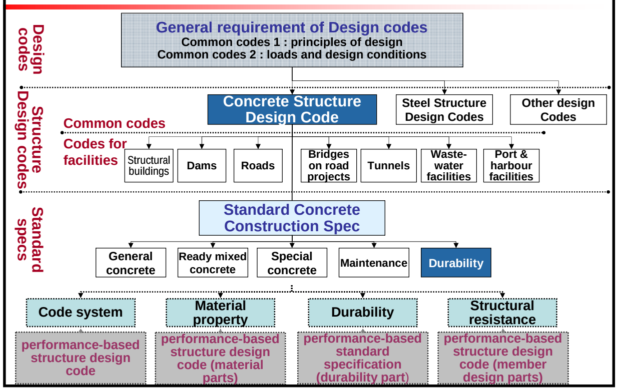
Roadmap to develop performance-based design codes and specification (general)



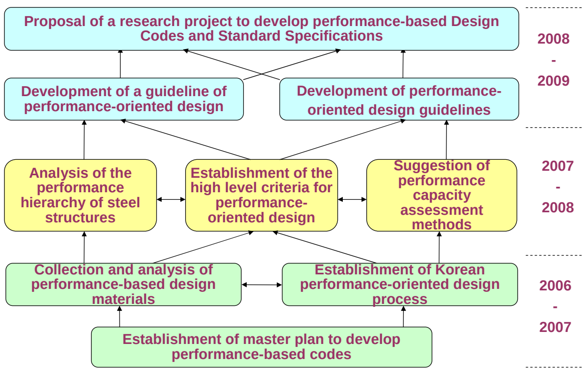
Roadmap of performance based pavement work specifications and contracting system



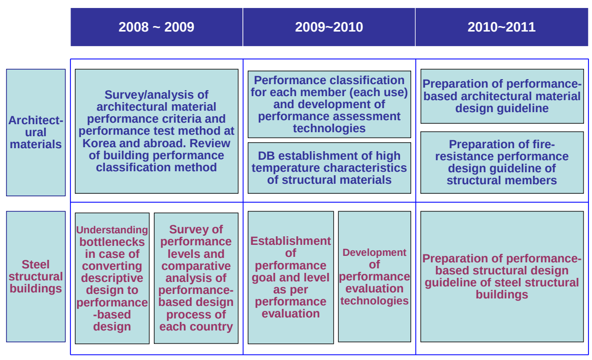
Roadmap of performance-based design codes for concrete structures



Roadmap of performance-based steel structure design guideline



Roadmap of performance-based building design guideline



Future plan

- It is expected that the development of performance-based codes and specifications for pavements and concrete structures will be reflected in the Standard Specifications in the future.
- It is further expected that in case of other facilities including steel structures and architectural buildings, research and development projects for performance-based codes and specifications will be progressed on an urgent basis.

CONCLUSION

- It seems to be encouraging to note that Asian countries are exerting their cooperative efforts for the harmonized design codes.
- One of good example is that successful development of the Asian Concrete Model Code (ACMC) developed by the International Committee of Concrete Model Code (ICCMC).
- In Asian countries, information exchanges and mutual close cooperation system for the harmonization in design codes including developing performance-based design codes in the civil engineering are very much necessary.

Thank You

Presentation from
TC-8 members and other representatives

ACECC TC-8 2nd Workshop on Harmonization of Design Codes in the Asian Region
Sep. 11, 2008, Sendai, Japan

Status of Design Codes in Taiwan

Shyh-Jiann Hwang
Professor, National Taiwan University
Chair, Concrete Technology Committee of CICHE (Chinese Institute of Civil and Hydraulic Engineering)

2nd ACECC Workshop — September 11, 2008

Harmonization of Design Codes in the Asian Region

Status of Design Codes in Taiwan

Shyh-Jiann Hwang
(National Taiwan University)

Chinese Institute of Civil and Hydraulic Engineering

Geographic Setting

Taiwan

Area: 36,000 km²

Population: 23 million

Outline

- General
- Establishment
- Modification
- Harmonization
- Conclusions

General

Status of Design Codes

Laws & Regulations

- **Building, Building Technics, Highway, Metro, Hydro-Engineering, Water Supply**

Design Codes

- **General**
- **Geotechnical Engineering**
- **Concrete Engineering**
- **Steel Structural Engineering**
- **Highway Engineering**

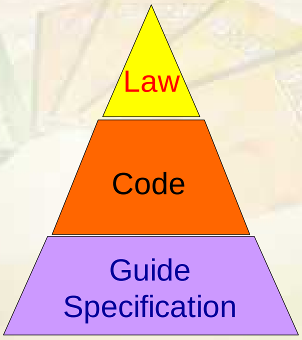
Standards & Specifications

- **Chinese National Standard (CNS)**
- **Test Standards**
- **Material Specifications**

Background

1. **The government regulates the establishment of design codes.**
2. **The building and civil sectors use common sets of guides and specifications even though each has its own governing law and code.**

Category



Chinese Institute of Civil and Hydraulic Engineering

Establishment

Chinese Institute of Civil and Hydraulic Engineering

Code-related Laws

Drafted by the relevant **government agencies** with the help of experts

Enacted by the **legislative body**

More than 100 code-related laws in Taiwan

Chinese Institute of Civil and Hydraulic Engineering

Codes

Drafted by relevant **engineering societies**

Reviewed, approved and published by the **competent government authority**

Modified by specialists, professors, and representatives of engineering societies and organizations before approval

20 sets of major codes in Taiwan

Chinese Institute of Civil and Hydraulic Engineering

List of General Design Codes

Code Name	Publisher	Issued
Building Design Code 建築技術規則	CPA	2002-11
Seismic Design Code and Commentary for Building 建築物耐震規範及解說	CPA	2006-01
Wind-Resistance Code and Commentary for Building 建築物風力規範條文、解說及示範例	CPA	1997-08
Seismic Isolation Design Code for Building 建築物隔震設計規範	CPA	2002-04

CPA: Construction and Planning Administration(營建署)

Chinese Institute of Civil and Hydraulic Engineering

List of Codes - Concrete Engineering

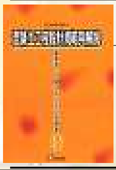
Code Name	Publisher	Issued
Design Code and Commentary for Structural Concrete 混凝土工程設計規範與解說(土木401-93)	CICHE	2004-12
Design Code for Structural Concrete 結構混凝土設計規範	CPA CICHE	2002-07
Specifications for Structural Concrete 結構混凝土施工規範	CPA CICHE	2002-07
Design Procedures & Samples for Structural Concrete 混凝土工程設計規範之應用(土木404-96)	CICHE	2007-10
Design Code for Pre-cast Concrete 預鑄混凝土工程設計規範	CPA	1997-06
Blast-Furnace Slag Concrete Code for Public Construction 公共工程高爐石混凝土使用手冊	PCC	2001-04
Fly Ash Concrete Code for Public Construction 公共工程飛灰混凝土使用手冊	PCC	1999-08
Design Criteria for High Performance Concrete (draft) 高性能混凝土設計準則(草案)	TANEEB	1995-11
Application Guideline of Self-Compacting Concrete 自充填混凝土使用手冊	CICHE	2006-09

CICHE:Chinese Institute of Civil & Hydraulic Engineering (中國土木水利工程學會)
CPA:Construction and Planning Administration (營建署)
PCC:Public Construction Commission (公共工程委員會)
TANEEB:Taiwan Area National Expressway Engineering Bureau (國道新建工程局)

Chinese Institute of Civil and Hydraulic Engineering

Draft of Concrete Design Code

Design Code	Publisher	Issued
Design Code for Structural Concrete	CPA	2002



Code Draft	Publisher	Issued
Design Code and Commentary for Structural Concrete (土木 401-86a)	CICHE	1997

Chinese Institute of Civil and Hydraulic Engineering

Draft of Concrete Construction Code

Construction Code	Publisher	Issued
Specification for Structural Concrete	CPA	2002

Code Draft	Publisher	Issued
Construction Code and Commentary for Structural Concrete (土木 402-88a)	CICHE	1999

Chinese Institute of Civil and Hydraulic Engineering

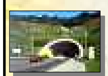
List of Codes - Geotechnical Engineering

Code Name	Publisher	Issued
Criteria for Site Investigation 工址地盤調　準則	CICHE	1993-06
Criteria for Geotechnical Investigation 大地工程調　作業準則	TANEEB	1999-06
Criteria for Geological Mapping and Commentary 工程地質測繪準則與解說	CICHE	1999-02
Design Criteria for Building Structural Foundation 建築物基礎構造設計規範	TGS	2001-12
Specification and Commentary for Foundation Construction 基礎工程施工規範與解說	CICHE	1998-11
Design Criteria, Specifications and Commentary for Earth Anchor 地錨設計與施工準則　解說	CICHE	2001-09
Design Criteria and Commentary for Tunneling 隧道工程設計準則與解說	CICHE	1999-01
Construction Specifications for Tunneling 隧道工程施工技術規範	TANEEB	1993-12
Construction Specifications for Shield Tunneling (Draft) 潛盾隧道施工技術規範(草案)	CTTA	1999-09

CICHE:Chinese Institute of Civil & Hydraulic Engineering (中國土木水利工程學會)
CPA:Construction and Planning Administration (營建署)
TGS:Taiwan Geotechnical Society (大地工程學會)
TANEEB:Taiwan Area National Expressway engineering Bureau (國道新建工程局)
CTTA:Chinese Taipei Tunneling Association (中華民國隧道協會)

Chinese Institute of Civil and Hydraulic Engineering

Guides/specifications



Drafted by the relevant engineering societies

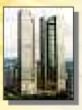
Approved by the competent government authority

Published by the engineering societies

20 sets of major guides/specifications in Taiwan

Chinese Institute of Civil and Hydraulic Engineering

Local natural conditions



Considered in establishing safety requirements in design codes

However, international codes such as those of the US, Japan, EC, and even PRC were also referred to.

Chinese Institute of Civil and Hydraulic Engineering

Modification

Modification

Reviewed and updated about every 3-6 years generally

Or after disasters caused by earthquakes, floods and typhoons

Lessons from Chi-Chi Earthquake

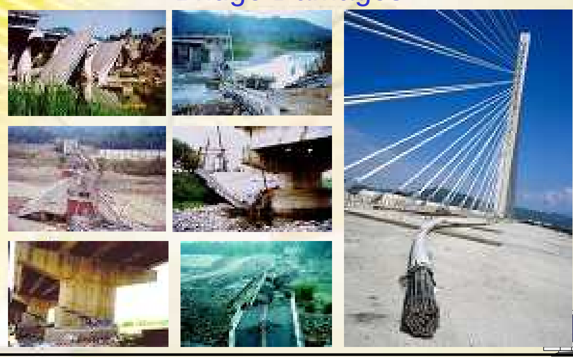
Lessons from Chi-Chi Earthquake

Damages of School Buildings

293 elementary and high schools were completely or partially damaged.

Lessons from Chi-Chi Earthquake

Bridge Damages



Modification-Example

Several design codes have been updated/upgraded or are being modified

To raise the level of earthquake resistance requirements based on the Chi-Chi Earthquake (M=7.3), 1999

Harmonization

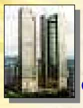
Research Project issued by
Public Construction Commission
Executive Yuan, September 2008

推動公共工程性能設計準則機制之研訂

Study on Mechanism of Performance Based Criteria for Public Construction

Jenn-Chuan Chern
Vice Minister, Public Construction Commission

Objective on Code Harmonization



- Unified Design Concept: Performance-Based Design
- Code Harmonization among different Fields (Building, Bridge, Highway…) in Taiwan
- Code Harmonization among different Asian Regions

Collaborative Study

- Different Disciplines: Concrete, Steel, Geotechnical, EQ…
- Different Society: CICHE, CSSE, NCREE, TSGE…
- Different Resource: ACECC, APEC, ICCMC, PLATFORM, ACMC…

International Committee of Concrete Model Code of Asia (ICCMC)

CICHE will use the format of ACMC Level 3 by ICCMC for guide and specification related to concrete engineering

The working Level 3 documents are to be prepared by each country that adopts the code by incorporating its own national concrete engineering practices.

Conclusions

- CICHE supports the code harmonization. However, government agreement and sponsorship are needed.
- Unifying Codes through performance based engineering is welcome.
- Level 3 document of ICCMC will be elaborated.

ACECC 2nd Workshop on Harmonization of Design Codes in the Asian Region
September 11, 2008, Sendai, Japan

THE CURRENT SITUATION OF MONGOLIAN BUILDING CODE SYSTEM

Ya.Duinkherjav

Prof and Chairman, Department of Civil Engineering, Head of concrete and steel testing laboratory, Mongolian University of Science and Technology /MUST/ , Ulaanbaatar Mongolia

E.Ganzorig

President of Mongolian Civil Engineers Association, Assistant prof of Civil Engineering Department. MUST, Ulaanbaatar, Mongolia

Abstract

Mongolian did a choice in 1990 to step into a completely new socio-economic system from post communism. Before this time, the country used Soviet Building Codes as its own. In the period of 1990-2000 the construction industry experienced dramatic decline due to the lack of an investment. But from 2005 the situation is reversed and the industry investment is increasing year by year as an effect of a macro economics positive stimulation. Following an increased investment from abroad especially from China, Japan, Republic of Korea, Taiwan, and USA, new techniques, materials and ideas are coming to the industry. This new situation of the industry pushes us to upgrade existing Industry Building Codes System.

History of Development of Building Codes in Mongolia

Until 1960 the development of construction industry was weak, most construction work were carried out by Soviet and Chinese workers and Soviet Building Codes were used directly without any translation. In 1960-1970 education system of national engineers and technical staffs and workers is established and following this the industry development was speeded. National work force needed educational and instructional materials on native language and relating with this measurements were taken to develop National Building Code System. To develop national codes works were done in three directions: (1) direct translation and usage of Soviet Codes; (2) adapt Soviet Codes with changes and revision considering country specifics; and (3) develop new national building code. It can be said here that Mongolian Building Code System founded on Soviet building code system and keeps this root until today.

The historically the development process of national codes can be divided into the following three stages:

From 1921 to 1960, the period of no national codes and Soviet Codes were used directly;

From 1960 to 1990, adaptation of Soviet Codes with changes and revision;

From 1990 to present, development of national codes,

Current System of Building Codes

Development of enforcement of Mongolian Building Codes is primary responsibility of Ministry of Construction and Urban Development and its relevant agencies. Building codes are industry standards that building owners, designers, contractors must follow in their respective activities. Its enforcement is monitored and controlled by State Professional Inspection Authorities. National Building Code system is unitary; there are no regional codes as used in other countries.

The framework of Building Code System encloses of the following major fields:

- Urban development;
- Allocation, regionalization, and usage of land and construction sites;
- Durability and strength of structures;
- Health and safety
- Operation and maintenance
- Cost estimation

Annual budget allocated from the State for development of building codes is around 30 to 50 million tugriks.

Building code system before 2003 consisted from 3 major fields:

I. Management and economics

II. Design and specifications

III. Construction

Each one of major fields contains codes in several groups as showed below.

I. Management and economics field subdivided into the following six groups:

1st group. Construction normative documents

2nd group. Design requirements, engineering surveying, management of economics

3d group. Construction administration and management

4th group. Norms to estimate duration of design and construction stages of project

5th group. Construction economics

6th group. Rules of officials

II. Design and specification field subdivided into the following 11 groups:

1st group. Fundamental norm for design

2nd group. Soil and foundation

3d group. Structure

4th group. Engineering equipments of buildings, outside engineering supplies

5th group. Transportation facilities

6th group. Hydrotechnical, power and melioration facilities and systems

7th group. Urban planning and construction

8th group. Residential and public buildings

9th group. Factory buildings and supporting facilities

10th group. Agricultural facilities

11th group. Warehouses and storage buildings

Construction field can be subdivided into 9 groups as follows:

1st group. Norms for construction and acceptance of work

2nd group. Soil and foundation

3d group. Structure

4th group. Isolation and protective isolation, finishing

5th group. Engineering equipments of buildings, outside engineering supplies

6th group. Transportation facilities

7th group. Hydrotechnical, power and melioration facilities and systems

8th group. Mechanization in construction

9th group. Production of construction materials and products

January, 2002 statistics showed that 283 building codes were effective in the industry and from the total 23 of them are norms of Management and Economics, 94 are for Design and Specifications, and 38 are for construction, and 128 are for cost estimation. It also stated that 260 standards are used and 199 of them are Russian GOST, 12 are ISO standards, 5 are DIN standards and 44 are from other countries national standards. Foreign standards are used with translation into Mongolian. Darkhan metallurgical factory is sole domestic producer of construction rebars which was built under Japanese project and Japanese several standards are used for its products.

From 2002 new system of building codes have been using in the industry, and its classification differs from the previous system. New system has 8 subgroups.

1st group. Management methodological norms

2nd group. General technical normative documents

3d group. Urban development and building normative documents

4th group. Normative documents for engineering equipments of buildings and outside supply systems

5th group. Normative documents for building structures and elements

6th group. Normative documents for construction materials and products

7th group. Normative documents for temporary facilities, form work

8th group. Construction economics normative documents

By August, 2008, 368 building codes are effective in the industry and from the total 23 of them are norms of Management and Economics, 89 are for Design and Specifications, and 144 are for construction and cost estimation, 30 recommendations and 56 documents are in Russian Fig.1.

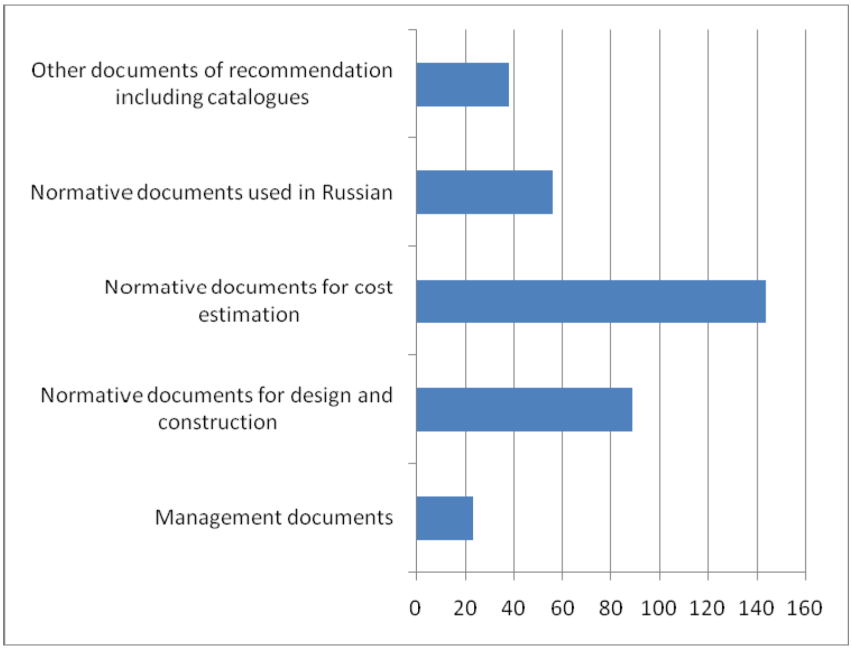


Figure 1.Effective building codes

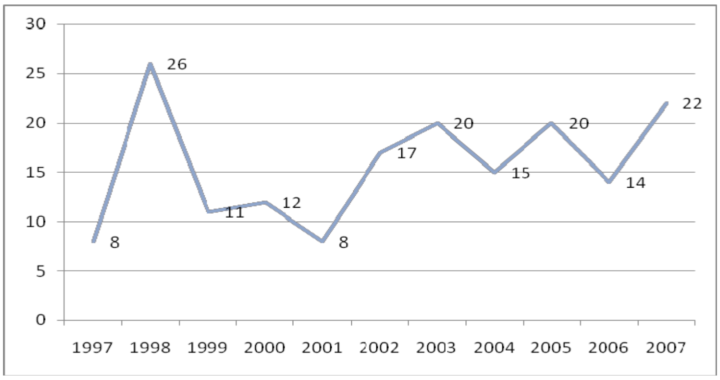


Figure 2. 173 normative documents are newly approved and enforced from 1997 to 2007.

Proposal of Change into Mongolian Building Code System

Considering today's rapid development of Mongolian construction industry and penetration of advanced materials and techniques, it needs to bring national normative documents making close to the level of international documents. To accomplish this objective the followings are needed:

- To transfer function of development of normative documents into non-governmental organizations, especially there are already capable professional associations such as Mongolian Association of Civil Engineers, Concrete Institute and so on,
- To bring collaboration from Asian professional associations of engineers into development activities of normative documents, organize study and analyze of documents of Asian countries and seek possibility to adapt reflecting country specifics,
- To enhance effectiveness of educational and professional development systems of engineers, special attention goes to MUST and MACE.

References

1. Directives to upgrade Building Code system in new market economy, MUDBY, ZGHABHBNAAG, 2003, UB,
2. Objectives and directions of construction standardization, Journal of Construction Information, 2000/4, ZGHABHBNAAG, UB,
3. Journal of Construction Information, 2008, ZGHABHBNAAG, UB,

THE CURRENT SITUATION OF MONGOLIAN BUILDING CODE SYSTEM

Sendai Japan
11 September 2008

THE CURRENT SITUATION OF MONGOLIAN BUILDING CODE SYSTEM

Duinkherjav Ya
Prof and Chairman, Department of Civil Engineering,
Head of concrete and steel testing laboratory,
Mongolian University of Science and Technology /MUST/ ,
Ulaanbaatar Mongolia

Abstract

- Mongolian did a choice in 1990 to step into a completely new socio-economic system from post communism. Before this time, the country used Soviet Union Building Codes as its own. In the period of 1990-2000 the construction industry experienced dramatic decline due to the lack of an investment. But from 2005 the situation is reversed and the industry investment is increasing year by year as an effect of a macro economics positive stimulation. Following an increased investment from abroad especially from China, Japan, Republic of Korea, Taiwan, and USA, new techniques, materials and ideas are coming to the industry. This new situation of the industry pushes us to upgrade existing Industry Building Codes System.

History of Development of Building Codes in Mongolia

- Until 1960 the development of construction industry was weak, most construction work were carried out by Soviet Union and Chinese workers and Soviet Union Building Codes were used directly without any translation. In 1960-1970 education system of national engineers and technical staffs and workers is established and following this the industry development was speeded. National work force needed educational and instructional materials on native language and relating with these measurements were taken to develop National Building Code System. To develop national codes works were done in three directions: (1) direct translation and usage of Soviet Union Codes; (2) adapt Soviet Union Codes with changes and revision considering country specifics; and (3) develop new national building code. It can be said here that Mongolian Building Code System founded on Soviet building code system and keeps this root until today.

- The historically the development process of national codes can be divided into the following three stages:
- From 1921 to 1960, the period of no national codes and Soviet Codes were used directly;
- From 1960 to 1990, adaptation of Soviet Union Codes with changes and revision;
- From 1990 to present, development of national codes,

Current System of Building Codes

- Development of enforcement of Mongolian Building Codes is primary responsibility of Ministry of Construction and Urban Development and its relevant agencies. Building codes are industry standards that building owners, designers, contractors must follow in their respective activities. Its enforcement is monitored and controlled by State Professional Inspection Authorities. National Building Code system is unitary; there are no regional codes as used in other countries.

The framework of Building Code System encloses of the following major fields:

- Urban development;
- Allocation, regionalization, and usage of land and construction sites;
- Durability and strength of structures;
- Health and safety
- Operation and maintenance
- Cost estimation
- Annual budget allocated from the State for development of building codes is around 30 to 50 million tugriks.

Building code system before 2003 consisted from 3 major fields:

I. Management and economics

II. Design and specifications

III. Construction

Each one of major fields contains codes in several groups as showed below.

I. Management and economics field subdivided into the following six groups:

- 1st group. Construction normative documents
- 2nd group. Design requirements, engineering surveying, management of economics
- 3rd group. Construction administration and management
- 4th group. Norms to estimate duration of design and construction stages of project
- 5th group. Construction economics
- 6th group. Rules of officials

II. Design and specification field subdivided into the following 11 groups:

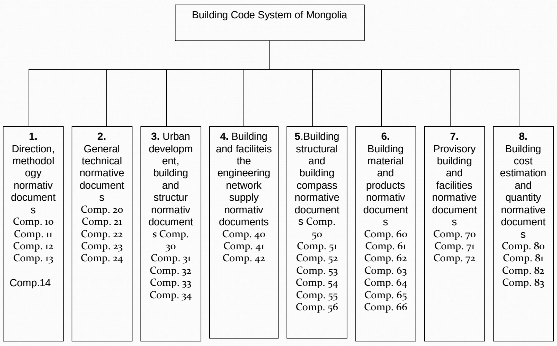
- 1st group. Fundamental norm for design
- 2nd group. Soil and foundation
- 3rd group. Structure
- 4th group. Engineering equipments of buildings, outside engineering supplies
- 5th group. Transportation facilities
- 6th group. Hydro technical, power and melioration facilities and systems
- 7th group. Urban planning and construction
- 8th group. Residential and public buildings
- 9th group. Factory buildings and supporting facilities
- 10th group. Agricultural facilities
- 11th group. Warehouses and storage buildings

III. Construction field can be subdivided into 9 groups as follows:

- 1st group. Norms for construction and acceptance of work
- 2nd group. Soil and foundation
- 3rd group. Structure
- 4th group. Isolation and protective isolation, finishing
- 5th group. Engineering equipments of buildings, outside engineering supplies
- 6th group. Transportation facilities
- 7th group. Hydro technical, power and melioration facilities and systems
- 8th group. Mechanization in construction
- 9th group. Production of construction materials and products

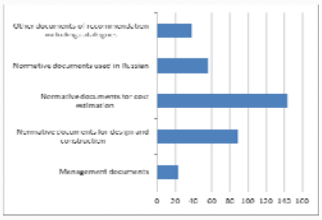
- January, 2002 statistics showed that 283 building codes were effective in the industry and from the total 23 of them are norms of Management and Economics, 94 are for Design and Specifications, and 38 are for construction, and 128 are for cost estimation. It also stated that 260 standards are used and 199 of them are Russian GOST, 12 are ISO standards, 5 are DIN standards and 44 are from other countries national standards. Foreign standards are used with translation into Mongolian. Darkhan metallurgical factory is sole domestic producer of construction rebar which was built under Japanese project and Japanese several standards are used for its products.

From 2002 new system of building codes have been using in the industry and its classification differs from the previous system. New system has 8 subgroups.

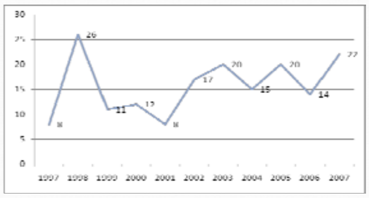


Our Codes

By August, 2008, 368 building codes are effective in the industry and from the total 23 of them are norms of Management and Economics, 89 are for Design and Specifications, and 144 are for construction and cost estimation, 30 recommendations and 56 documents are in Russian Fig.1.



173 normative documents are newly approved and enforced from 1997 to 2007.



Proposal of Change into Mongolian Building Code System

- Considering today's rapid development of Mongolian construction industry and penetration of advanced materials and techniques, it needs to bring national normative documents making close to the level of international documents.

To accomplish this objective the followings are needed:

- To transfer function of development of normative documents into non-governmental organizations, especially there are already capable professional associations such as Mongolian Association of Civil Engineers, Concrete Institute and so on,
- To bring collaboration from Asian professional associations of engineers into development activities of normative documents, organize study and analyze of documents of Asian countries and seek possibility to adapt reflecting country specifics,
- To enhance effectiveness of educational and professional development systems of engineers, special attention goes to MUST and MACE.

Thank you for your attention.

ACECC TC-8 2nd Workshop on Harmonization of Design Codes in the Asian Region
Sep. 11, 2008, Sendai, Japan

Introduction of Asian Concrete Model Code (ACMC)

Yoshitaka Kato
Institute of Industrial Science, the University of Tokyo, Tokyo, Japan

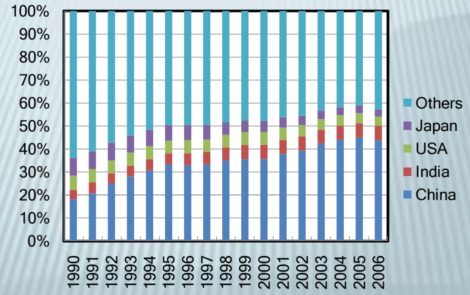
icmc

Yoshitaka KATO — University of Tokyo
Tamon UEDA — Hokkaido University
Koji TAKEWAKA — Kagoshima University
Hiroshi YOKOTA — Port and Airport Research Institute

INTRODUCTION OF ASIAN CONCRETE MODEL CODE (ACMC)

BIG CONSTRUCTION MARKET IN ASIA

World wide cement consumption



year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Billion ton	0.94	0.91	0.93	0.92	0.94	0.96	0.99	1.02	1	1.03	1.07	1.08	1.13	1.17	1.22	1.27	1.4

BIG CONSTRUCTION MARKET IN ASIA

World wide cement consumption

2006 **More than 50% in Asia**

1st : China (1.1 billion ton, 44%)
2nd : India (0.16 billion ton, 6%)
3rd : USA (0.1 billion ton, 4%)
4th : Japan (0. 07 billion ton, 3%)

Typical unit weight of cement in concrete = 300 kg/m^3
1.4 billion ton cement consumption (2006)
→ 4.7 billion m^3 in the world
Average unit price of concrete (m^3) in Japan = 10,000 (JPY)
→ 47 trillion JPY in the world (21 trillion JPY in China)

3 GROUPS IN THE WORLD CONSTRUCTION MARKET

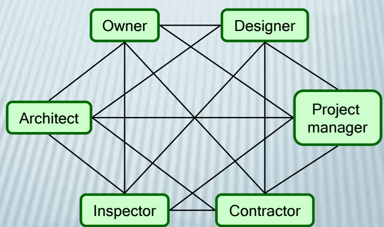
- Europe
- America (North/South America)
- Asia (more than 50%)

How about "Model Codes" ?

- Europe : Euro codes
- America : ACI codes
- Asia : did not have one

SHOULD ASIA HAVE OWN MODEL CODES?

- International big projects
  - There are many players



Creates confusing and misunderstanding

SHOULD ASIA HAVE OWN MODEL CODES?

- International big projects

Common language = Common model codes

Cannot Asia use other model codes?

Inappropriateness in codes in Europe and North America (due to difference in material quality, climate, technological level and economical level)

Creates confusing and misunderstanding

TO DEVELOP ITS OWN MODEL CODE IN ASIA

- The Model Code is
  - to help the countries to develop their own codes
  - to reduce confusion/misunderstanding in multi-national projects
- The Model Code should be
  - flexible in its nature to fit the diversity in Asia

HISTORY FOR ASIAN CONCRETE MODEL CODE (ACMC)

- 1992: JCI Research Committee on Concrete Model Code
- 1994: International Committee on Concrete Model Code for Asia (ICCMC)
- 1998: First draft of ACMC
- 1999: Second draft of ACMC
- 2001: ACMC 2001
- 2004: Vietnamese version for maintenance part of ACMC
- 2006: ACMC 2006

COMMITTEE MEMBERS AND MEETINGS (AS OF MAY 2007)

- ICCMC has
  - over 80 individual members
  - 6 representative members
  - 10 corporate members

  from 14 countries/economies (Australia, Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam)
- ICCMC has been organizing committee meetings regularly with local institutional hosts. In total 22 meetings have been held in 12 countries/economies.

OBJECTIVES OF ICCMC

The objectives of the Committee shall be to develop and maintain a concrete model code for Asia and promote co-operation and understanding among countries in the Asia-Pacific region through the following things.

- Initiation and support of collaborative research activities relating to various aspects of concrete, and through synthesis of findings of such research;
- Dissemination of research results and experience of development activities by way of publications, symposia, workshops and/or seminars;
- Updating and revising the model code, and through development of new knowledge to meet the needs of changing time;
- Interaction with the members and keeping them aware of the activities of the Committee;

ACMC 2006

3 Parts:

"Structural design"

"Materials and construction"

"Maintenance"

Scope:

All kinds of concrete structures (plain concrete, reinforced concrete, prestressed concrete, and composite structures with concrete)

2 Features:

Performance-based concept

Multi-level code document structure

PERFORMANCE-BASED CONCEPT

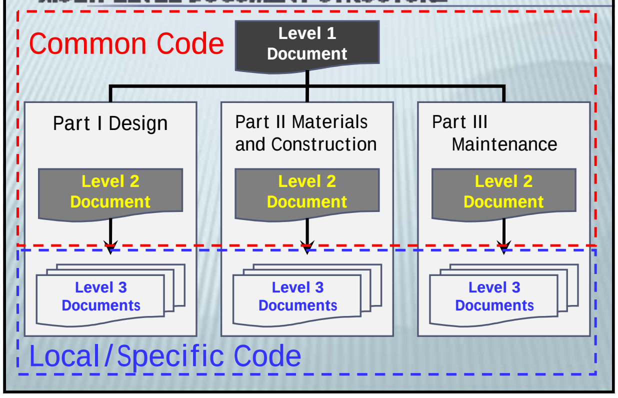
- **Clear description of the required performance of a structure** (in such a way that the owners and users of the structure, who are likely to be non-engineers, can understand)
- No specification on how to satisfy the required performance or how to prove that the required performance is satisfied, which means that **you can choose any method if proved to be appropriate**

Best way

to assure easy understanding among people with different background

to accommodate the diversity in technological and economical level

MULTI-LEVEL DOCUMENT STRUCTURE



MULTI-LEVEL DOCUMENT STRUCTURE

The common Level 1 document specifies **the general principles and framework for the performance based design** of concrete structures as well as for their construction and maintenance.

The Level 2 document servers as an **operational and practical model code with specifications for the required performance**. To allow for the differences in design, construction and maintenance practices among different countries, national standards, codes of practice or design guidelines when fully developed may be simpler or more detailed than this model code.

The Level 3 document includes **example of design, construction and maintenance guidelines** confirming to the Level 1 and Level 2 documents.

LEVEL1 DOCUMENT TABLE OF CONTENTS

LEVEL1 DOCUMENT TABLE OF CONTENTS

1. INTRODUCTION
1.1 Scope

This model code specifies **the general principles for the verification and evaluation of the performance of all types of concrete structures** as well as the structural and nonstructural components thereof, **under various mechanical actions and environmental effects. The code incorporates the concept of performance based design using limit state design methodology.** It is applicable to the design, construction and maintenance of concrete structures.

. . .

This code provides a set of minimum requirements for the performance of construction materials, standard for workmanship, measures of quality control and appropriate construction records that must be complied with on site in order to meet the design requirements for strengths, safety, serviceability and durability of the structure.

Also **provided are guidelines that could be adopted in countries of Asia and the Pacific region in their attempts to establish relevant national codes.**

LEVEL3 DOCUMENTS

ACMC 2006 - Level 3 document, "Design for Fire Actions - Guidelines for the Design of Reinforced Concrete Buildings against Fire Actions

ACMC 2001 - Level 3 document, "Materials and Construction - Guidelines for materials and construction based on Japanese Standard Specifications

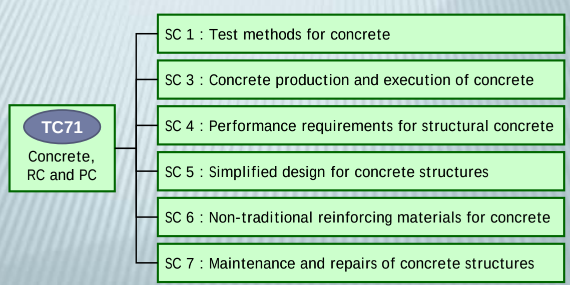
ACMC 2001 - Level 3 document, "Design for Seismic Action - An example of seismic performance examination for RC building designed according to the Architectural Institute of Japan (AIJ) Guidelines

Ministry of Construction Vietnam approved Vietnam National Standard TCXDVN 318: 2004- "Concrete and Concrete Reinforced Structures - Guide to Maintenance" which was prepared based on ACMC 2001

ACMC 2001 - Level 3 document, "Maintenance for Chloride Attach - Guidelines for maintenance and rehabilitation of concrete structures against chloride induced deterioration''

COLLABORATION BETWEEN "ICCMC" AND "ISO"

ISO/TC 71 (Concrete, Reinforced Concrete and Prestressed Concrete) is a technical committee established to deal with all kinds of ISO documents related to concrete. There are six subcommittees under TC 71.



COLLABORATION BETWEEN "ICCMC" AND "ISO"

ISO/TC 71 (Concrete, Reinforced Concrete and Prestressed Concrete) is a tech... ents re...

In SC 4 there is an Ad-Hoc Working Group on a performance-based code, which was initiated by members from **ICCMC**, to study how to implement the performance-based concept and a regional code like ACMC, into the ISO system of codes.

SC 7, proposed by the members from **ICCMC**, is currently chaired by Prof Song of Korea with the writer as Secretary.

SC 7 is now drafting an umbrella code for maintenance based on **ACMC**.

BENEFIT FOR ASIAN COUNTRIES

For Asian Countries with Own Code

✓Dissemination of their technology to be international code in Asia and ISO

✓Strengthening their presence in international circle such as ISO through collaboration among Asian countries

For Asian Countries without Own Code

✓Development of national codes

✓Enhancement of technological level

✓Strengthening their presence in international circle

DIFFICULTIES IN CODE DRAFTING AND INTERNATIONAL COLLABORATION

Volunteer work from limited countries

✓Unfamiliarity for code drafting

✓Small motivation with no direct benefit such as research grant to individual

Difficulty in being recognized by government

✓Country where codes are well established shows little interest

✓ICCMC is not a governmental body

•**Financial support is still necessary for many Asian countries to participate international collaboration.**

•**Country like Japan where civil and architectural structures are dealt by different organization needs unification of codes are preferable.**

Acknowledgments

will be extended to

Members in

ICCMC chaired by Profs Byun & Ueda

JCI Research Committee on ACMC

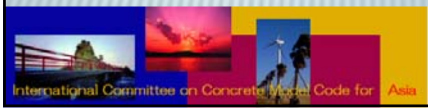
chaired by Prof Hatanaka

JCI Domestic Committee on ISO/TC71

chaired by Prof Uomoto

Thank you for your attention

http://www.iccmc.org



iccmc

Seismic Design Specifications for Highway Bridges in Japan

G.F. Zhang[1] and S. Unjoh[2]
[1]*Researcher, Bridge and Structural Technology Research Group, Public Works Research Institute, Tsukuba, Japan*
[2]*Chief Researcher, Bridge and Structural Technology Research Group, Public Works Research Institute, Tsukuba, Japan*

1 INTRODUCTION

Seismic design methods for highway bridges in Japan has been developed and improved based on the lessons learned from the various past bitter experiences after the Great Kanto Earthquake (M7.9) in 1923. By introducing the various provisions for preventing serious damage such as the design method against soil liquefaction, design detailing including the unseating prevention devices, a number of highway bridges which suffered complete collapse of superstructures was only a few in the recent past earthquakes. However, the Hyogo-ken-Nanbu Earthquake of January 17, 1995, caused destructive damage to highway bridges. Collapse and nearly collapse of superstructures occurred at 9 sites, and other destructive damage occurred at 16 sites [2, 3]. The earthquake revealed that there are a number of critical issues to be revised in the seismic design and seismic strengthening of bridges. Based on the lessons learned from the Hyogo-ken-Nanbu Earthquake, the design specifications for highway bridges were significantly revised in 1996 [3, 4, 5]. The intensive earthquake motion with a short distance from the inland earthquakes with Magnitude 7 class as the Hyogo-ken-Nanbu Earthquake has been considered in the design.

The current version was revised based on the performance-based design code concept with the propose to enhance the durability of bridge structures for a long-term use, as well as the inclusion of the improved knowledges on the bridge design and construction methods. The current Design Specifications of Highway Bridges was issued by the Ministry of Land, Infrastructure, Transport and Tourism on December 27, 2001. The Japan Road Association (JRA) has released it with the commentary in March 2002. This paper summarizes the current JRA Design Specifications of Highway Bridges, Part V: Seismic Design, issued in March 2002.

2 PERFORMANCE-BASED DESIGN SPECIFICATIONS

The JRA Design Specifications has been revised based on the Performance-based design code concept for the purpose to respond the international harmonization of design codes and the flexible employment of new structures and new construction methods. The performance-based design code concept is that the necessary performance requirements and the verification policies are clearly specified. The JRA specifications are employed the style to specify both the requirements and the acceptable solutions including the detailed performance verification methods which are based on the existing design specifications including the design methods and the design details. For example, the analysis method to evaluate the response against the loads is placed as one of the verification methods or acceptable solutions. Therefore, designer can propose new ideas or select other design methods with the necessary verification.

The most important issue of the performance-based design code concept is the clear specifications of the requirements, which the designers are allowed to select other methods, and the acceptable solutions, which the designers can select other methods with the necessary verification. In the JRA specifications, they are clearly specified including the detailed expressions. In future, the acceptable solutions will be increased and widened with the increase of the verification of new ideas on the materials, structures and construction methods.

The code structure of the Part V: Seismic Deign is as shown in Fig. 1. The static and dynamic verification methods of the seismic performance as well as the evaluation methods of the strength and ductility capacity of the bridge members are placed as the verification methods and the acceptable solutions, which can be modified by the designers with the necessary verifications.

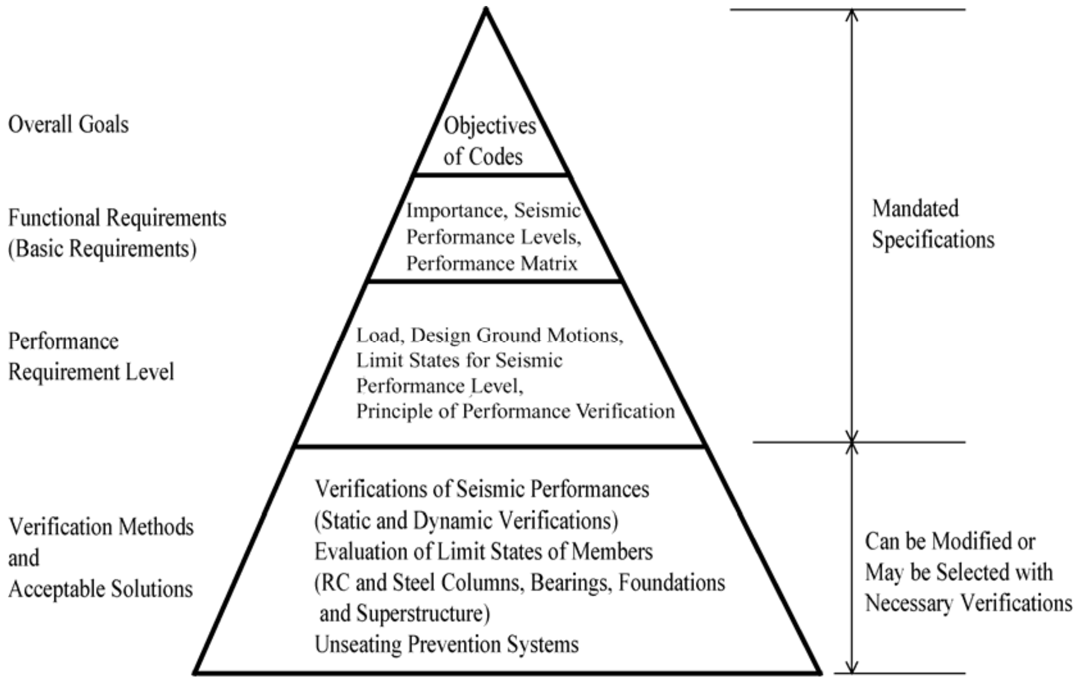


Figure 1. Code Structure of JRA Design Specifications, Part V: Seismic Design

Table 1 Seismic Performance Matrix

Type of Design Ground Motions		Standard Bridges (Type-A)	Important Bridges (Type-B)
Level1 Earthquake: Ground Motions with High Probability to Occur		SPL 1: Prevent Damage	
Level 2 Earthquake: Ground Motions with Low Probability to Occur	Interplate Earthquake (Type-I)	SPL 3: Prevent Critical Damage	SPL 2: Limited Damage for Function Recovery
	Inland Earthquake (Type-II)		

3 BASIC PRINCIPLES OF SEISMIC DESIGN

Table l shows the performance matrix including the design earthquake ground motion and the Seismic Performance Level (SPL) provided in the revised JRA Seismic Design Specifications in 2002. There is no revision on this basic principle from the 1996 Version.

The two level ground motion as the moderate ground motions induced in the earthquakes with high probability to occur (Level 1 Earthquake) and the intensive ground motions induced in the earthquakes with low probability to occur (Level 2 Earthquake).

The Level 1 Earthquake provides the ground motions induced by the moderate earthquakes and the ground motion considered in the elastic design method in the past for a long time is employed. For the Level 2 Earthquake, two types of ground motions are considered. One is the ground motions which is induced in the interplate-type earthquakes with the magnitude of around 8. The ground motion at Tokyo in the 1923 Kanto Earthquake is a typical target of this type of ground motion. The other is the ground motion developed in earthquakes with magnitude of around 7 at very short distance. The ground motion at Kobe during the Hyogo-ken-Nanbu Earthquake is a typical target of this type of ground motion. The former and the latter are named as Type-I and Type-II ground motions, respectively. The recurrence period of the Type-II ground motion may be longer than that of the Type-I ground motion, although the estimation is very difficult.

In the 2002 revision, the design ground motions are named as Level 1 Earthquake and Level 2 Earthquake. One more important revision on the design earthquake ground motion is that the site-specific design ground motions shall be considered if the ground motion can be appropriately estimated based on the informations of the earthquake including past history and the location and detailed condition of the active faults, ground conditions including the condition from the faults to the construction sites. To determine the site-specific design ground motion, it is required to have the necessary and accurate informations of the earthquake ground motions and ground conditions as well as the verified evaluation methodology of the fault-induced ground motions. However, the area to get such detailed informations in Japan is very limited so far. Therefore, the continuous investigation and research on this issue as well as the reflection on the practical design of highway bridges is expected.

Table 2 Key Issues of Seismic Performance

SPL	Safety	Functionability	Repairability	
			Short Term	Long Term
SPL 1: Prevent Damage	Safety against Unseating of Superstructure	Same Function as Before Earthquake	No Need of Repair for Function Recovery	Simple Repair
SPL 2: Limited Damage for Function Recovery	Safety against Unseating of Superstructure	Early Function Recovery can be Made	Function Recovery can be Made by Temporary Repair	Relatively Easy Permanent Repair Work can be Made
SPL 3: Prevent Critical Damage	Safety against Unseating of Superstructure	-	-	-

4 GROUND MOTION AND SESIMIC PERFORMANCE LEVEL

The seismic design of bridges is according to the performance matrix as shown in Table 1. The bridges are categorized into two groups depending on their importances; standard bridges (Type-A bridges) and important bridges (Type-B bridges). Seismic Performance Level (SPL) depends on the importance of bridges. For the moderate ground motions induced in the earthquakes with high probability to occur, both A and B bridges shall behave in an elastic manner without essential structural damage (SPL 1). For the extreme ground motions induced in the earthquakes with low probability to occur, the Type-A bridges shall prevent critical failure (SPL 3), while the Type-B bridges shall perform with limited damage (SPL 2) .

The SPLs 1 to 3 are based on the viewpoints of "Safety", "Functionability" and "Repairability" during and after the earthquakes. Table 2 shows the basic concept of these three viewpoints of the SPL.

5 VERIFICATION OF SEISMIC PERFORMANCE

5.1 Seismic Performance Level and Limit States

As mentioned in the above, the seismic performance is specified clearly. It is necessary to determine and select the limit states of highway bridges corresponding to these seismic performance levels to attain the necessary performance in the design procedure of highway bridges.

In the 2002 revision, the determination principles of the limit state to attain the necessary seismic performance are clearly specified. For example, the basic principles to determine the limit state for SPL 2 is: 1) the plastic hinges shall be developed at the expected portions and the capacity of plastic hinges shall be determined so that the damaged members can be repaired relatively easily and quickly without replacement of main members, 2) the plastic hinges shall be developed at the portions with appropriate energy absorption and with high repairability, 3) considering the structural conditions, the members with plastic hinges shall be combined appropriately and the limit states of members with plastic hinges shall be determined appropriately. Based on the basic concept, the combinations of members with plastic hinges and the limit states of members for ordinary bridge structures are shown in the commentary.

Table 3 Applicable Verification Methods of Seismic Performance Depending on Earthquake Response Characteristics of Bridge Structures

<table>
<tr><td rowspan="2">Dynamic Characteristics
SPL to be Verified</td><td rowspan="2">Bridges with Simple Behavior</td><td rowspan="2">Bridges with Multi Plastic Hinges and without Verification of Applicability of Energy Constant Rule</td><td colspan="2">Bridges with Limited Application of Static Analysis</td></tr>
<tr><td>With Multi Mode Response</td><td>Bridges with Complicated Behavior</td></tr>
<tr><td>SPL 1</td><td rowspan="2">Static Verification</td><td>Static Verification</td><td rowspan="2">Dynamic Verification</td><td rowspan="2">Dynamic Verification</td></tr>
<tr><td>SPL 2/SPL 3</td><td>Dynamic Verification</td></tr>
<tr><td>Example of Bridges</td><td>Other Bridges</td><td>1) Bridge with Rubber Bearings to Distribute Inertia Force of Superstructure
2) Seismically Isolated Bridge
3) Rigid Frame Bridges
4) Bridges with Steel Columns</td><td>1) Bridge with Long Natural Period
2) Bridge with High Piers</td><td>1) Cable-stayed Bridges
2) Suspension Bridges
3) Arch Bridges
4) Curved Bridges</td></tr>
</table>

5.2 Verification Methods

It is the fundamental policy of the verification of seismic performance that the response of the bridge structures against design earthquake ground motions does not exceed the determined limit states. Table 3 shows the applicable verification methods of seismic performance used. In the seismic design of highway bridges, it is important to increase the strength and the ductility capacity to appropriately resist the intensive earthquakes. The verification methods are based on the static analysis and dynamic analysis. In the 1996 design specifications, the lateral force coefficient methods with elastic design, ductility design methods and dynamic analysis were specified and these design methods had to be selected based on the structural conditions of bridges. The basic concept is the same as 1996 one but the verification methods are rearranged to the verification methods based on static and dynamic analyses.

The static verification methods including the lateral force design method and the ductility design method are applied for the bridges with simple behavior with predominant single mode during the earthquakes. The dynamic verification method is applied for the bridges with complicated behavior, in such case the applicability of the static verification methods is restricted. In the 1996 design specifications, for the bridges with complicated behavior both the static and dynamic analyses had to be applied and satisfied. In the 2002 one, the applicability of the dynamic analysis is widened and the dynamic verification method is expected to be used mainly with appropriate design consideration.

5.3 Major Revisions of the Verification Methods of Seismic Performance

(1) Verification of Abutment-Foundation on Liquefiable Ground against Level 2 Earthquake

In the 1996 design specifications, the performance of the abutment-foundations was not verified in detail. This is because 1) the serious damages to abutment-foundations were not found in the past earthquakes when the soil liquefaction was not developed, 2) abutment-foundation is affected by the backfill soils during earthquakes and the effect of the inertia force of abutment itself is relatively small comparing with the pier-foundations, 3) since abutments generally resist against back-fill earth pressure, the abutment-foundations tend to develop displacement to the direction of the earth pressure that is to the center of bridges, then it is generally low probability to have the unseating of superstructures.

On the other hand, recently, the dynamic earth pressure against Level 2 Earthquake based on the modified Mononobe-Okabe theory has been proposed and the behavior of the abutment-foundations can be evaluated during the Level 2 earthquakes. Based on investigations using the modified Mononobe-Okabe theory, it is shown that the abutment-foundations designed according to the Level 1 Earthquake generally satisfy the performance requirement during the Level 2 Earthquake. Therefore, based on these results, the performance of the abutment-foundations only on the liquefiable ground shall be verified in order to give the necessary strength to the foundations and to limit the excessive displacement even if the nonlinear behavior is expected in the abutment-foundations.

(2) Verification of Strength and Ductility of Steel Column

In the 1996 design specifications, the concrete infilled steel columns was designed according to the static ductility design methods using the response evaluation based on the energy equal theory. The force-displacement relation was based on the experimental data of steel columns. On the other hand, steel columns without infilled concrete was designed based on the dynamic analysis because the applicability of the static response evaluation was not verified.

In the 2002 design specifications, new and more appropriate force-displacement relation models for steel columns with and without infilled concrete are proposed based on the experimental data of steel columns which has been made before and after the last 1996 revision. Using these new models, the seismic performance is verified based on the dynamic analysis.

(3) Verification of Strength and Ductility of Superstructure

Generally, the seismic design of superstructures is not critical except the portion around the bearing supports which are the connection between superstructure and substructures. However, the seismic design sometimes becomes critical in the design of rigid frame bridges and arch bridges in the longitudinal direction, and in the design of bridges with relatively long spans to the bridge width in the transverse direction.

The nonlinear behavior of superstructures against cyclic loading is investigated in the recent research. Therefore, the verification method of the limited nonlinear performance for the superstructures is newly specified with the assumption of energy absorption at the plastic hinges in the columns.

6 CONCLUDING REMARKS

This paper presented an outline of the current JRA Seismic Design Specifications of Highway Bridges issued in 2002. Based on the lessons learned from the Hyogo-ken-Nanbu Earthquake in 1995, the "Part V: Seismic Design" of the "JRA Design Specifications of Highway Bridges" was totally revised in 1996, and the design procedure moved from the traditional Seismic Coefficient Method to the Ductility Design Method. Major point of the revision was the introduction of explicit two-level seismic design methods. In the 2002 revision, the target point of the revision is to be based on the performance-based design code concept and to enhance the durability of bridge structures for a long-term use, as well as the inclusion of the improved knowledges on the bridge design and construction methods. It is expected to have the circumstances to employ the new ideas on the materials, structures and constructions methods to construct safer, more durable and more cost-effective bridges in the future.

REFERENCES

1) Japan Road Association: Design Specifications of Highway Bridges, Part I Common Part, Part II Steel Bridges, Part III Concrete Bridges, Part IV Foundations, and Part V Seismic Design, 2002
2) Ministry of Construction: Report on the Damage of Highway Bridges by the Hyogo-ken Nanbu Earthquake, Committee for Investigation on the Damage of Highway Bridges Caused by the Hyogo-ken Nanbu Earthquake, 1995
3) Japan Road Association: Design Specifications of Highway Bridges, Part I Common Part, Part II Steel Bridges, Part III Concrete Bridges, Part IV Foundations, and Part V Seismic Design, 1996
4) Kawashima, K.: Impact of Hanshin/Awaji Earthquake on Seismic Design and Seismic Strengthening of Highway Bridges, Report No. TIT/EERG 95-2, Tokyo Institute of Technology, 1995
5) Kawashima, K. et. al.: 1996 Design Specifications for Highway Bridges, 29th UJNR Joint Panel Meeting, May 1996

APPENDIX

2002 JRA Design Specifications for Highway Bridges, Part V: Seismic Design

Table of Contents

PUBLIC WORKS RESEARCH INSTITUTE

SEISMIC DESIGN SPECIFICATIONS FOR HIGHWAY BRIDGES IN JAPAN

Guangfeng ZHANG, Dr. Eng.
Public Works Research Institute

Sep. 11, 2008

Current Design Codes for Highway Bridges

Specifications for Highway Bridges -2002 Version-

Issued by Japan Road Association (JRA)

- Part I: Common
- Part II: Steel Bridges
- Part III: Concrete Bridges
- Part IV: Substructures
- Part V: Seismic Design

Specifications for highway bridges with a span length of 200 m or less

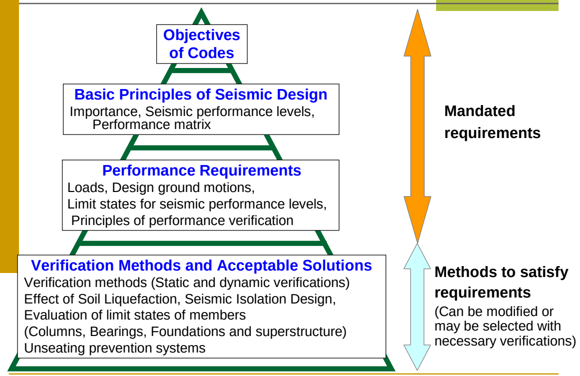
Current Seismic Design Code

2002 Seismic Design Specifications for Highway Bridges

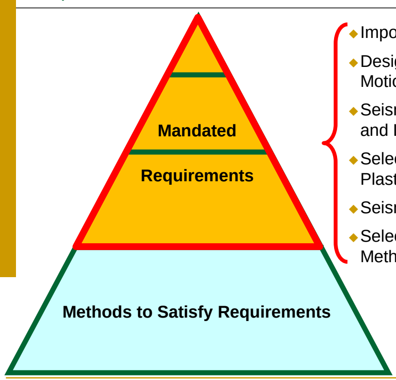
Performance-Based Design Code Concept

- Design requirements are clearly specified
- Existing detailed design methods are specified as verification methods and the examples of acceptable solutions

Performance-Based Design Code Structure (Pyramid)



Requirements



- Importance of Bridges
- Design Earthquake Ground Motions
- Seismic Performance Levels and Limited States
- Selection of Members for Plastic Hinges
- Seismic Performance Matrix
- Selection of Verification Methods

Importance of Bridges

Class	Definitions
Class A bridges	Bridges other than Class B bridge
Class B bridges	● Bridges of National expressways, urban expressways, designated city expressways, Honsyu-Shikoku highways, and general national highways ● Double-section bridges and overbridges of prefecture highways and municipal roads, and other bridges, highway viaducts, etc., especially important in view of regional disaster prevention plans, traffic strategy. etc.

Design Earthquake Ground Motions

Two-Level Design Concept

Level 1 Earthquake Ground Motion

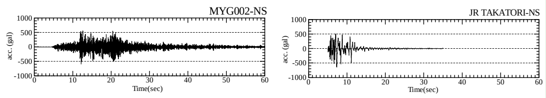
Earthquake ground motion with high probability of occurrence for the bridge service life (for Elastic Design)

Level 2 Earthquake Ground Motion

Earthquake ground motion by strong earthquake with low probability of occurrence for the bridge service life (for Ductility Design)

Type I : Interplate-type Earthquake (e.g. Kanto Earthquake)

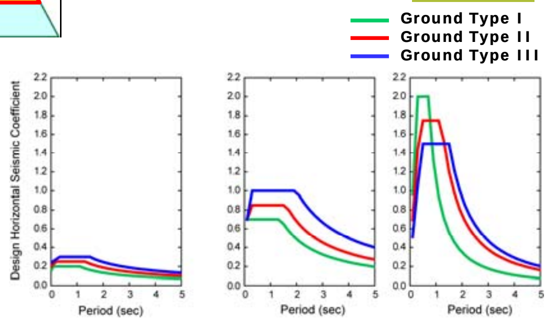
Type II : Inland-type Earthquake (e.g. Kobe Earthquake)



Type I: Long Duration

Type II: Short Duration, Strong Pulses

Design Earthquake Ground Motions - Spectra

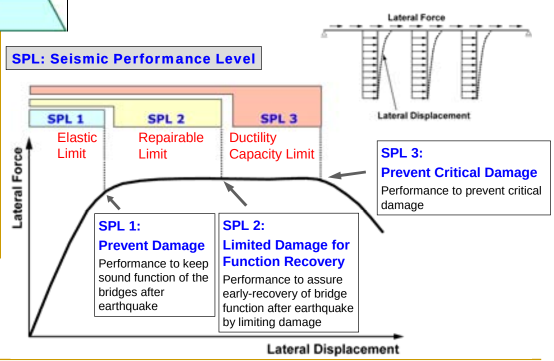


Level 1 Max: 0.2-0.3

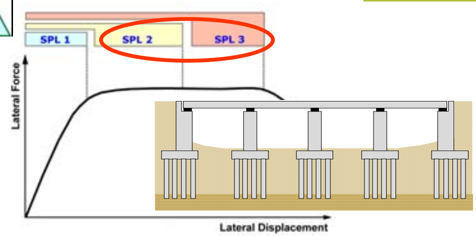
Level 2, Type I Max: 0.7-1.0

Level 2, Type II Max: 1.5-2.0

Seismic Performance Levels and Limit States



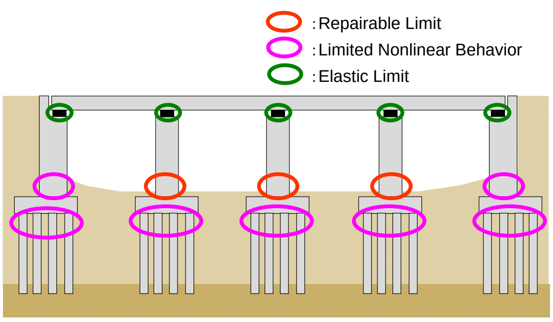
Principles in Selection of Members for Energy Absorption



- Reliable Energy Absorption
- No Significant Effect on Bridge Stability
- Repairable Damage and Easy to Repair (Repairability)
- Possibility to Maintain Traffic Function after Damage (Functionability)

Example for Selection of Limit States (SPL 2)

General Continuous Multi-Span Bridge



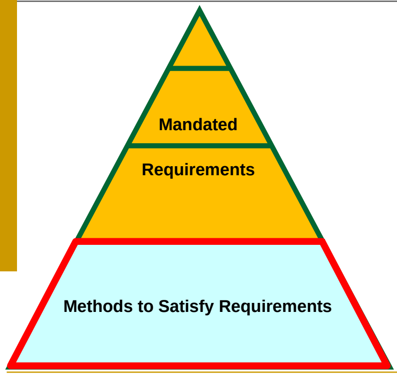
Seismic Performance Matrix

		Type-A (Standard Bridge)	Type-B (Important Bridge)
Level 1 EQ. High Probability to Occur		**SPL 1:** Keeping Sound Functions of Bridges	
Level 2 EQ. Low Probability to Occur	**Type I EQ.** Interplate EQ. **Type II EQ.** Inland EQ.	**SPL 3:** No Critical Damage	**SPL 2:** Limited Damage for Function Recovery

Selection of Verification Methods

	Bridges with simply behavior (1)	Bridges with multi plastic hinges and without applicability of energy constant rule (2)	Bridges with multi mode response (3)	Bridges with complicated behavior (4)
SPL 1	Static verification	Static verification	Dynamic verification	Dynamic verification
SPL 2 SPL 3	Static verification	Dynamic verification	Dynamic verification	Dynamic verification
Example of Bridges	Others	◆ Bridges with rubber bearings ◆ Seismically isolated bridges ◆ Rigid-frame bridges ◆ Bridges with steel columns	◆ Bridges with long natural period ◆ Bridges with high piers	◆ Cable-stayed bridges ◆ Suspension bridges ◆ Arch bridges ◆ Curved bridges

Verification Methods and Acceptable Solutions



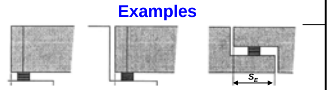
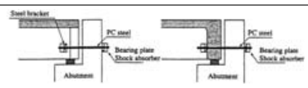
Verification Methods and Acceptable Solutions

Contents

- Verification Metho
- Effect of Soil Lique
- Seismic Isolation I
- Evaluation of the L
  - RC Columns
  - Steel Columns
  - Pier Foundations
  - Abutment Foundations
  - Superstructure
- Unseating Prevention Systems

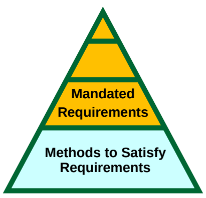
- Evaluation of Failure Mode, Lateral Strength and Ductility Capacity
- Calculation of Lateral Strength and Displacement, Shear Strength
- Stress-Strain Curve of Concrete Considering the Lateral Confinement and Earthquake Type
- Structural Details for Improving Ductility Performance

Unseating Prevention System

Items	Examples
Seating Length	
Unseating Prevention Structure	
Structure for Protecting Superstructure from Subsidence	
Excessive Displacement Stopper	

Concluding Remarks

Performance-Based Design Code



Can be modified or may be selected with necessary verifications

- Performance requirements are clearly specified
- Existing design methods are specified as verification methods and examples of acceptable solutions
  ⇨ Designers have more freedom in selecting design method

The End

Collapsed Matsurube Bridge in the Iwate-Miyagi Inland Earthquake 2008

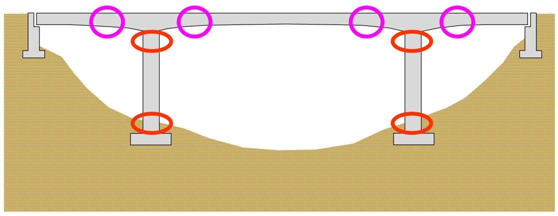
Thank You for Your Kind Attention

Example for Selection of Limit States (SPL 2)

Frame Type Bridge

:Repairable Limit

:Limited Nonlinear Behavior



Static Verification

Demand ≤ Capacity

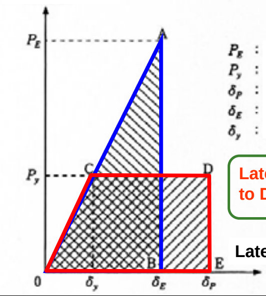
Static Analytical Methods

- Seismic Coefficient Method
- Ductility Design Method

- Loads caused by EQ. are applied statically
- Nonlinear response displacement is estimated based on Energy Constant Rule
- Applicability of static analysis is limited only for simple structures

Energy Constant Rule

Energy absorptions for elastic structure and elasto-plastic structure are equal



P_E : Elastic Lateral Force
P_y : Yield Force
δ_P : Elasto-plastic Displacement
δ_E : Elastic Displacement
δ_y : Yield Displacement

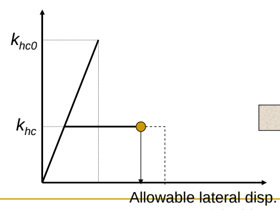
Lateral force can be reduced due to Ductility Capacity of structures

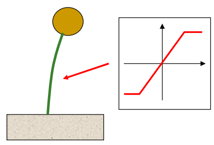
Force Reduction Factor

$$c_S = \frac{1}{\sqrt{2\mu_a - 1}}$$

μ_a: Allowable ductility ratio for the structural system having an plastic force- displacement relation

Base on
- Ductility Design Concept
- Energy Constant Rule





$k_{hc}=c_s\,c_z\,k_{hc0}$

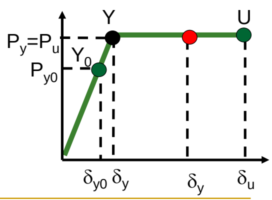
Allowable Ductility Ratio

$$\mu_a = \begin{cases} 1 + \dfrac{\delta_u - \delta_y}{\alpha \delta_y} & \text{: Flexural failure} \\ 1.0 & \text{: Shear failure after flexural yielding} \\ 1.0 & \text{: Shear failure} \end{cases}$$

Safety factor α

Seismic Performance	Type I EQ.	Type II EQ.
SPL2	3.0	1.5
SPL3	2.4	1.2

Type I: Interplate Type
Type II: Inland Type



Dynamic Verification

Demand ≤ Capacity

Maximum response value of structural members

- Cross sectional force $\boxed{F_D} \leq \boxed{P_a}$
- Curvature $\boxed{\phi_D} \leq \boxed{\phi_a}$
- Deformation $\boxed{\delta_D} \leq \boxed{\delta_a}$

Check points

- Unexpected yielding occurs in structural members
- Bridge does not become unstable due to yielding

Effects of Seismically Unstable Ground

Unstable Ground during Earthquake

(1) Extremely soft soil layer
(2) Sandy layer affecting the bridge due to liquefaction and the lateral spreading

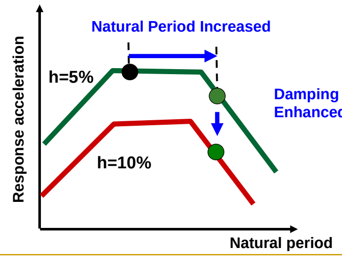
Seismic Performance Verification

Following cases are verified
(1) Neither liquefaction nor liquefaction-induced lateral spreading will occur
(2) Liquefaction will occur
(3) Liquefaction-induced lateral spreading will occur

Seismically Isolated (Menshin) Bridges

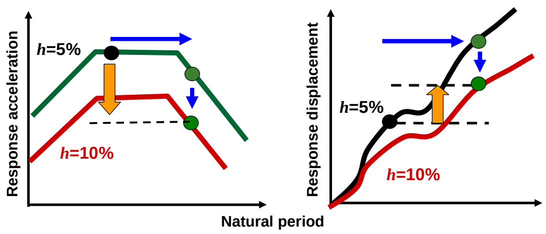
Concept of Seismically Isolated Bridges

Reduction of inertia force of superstructure by
1) Increase natural period
2) Enhance damping performance



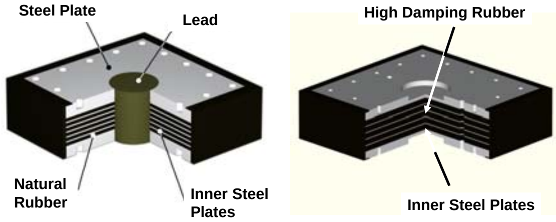
Acceptable Conditions of Seismically Isolated (Menshin) Bridges

- **Firm ground and stable ground**
- **High stiffness of the substructure, and short natural period of the bridge**
- **Multi-span continuous bridge**

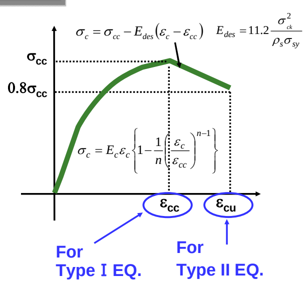


Seismic Isolation Bearings

Lead Rubber Bearing (LRB) | **High Damping Rubber Bearing (HDR)**



Strain-Stress Curve of Concrete



$$\sigma_{cc} = \sigma_{ck} + \boxed{3.8\alpha\rho_s\sigma_{sy}}$$

Confined effect

$$\varepsilon_{cc} = 0.002 + \boxed{0.033\beta\frac{\rho_s\sigma_{sy}}{\sigma_{ck}}}$$

σ_{ck} : Design strength of concrete
σ_{sy} : Yield of lateral confining reinforcement
A_h : Sectional area
s : Spacing
d : Effective length

ACECC 2nd Workshop on Harmonization of Design Codes in the Asian Region
September 11, 2008, Sendai, Japan

Necessity of Design Codes for Cambodia

VONG Seng
Vice President, Cambodian Association of Civil Engineers, Cambodia
Lecturer, Institute of Technology of Cambodia, Cambodia
MOM Mony
President, Cambodian Association of Civil Engineers, Cambodia
Managing Director, Mony Engineering Consultants Ltd, Cambodia

1 INTRODUCTION

The best opportunity for Cambodia to make her own design codes is to follow the activities of the harmonization of design codes in the Asian Region and to produce her own national application documents.

This paper presents the current use of different design codes in Cambodia and the problem and difficulties of using different design codes. The objective of this paper is to present the necessity of design codes for Cambodia with the consideration of local conditions such as materials, climate, skilled labour, equipments and construction method.

2 CAMBODIAN SITUATION

2.1 General situation

Cambodia is a country situated in the Southeast Asia and surrounded by Laos, Vietnam, Thailand and gulf of Siam. It has a saucer-shaped with gently rolling alluvial plain drained by the Mekong River and shut off by mountain ranges which the Dangrek Mountains formed the frontier with Thailand in the northwest and the Cardamom Mountains and the Elephant Range are in the southwest. About half of the land is tropical forest. There are many rivers to collect the water from high land to the plain. In the rainy season the water from the high land and Mekong River flows into a big reservoir of Tonle Sap Lake.

The modernized construction including buildings and road network development was started in Cambodia before 1960s. However, all most all of these constructions had been damaged by the civil war that suffered the country about 20 years from 1970 to until end of 1980s. After finished the civil war, rehabilitation and redevelopment of buildings and infrastructures have been aggressively carried out by people and the new government.

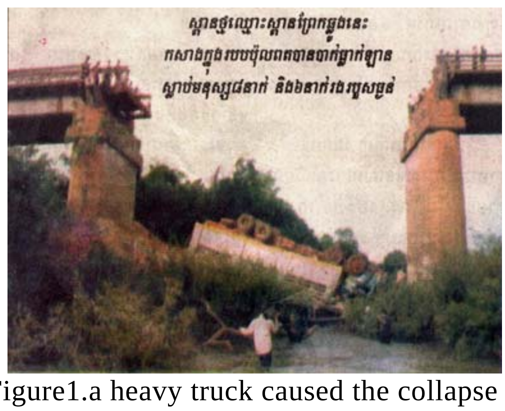


Figure1.a heavy truck caused the collapse of a bridge on National Road 7 on May 14, 2004

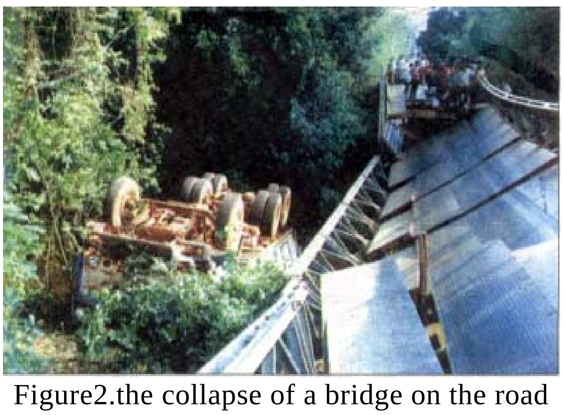


Figure2.the collapse of a bridge on the road from Siem Reap to Bantey Srey temple on April 10, 2004

The rehabilitation and maintenance of the road networks is now most critical and urgent requirement for the country. The large numbers of bridges along the national roads do not cope with the existing traffic loads as they were design to cater lower loads than the prevailing one.

There are many cases of bridge collapse due to overloading and/or due to poor structural design. In addition, there were no enough bridges to provide access to all part of the country throughout a year. As a result, large parts of the country remain isolated during rainy season.

The demands of buildings are increasing rapidly as the increasing speed of population (10.7 million in 1993 and 14.0 million in 2006) and the economic growth (GDP growth rate: 13.4% in 2005, 10.0% in 2004) in which construction increased 20.1% in 2005 due to political stability and the development plan of new government. Based on the knowledge of the authors, most buildings constructions are not in good quality.

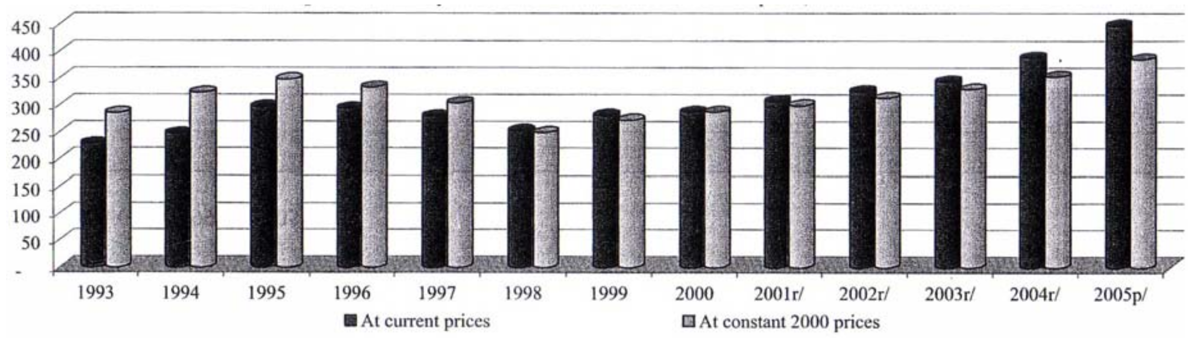


Figure 3. Per capita GDP in US$ in current and constant prices 1993-2005

2.2 Climate

Cambodia has a tropical monsoon climate, with the wet southwest monsoon occurring between November and April and the dry northeast monsoon the remainder of the year. Temperatures in Cambodia are fairly uniform throughout the Tonle Sap Basin area, with only small variations from the average annual mean of around 25°C. The maximum mean is about 28°C; the minimum mean, about 22°C. Maximum temperatures of higher than 32°C, however, are common and, just before the start of the rainy season, they may rise to more than 38°C. Minimum temperatures rarely fall below 10°C. The relative humidity is high at night throughout the year; usually it exceeds 90 percent. During the daytime in the dry season, humidity averages about 50 percent or slightly lower, but it may remain about 60 percent in the rainy period.

3 DESIGN CODES USED IN CAMBODIA

The main reasons that the different design codes are used in Cambodia are explained in the following paragraphs.

The rehabilitation and redevelopment of infrastructures are executing by the government with the Official Development Assistance so call ODA from the developed countries, such as Japan, France, Australia, USA and Germany. However, it can be observed the fundamental problem that those works are still not be done by local engineers and technicians. Because, all most all of rehabilitation and reconstruction infrastructure works are carried by the contractors coming from donor countries themselves and they apply their own design standards and technologies to the works. Although Cambodian design standards have already been set up under the Australian ODA scheme, it is still not suitable for local conditions.

In case, the construction is done by local engineers, the design codes used are different among engineers themselves because of Cambodian engineers who got the formation abroad such as in Japan, European countries and United States etc., they used the design codes of those countries, and for Cambodian engineers who got the formation inside the country they used the design codes that they learned from their own professors who also teach different design codes based on their own experiences and knowledge.

For the constructions which are done by foreign investments, they used engineers from their own country to work with local engineers by applying their own design standards.

Based on the knowledge of the authors, the popular design codes used in Cambodia are ACI, AISC /LRFD AASHTO, European Codes (EuroCode), French Codes, Russian Codes, JSCE standards and Australian Standard.

4 PROBLEM AND DIFFICULTIES

On Cambodian market, the construction materials are imported from various countries except some raw materials such as sand and crushed stone. In each design code, it requires the materials with quality defined in code. Therefore it is quite difficult to find the materials to be suitable to the design code used. It is also difficult to check the quality of materials to satisfy the design codes used due to the lack of equipment for testing, the test condition, test method and the capable of engineers about those design codes.

The different design codes used in Cambodia are not suitable for local conditions such as climate, materials, skilled labour, equipment, and construction method. It is high risk to use these design codes without studying and doing research.

5 NECESSITY OF DESIGN CODES FOR CAMBODIA

For the future development of the country of Cambodia, it is important to set up a kind of system that all the construction works shall be carried out by local engineers and technicians. The design codes are necessarily required for Cambodia to ensure the quality of construction in term of economical development.

At present time with her own capability, Cambodia will not be able to develop her own design codes without foreign assistance. However by expecting the Asian Codes will develop with the consideration of the environment in regional area of Asia, Cambodia would be able to profit from these codes to make her own national application documents.

REFERENCES

A dissertation submitted to Kochi University of Technology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 2006, *Vong Seng, Design of prestressed concrete bridge girder using self-compacting concrete for Cambodian rehabilitation*, Japan

National Institute of Statistics, Ministry of Planning (2006), *Cambodian Statistical Yearbook 2006*, Cambodia

Proc. ACECC Workshop on Harmonization of Design Codes in the Asian Region (2006), Taipei, *Ueda T., Towards Harmonization of Design Codes in Asia- Structural Concrete*- p101-104. Taiwan

Cambodian Association
of Civil Engineers

ACECC 2nd Workshop

on Harmonization of Design Codes in the Asian Region

September 11, 2008, Sendai, Japan

THE NECESSITY OF DESIGN CODES FOR CAMBODIA

VONG Seng, MOM Mony

Presented by VONG Seng

Content

Cambodian Situation

Design Codes Used in Cambodia

Problem and difficulties

Necessity of Design Codes for Cambodia

Cambodian Situation

- Before 1970: Buildings, infrastructures in Cambodia were developed
- During 1970's and 1980's: almost all constructions, infrastructures including road networks had been destroyed by the war
- After finished the civil war (1991): rehabilitation and redevelopment of the infrastructures have been aggressively carried out by new government.
- Recent years : a number of bridges were collapsed due to overloaded vehicles and/or poor structural design. Most building constructions are not in good quality

Cambodian Situation

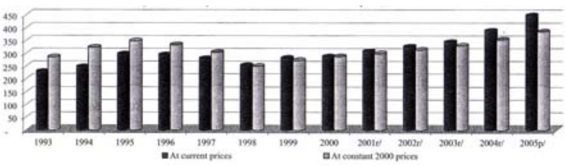
Examples on recent bridge damages

A heavy truck caused the collapse of a bridge on May 14, 2004 on National Road # 7 in Kratie province

A bridge on the road from Siem Reap City to Banteay Srey temple was destroyed on April 10, 2004 following the passage of a convoy of heavy trucks carrying timber.

Cambodian Situation

Per capita GDP in US$ in current and constant prices 1993-2005



- Population 10.7 million in 1993 and 14.0 million in 2006

- Economic growth: GDP growth rate: 13.4% in 2005 and 10.0% in 2004 in which construction increased 20.1% in 2005

Design Codes Used Cambodian

The main reasons of using different design codes in Cambodia are:

- Official Development Assistance (ODA) from the developed countries such as Japan, France, Australia, USA and Germany, they use their own standard

  Although Cambodian road and bridge design standards have already been set up under the Australian ODA scheme, it is still not suitable for local conditions.

- Engineers are got the formation in different design codes

- Foreign invesements on construction industry are from different countries

Design Codes Used Cambodian

Construction design codes used in Cambodia

- ACI, AISC /LRFD AASHTO
- Eurocodes
- French codes
- Russian codes
- JSCE standard
- Australian Standard
- British Standard
- ...

Problem and Difficulties

On Cambodian market, the construction materials are imported from various countries except some raw materials such as sand and crushed stone.

In each design code, it requires the materials with quality defined in code.

Therefore it is difficult to find the materials to be suitable to the design code used.

It is also difficult to check the quality of materials to satisfy the design codes used due to the lack of equipment for testing, the test condition, test method and the capable of engineers about those design codes.

Problem and Difficulties

The different design codes used in Cambodia are not suitable for local conditions such as

Climate

Materials

Skilled labour

Equipment

Construction method

It is high risk to use these design codes without studying and doing research.

Necessity of Design Codes for Cambodia

For the future development of the country of Cambodia, it is important to set up a kind of system that all the construction works shall be carried out by local engineers and technicians. The design codes are necessarily required for Cambodia to ensure the quality of construction in term of economical development.

At present time with her own capability, Cambodia will not be able to develop her own design codes without foreign assistance. However by expecting the Asian Codes will develop with the consideration of the environment in regional area of Asia, Cambodia would be able to profit from these codes to make her own national application documents.

Structural Steel Design Specifications in Thailand

Dr. Taweep Chaisomphob
Chairman, Steel Structure Committee Engineering Institute of Thailand
Department of Civil Engineering, Sirindhorn International Institute of Technology,
Thammasat University, Thailand

Structural Steel Design Specifications in Thailand

Dr. Taweep Chaisomphob

Chairman, Steel Structure Committee
Engineering Institute of Thailand

Department of Civil Engineering
Sirindhorn International Institute of Technology
Thammasat University

ACECC TC-8 2nd Workshop on Harmonization of Design Codes in the Asian Region on September 11, 2008, at Tohoku University, Sendai, Japan

Topics

- Engineering Institute of Thailand Under H.M. the King's Patronage
- Hot rolled steel building design specifications
- Cold formed steel building design specifications
- Material standards
- Design loads
- Remarks on Thai design standard

Engineering Institute of Thailand Under H.M. the King's Patronage

The Engineering Institute of Thailand (EIT), founded in 1943, is a sole professional association in engineering discipline in Thailand. Currently, EIT has over twenty four thousand members in various disciplines, including Civil, Electrical, Mechanical, Industrial, Mining, Environmental and Chemical Engineering, etc.

Engineering Institute of Thailand Under H.M. the King's Patronage

Objective

•Conduct and promote the continuing education, research, publication in engineering.
•Promote and support engineering career.
•Set up the code, specification, regulation for engineering practice.
•Provide engineering consultants.
•Provide engineering ethics.

Engineering Institute of Thailand Under H.M. the King's Patronage

EIT provides academic documents in 6 types

1. Text
2. Experienced book
3. Code of practice
4. Manual
5. Technical terms
6. Journal & Magazine

Hot rolled steel building design specifications

- At present, EIT standard 1020-51 for hot rolled steel building follows AISC (American Institute of Steel Construction) design specification, entitled "Load and Resistance Factor Design Specification for Structural Steel Buildings", which was issued in 1999.
- This AISC specification provides a limit state design method including strength and serviceability limit states.

Hot rolled steel building design specifications

Table of content of E.I.T. Standard 1020-46

1. General Provisions
2. Design Requirements
3. Frames and Other Structures
4. Tension Members
5. Column and Other Compression Members
6. Beams and Other Flexural Members
7. Plate Girders

Hot rolled steel building design specifications

Table of content of E.I.T. Standard 1020-46

8. Members under Combined Forces and Tension
9. Composite Members
10. Connections, Joints, and Fasteners
11. Concentrated Forces, Ponding, and Fatigue
12. Serviceability Design Considerations
13. Fabrication, Erection, and Quality Control
14. Evaluation of Existing Structures

Cold formed steel building design specifications

- EIT standard for cold formed steel building is now under drafting, and follows AISI (American Iron and Steel Institute) design specification, entitled "North American Specification for the Design of Cold-formed Steel Structural Members", which was issued in 2007.
- This AISI specification provides an integrated treatment of Allowable Strength Design (ASD) and Load and Resistance Factor Design (LRFD) by including the appropriate resistance factors for use with LRFD, and the appropriate safety factors for use with ASD.

Cold formed steel building design specifications

Table of content of Draft E.I.T. Standard

1. General provisions
2. Elements and Properties of sections
3. Tension members
4. Flexural members
5. Combined axial load and bending

Cold formed steel building design specifications

Table of content of Draft E.I.T. Standard

6. Structural assemblies and systems
7. Connections and joints
8. Tests for special cases

Material Standard

Hot rolled steel section

- In Thailand, steel material standard for hot rolled structural steel sections is

TIS (Thai Industrial Standard) 1227-2539

- This standard follows JIS G 3192 and JIS G 3106

Material Standard

Hot rolled steel section in TIS 1227-2539
Steel grade and chemical component

Steel Grade	Chemical Component (percent by weight)				
	Carbon Max.	Silicon Max.	Manganese	Phosphorus Max.	Sulfur Max.
SM 400	0.20	0.35	0.60– 1.40	0.035	0.035
SM 490	0.18	0.55	1.60 max.	0.035	0.035
SM 520	0.20	0.55	1.60 max.	0.035	0.035
SM 570	0.18	0.55	1.60 max.	0.035	0.035
SS 400	-	-	-	0.050	0.050
SS 490	-	-	-	0.050	0.050
SS 540	0.30	-	1.60 max.	0.040	0.040

Material Standard

Hot rolled steel section in TIS 1227-2539
Steel grade and material properties

Steel Grade	Min. Yield Strength (MPa)		Ultimate Strength (MPa)	Min. Elongation %			Min. Impact Strength (Joule)
	Thickness ≤ 16 mm.	Thickness >16 mm.		Thickness < 5 mm.	Thickness 5 – 16 mm.	Thickness >16 mm.	
SM 400	245	235	400-510	23	18	22	27
SM 490	325	315	490-610	22	17	21	27
SM 520	365	355	520-640	19	15	19	27
SM 570	460	450	570-720	19	19	26	47
SS 400	245	235	400-510	21	17	21	-
SS 490	285	275	490-610	19	15	19	-
SS 540	400	390	540 min.	16	13	17	-

Material Standard

Hot rolled steel section in TIS 1227-2539
Sectional shape

Type		Sectional shape
Angle steel	Equal leg	
	Unequal leg	
Channel steel		
H-section steel		
I-section steel		
T-section steel		

Material Standard

Cold formed steel section

- In Thailand, steel material standard for cold formed structural steel sections is

TIS (Thai Industrial Standard) 1228-2549

- This standard follows JIS G 3350

Material Standard

Cold formed steel section in TIS 1228-2549
Steel grade and chemical component

Steel Grade	Chemical Component (percent by weight)				
	Carbon Max.	Silicon Max.	Manganese	Phosphorus Max.	Sulfur Max.
SSC 400	0.25	-	-	0.050	0.050

Material Standard

Cold formed steel section in TIS 1228-2549
Steel grade and material properties

Steel grade	Min. Yield Strength (MPa)	Ultimate Strength (MPa)	Min. Elongation %	
			Thickness ≤ 5 mm.	Thickness > 5 mm.
SSC 400	245	400-540	21	17

Material Standard

Cold formed steel section in TIS 1228-2549
Sectional shape

Type		Sectional shape
Light angle steel	Equal leg	
	Unequal leg	
Light channel steel		
Lip channel steel		
Light Z steel		
Lip Z steel		
Hat steel		

Design Load

- In Thailand, the design load is specified in the Building Control Act, B.E. 2522, issued by Department of Public Works and Town & Country Planning, Thai Ministry of Interior.
- This act is necessary for securing the buildings in safety and good condition, and provides various type of regulations (procedure, area restriction, fire safety, construction safety, equipment, shape of building, etc.).

Design Load

- From the Ministerial Regulation No. 6, B.E 2527, under the Building Control Act, B.E 2522, the load factor and load combination are given :

(1) Case of no wind loads

$$\boxed{U = 1.7D + 2.0L}$$

where U = required strength
D = dead load
L = live load

Design Load

(2) Case of wind loads considered

$$\boxed{U = 0.75(1.7D + 2.0L + 2.0W)} \quad \text{or}$$

$$\boxed{U = 0.9D + 1.3W}$$

where W = wind load

Design Load

Minimum uniformly distributed live load for building design in Ministerial Regulation No. 6, B.E 2527

Type and Occupancy or Use	Live Load (kg/m^2)
1. Roof	30
2. Concrete canopy or roof	100
3. Habitation, bathroom, toilet, kindergarten	150
4. Condominium, dormitory, row-houses, hotel	200
5. Office and Bank	250
6. (a) Commercial building, portion of row or row building to be used commercially, college and school. (b) Hall, stair and hallway of a suite, dormitory, hotel, hospital, office, and bank.	300

Design Load

Minimum uniformly distributed live load for building design in Ministerial Regulation No. 6, B.E 2527

Type and Occupancy or Use	Live Load (kg/m^2)
7. (a) Market place, department store, meeting hall, theatre, restaurant, reading room in a library, and parking area or garage. (b) Hall, stair, hallway of commercial building, university, college or school.	400
8. (a) Warehouse, stadium, museum, factory, storage room. (b) Hall, stair, hallway of market place, department store, meeting hall, theatre, restaurant and library.	500
9. Library space or garage for shelf	600
10. Parking area or garage for truck	800

Design Load

Minimum wind pressure for building design in Ministerial Regulation No. 6, B.E 2527

Height (m)	Wind Pressure kPa (kg/m^2)
0-10	0.5 (50)
10-20	0.8 (80)
20-40	1.2 (120)
>40	1.6 (160)

Remarks on Thai Design Standard

- EIT (Engineering Institute of Thailand) steel building design standards are based on American standards : AISC and AISI specifications for hot rolled steel and cold formed steel, respectively.
- There are no Thai structural steel design standards for infrastructures such as bridges. At present, the design of infrastructures adopts the standards of developed countries, such as AASHTO specifications for steel bridges.

Summary

Discussion Report of the Workshop

Discussion Reports and Summaries of the 2nd Workshop

Y. Honjo
Chair of ACECC TC-8
Gifu University, Japan

K. Horikoshi
Secretary of TC-8,
Chair of Committee on ACECC, Japan Society of Civil Engineers, Tokyo, Japan
Civil Engineering Research Institute, Taisei Corporation, Japan

1 JAPANESE EXPERIENCE TOWARD PERFORMANCE BASED DESIGN

Two aspects of the background as to how the performance based design concept was introduced into Japan were explained as follows:

After enforcement of the WTO-TBT agreement 1995, the government enforced a policy of deregulation in 1998. In 2002, there was another 3 year plan of regulation reform promotion. Among various political actions, what had direct relationship to our business was the revision of the various technical standards, and in 2003, revision work for Technical Standard for Port and Harbor Structure (TSPHS) and Specification for Highway Bridges (SHB) started in 2003. In 2007 the revision of TSPHS had completed whereas that of SHB is still underway. These are the government activities.

There are also the activities by professional societies. In the Japanese Geotechnical Society (JGS), a committee organized in 1997 proposed a draft on the performance based design model code, which is called Geo-Code 21, whose first draft was completed in 2001 and the final version was published in 2004. Besides the JGS, there are similar activities in the fields of steel and concrete. Ministry of Land, Infrastructure, Transport and Tourism (MLIT) gave a project to Japanese Society of Civil Engineers (JSCE). The ministry asked to draft a basic code for the performance based design, which is called “Code PLATFORM ver. 1” (Principles, guidelines and terminologies for structural design code drafting founded on the performance based design concept ver.1.0) and had completed in 2003. The new Technical Standard for Port and Harbor Structure (TSPHS) is heavily based on the concept of this “Code PLATFORM ver.1”.

It looks from outside that the government had a firm and constant policy and the professional society followed it from the very initial stage, and had developed basic concepts, and eventually those concepts were developed to the final practical code. So it seems to be a very successful and happy story but the reality is slightly different.

For a country like Japan WTO-TBT agreement is one of the basic policies for industry and trade. The purpose of this agreement was to ensure the technical regulations and standards not to create unnecessary barriers to international trade. It is stated in the agreement that technical regulations should be based on the international standards, and also they recommended performance based regulations, rather than the specific regulations. (i.e. It is regulated in the Article 2, Item 2.4 of the agreement, the WTO members should use technical regulations based on the product requirement in terms of performance.) This was one of the starts of the performance based design. Based on this agreement, the deregulation policy of the government started in 1998. This was a very important project for the Japanese government, the head of which was the Prime Minister himself.

However, the real impact to code harmonization came at the next stage. The 3 years plan for regulation reform promotion started in 2001. MLIT had their own program on restructuring of public work costs, and among them there was a revision of the technical standards for the port and harbor facilities to performance based version, and also review of the highway bridge specifications. Based on the above policies, there has been a basic stream for the performance based design.

The movements at the top government toward the directions explained above had not been really known by the engineering societies until 2003. It was lucky that the performance based code like code PLATFORM ver.1 was ready when the code writers of TSPHF started to work on the revision of this code toward the performance based design.

Finally, the authors would like to express their experience on the development of these codes since 1997. When we started to work on the performance based design code at JGS in 1997. We were not really sure that whether PBD can be really a future concept for design code. However, this concept and design code written on this concept became popular very quickly, and this is now the basic concept to lead this area.

It should be noted that the PBD is not an engineer driven concept but is government policy driven. Therefore it has become popular very quickly. Performance based design is a user/administrator oriented approach as you find in the Nordic Five Level, it is not engineers who developed this, but the government/administrators who developed this concept.

2. PERFORMANE BASED DESIGN

We may divide the designs into two parts, that is, performance requirement, and if such requirement is set, we need to have some verification method. And the international agreement is, as far as the performance requirement are concerned, we have to use performance based design, or you can call it performance based specification to specify what we require for the structure, then after the performance requirement is set, we need to verify it and based on the international standard like ISO2394, limit state design method is recommended to verify the performance. Performance based design and limit state design, or reliability based design, is not a controversial concept but actually they are supplementing each other.

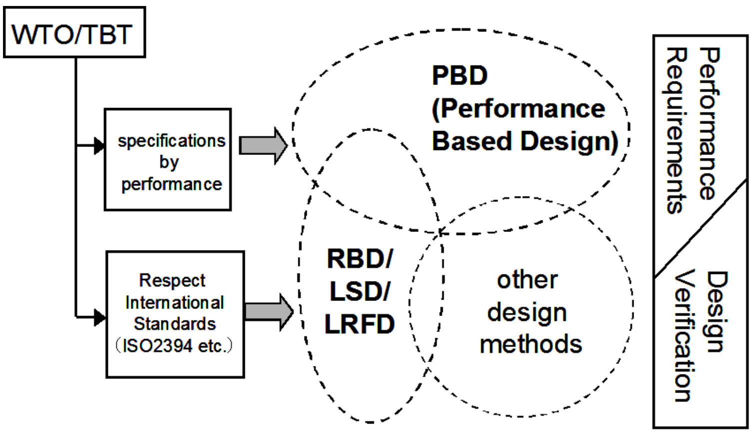


Figure 1 WTO/TBT agreement, PBD and LSD/RBD

Dr. Foliente worked on the performance based design for the buildings, and described as: "*Performance approach is, in essence, the practice of thinking and working in terms of end rather than means*."

It is very useful to review the history of performance based design. There are two important sources of the performance based design as shown below:

2.1 Nordic Five Level

One of them is called Nordic Five Level and this is first proposed in the document titled "Structure for the building regulations." published in 1978 in Scandinavia. Here, the word "structure" means the structure of regulations rather than building structures. In the preface, it is stated as follows:

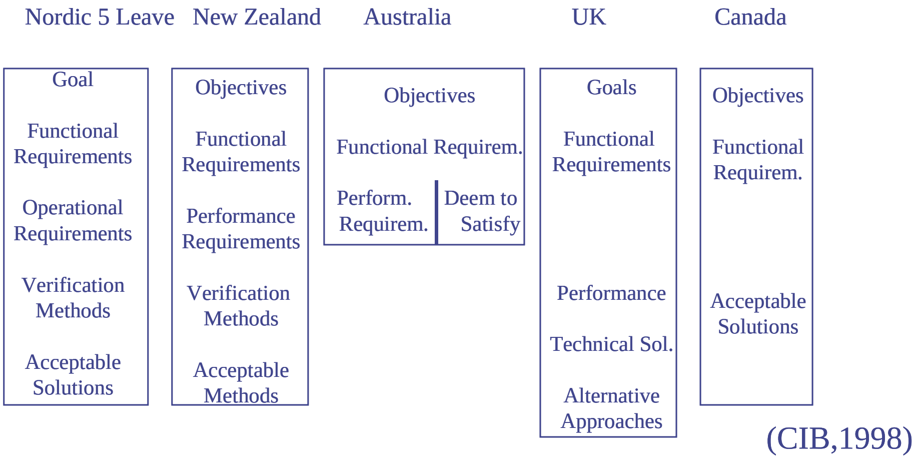


Figure 2 Nordic 5 Levels

> *The system of rules which now governs building in the Nordic countries is made up of legislation, regulations and other building rules. In the action program of the Nordic Council of Ministers for the Nordic co-operation which the building sector is stated that the system of rules should in the first place be structures into a limited number of levels characterizing the purpose of the regulations from the comprehensive objective of the statute down to the technical solution. In this way co-operation would be facilitated even if the administrative system varies from country to country.*

What is meant is that they would like to harmonize their regulations in the Scandinavian countries, but even in the Scandinavian countries the structure of regulations are different and very difficult to harmonize. So initially the performance based design concept was aimed at harmonizing the regulation system and this is the structure they have developed. This is what is called Nordic Five Levels, originally proposed so its performance requirement is given by three levels; Goal, Functional, and Operational requirements (Figure 2). And after the requirement is set, they have specification method and the acceptable solutions. And only this part is mandatory, and in this way, people can harmonize their regulation structures relatively easily. Because of this merit, many other countries followed their regulations.

2.2 Vision 2000

The other source is from California, USA. In early 1990s, there were several earthquakes which caused considerable economic damage especially to the buildings. They found that there was a communication gap between the designers and the owners of the buildings. The owner were told by the designers that their buildings were seismic resistant. However when the earthquakes happened, even though the buildings did not collapse, there was considerable damage inside, all the equipments were destroyed and there were some injured people. The owners realized that seismic resistance by the engineers was that they would not collapse during the earthquake, however, for the owners, they thought even after a serious earthquake, the building should be fully operational. Subsequently, they proposed a performance matrix in the report “Vision 2000” in 1995 by Structural Engineering Association of California. The owners of buildings can choose the requirement, and the designer can design the building based on the requirement. This will minimize a communication gap between designers and building owners.

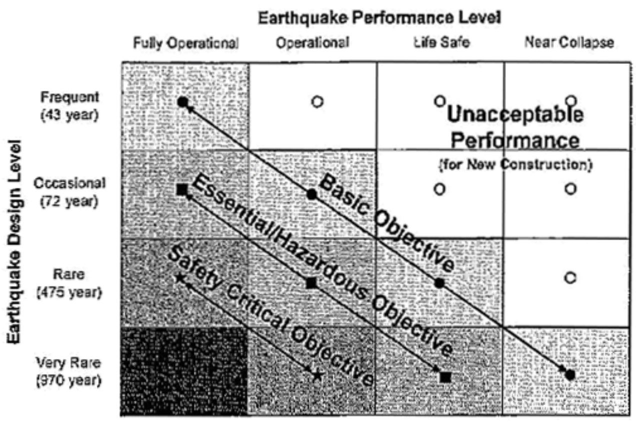


Figure 3 Recommended performance objectives for buildings

2.3 New Codes on Performance Based Design(PBD) concept

Several design codes based on PBD concept have been developed in Japan by 2005. Code PLATFORM ver.1 and Geocode 21 are some of the earlier results of these codes. The contents are actually a combination of the Nordic Five Level and the performance based matrix and this is similar to what Dr. Kikuchi presented in this workshop. It started from the objective of structure by general terminology then performance requirement is the requirement for the structure to fulfil this objective in general terminology and then performance criteria that is a breakdown of the performance requirement by verifiable work. So we propose to use the performance based matrix. Therefore, it becomes clearer and of course for the verification part we proposed to use the LRFD.

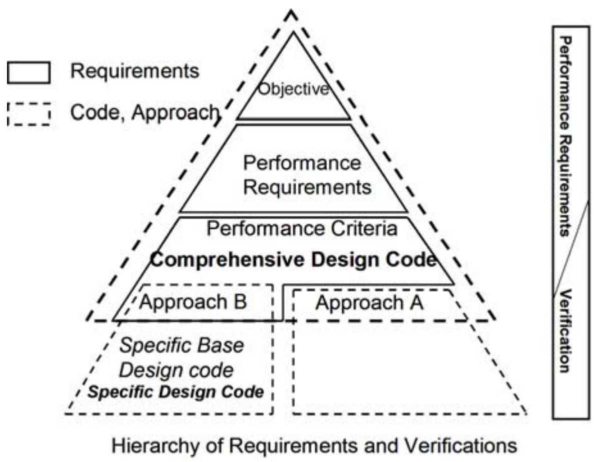


Figure 4 Hierarchy of performance requirements, verification and codes

2.4 Can Performance Based Design (PBD) be a basic concept for code harmonization in Asia?

When Structural Eurocodes started their work in 1970's, they employed the limit state design concept, which was a bland new concept at that time, to harmonize their design codes. A new concept is required to harmonize codes in the Asian region. We propose to use this PBD concept to harmonize the design codes in Asian region because some countries in our region are now starting their work towards this direction.

3 GLOSSARY OF TERMINOLOGIES FOR DESIGN CODE

The first draft of "Glossary of Terminologies for Design Code" was introduced by one of the author of this paper (Yusuke Honjo), which is included in the proceedings. Various codes were referred to make the draft. Since any of the definitions was revised at this stage, there may be some inconsistency. It may be necessary to discuss the inconsistency, although there is an opinion that we should respect the original definitions.

During the workshop it was confirmed that all participants agree to create such Glossary of terminologies. The terminologies should be based on the concept of the performance based design. It is necessary to clarify what the performance based design is so that all the members have the common understanding.

The definition of PBD in the present draft has been taken from JSCE 2001, guideline for performance based design for civil engineering steel structures by JSCE.

> A design methodology for designing a structure exclusively to satisfy performance requirements regardless of the structural format, structural material, design procedure or construction method. This design methodology explicitly presents the objectives of the structure and the performance requirements to achieve the objectives, defines the performance criteria to provide the performance requirements (functions) and provides the functions satisfactorily by securing the performance requirements throughout the working life of the structure. Similar terms include performance-based design, performance based specification, performance-expressing design and performance-oriented design.

4 FUTURE ACTIVITIES OF TC-8

We have realized that some countries are very interested in levelling up theirs codes, and the performance based design concept may be the best for levelling up. On the other hand, it is also true that some countries also need their daily design codes which can be used even today. It may be not easy to solve both issues at the same time. For the latter issue, JSCE may be able to offer some information or to arrange some meetings between those countries.

What we create from now has no legal power to enforce anyone to do anything but it is a recommendation for the future code. If we can create a good concept or/and an ideal code, we are able to attract more people and countries. We need to have more concrete idea what performance based design is, and what would be the contents of the basic code. These discussions should be made in the next stage of TC-8 activities. We should make the committee document, and send this to all the members for their comments. In Hanoi next April, we can make it final.

5 OTHER TOPICS

Governmental Policy and Engineering Association

Since we belong to engineering association, we cannot get any information on governmental policy. However it is true that the governmental policy can accelerate code development activities drastically. Generally the revision work by the government is very conservative. It is not easy to implement a new concept such as performance based design or even the limit state design. In such situations, the work of professional engineering society as represented as the Geo Code 21 or the Code Platform will be very effective. These ideal codes were developed without any governmental restrictions. These ideal works can be refereed as needed basis. Engineers also follow the ideal codes.

Necessity of activities by young engineers

It is important to invite young code drafters to our activities. According to the experience of Japanese Geotechnical Society, they intentionally picked up prospective young code drafters typically under 40 years old. Now after 10 years later, these people have become key persons in code developments. Through the work of code drafting, they discussed intensively, which have resulted in the creation of strong human network.

5.2 Funds for Activities

Funding is always very important issue. Geotechnical Society has got a fund from the government. Although it was not big amount, but sufficient enough for 24-25 people to gather occasionally and make discussions as well as to cover printing cost and transportation. We need to apply for such fund continuously for the continuous activities.

6. CONCLUDING REMARKS

This workshop is the first workshop since the formulation of the TC in 2007. Through today's workshop, we were able to learn, and exchange our code development problems in each country as well as the future direction for us to go. As you may know in Asian countries, we have similar natural conditions and we have similar types of disasters, so we can cooperate for the common code development together. ACECC will strongly continue this activity on code harmonization.

Finally we would like to give sincere thanks especially to the following organizing members in JSCE committee for ACECC:

Prof. Eiki Yamaguchi (Kyushu Institute of Technology, Vice Chair of JSCE Committee for ACECC)
Mr. Masayuki Torii (Nishimatsu Construction Co., Ltd, Secretary General of JSCE Committee for ACECC)
Mr. Masaaki Nakano (Nippon Koei Co., Ltd, Secretary of JSCE Committee for ACECC)
Ms. Emiko Serino (Secretary of JSCE Committee for ACECC)
Mr. Hiroyuki Yanagawa (JSCE)

Performance based Design concept and Design code development in Japan
- Two different stories on the same event -

Y. Honjo, chair of ACECC TC-8
Gifu University
本城 勇介, 岐阜大学

Story one: one side of story on PBD in Japan

1995 WTO/TBT agreement enforced
1997 JGS committee for PBD started
1998 Three year plan for Deregulation
2001 1st draft of Geo-code 21.
2001 Three year plan for regulation reform promotion
2003 revision work for TSPHS started and SHB started.
2003 MLT/JSCE code PLATFORM ver.1 published
2004 Geo-code 21 published
2007 TSPHS completed, SHB revision underway.

WTO/TBT agreement:

- WTO/TBT was enforced in 1995, and is applied to all WTO member countries.
- Purpose of the agreement is to ensure that technical regulations and standards … do not create unnecessary obstacles to international trade.
  - Technical regulations should based on international standards, if such exist.
  - Performance based regulations.

WTO/TBT (1995)

(AGREEMENT ON TECHNICAL BARRIERS TO TRADE)

Article 2: Preparation, Adoption and Application of Technical Regulations by Central Government Bodies

2.4 Wherever technical regulations are required and relevant international standards exist … Members shall use them, or relevant part of them, as basis for their technical regulations …

2.8 Wherever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or descriptive characteristics.

Government Policy for deregulation (1)

Headquarter for Administrative reform (Head the Prime Minister)
'Three years plan for Deregulation '
March, 1998 the cabinet decision

1) All economic regulation should be eliminated in principle. The social regulations should be minimized. All regulation should be eliminated or deregulated.
2) Rationalization of regulation methods. For example, tests can be outsourced from the private sector.
3) Simplification and clarification of the contents of the regulations.
4) International harmonization of the regulations.
5) Speed up of the regulation related procedures.
6) Transparency of the regulation related procedure.

Government Policy for deregulation (2)

'Three years plan for regulation reform promotion'
March, 2001 the cabinet decision

1) Realization of sustainable economic development by promotion of economic activities.
2) Realization of transparent, fair and reliable economic society
3) Secure diversified alternatives for life styles.
4) Realization of economic society that is open to the world.

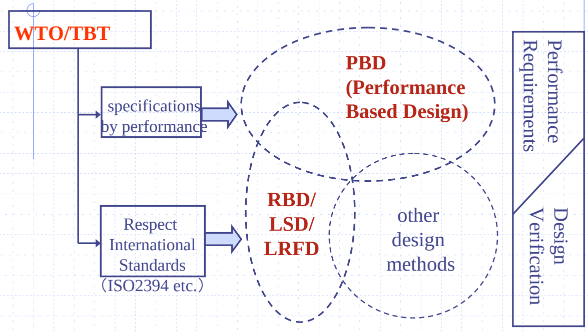
Background in Administrative Aspects

- 'Three years plan for promotion of regulation reform' March, 2001, the cabinet decision

  → For Codes and Standards,
  Harmonized to International Standards,
  Performance based Specification

- Ministry of Land and Transportation, Program on Restructuring of Public Works Costs, March, 2003 →
  - Revision of Common specifications for civil works
  - Review of Highway Bridge Specifications
  - Revision of Technical Standards for Port and Harbor Facilities to performance based.

WTO/TBT agreement, PBD and RBD



Events calendar

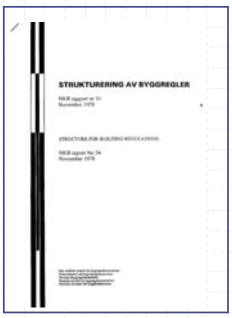
1995 WTO/TBT agreement enforced
1997 JGS committee for PBD started
1998 Three year plan for Deregulation
2001 1st draft of Geo-code 21.
2001 Three year plan for regulation reform promotion
2003 revision work for TSPHS started and SHB started.
2003 MLT/JSCE code PLATFORM ver.1 published
2004 Geo-code 21 published
2007 TSPHS completed, SHB revision underway.

What is PBD ?

Performance approach (PBD) is, in essence, the practice of thinking and working in terms of end rather than means.

(Foliente, G.C. 2000)

Performance based design(1)
performance based specifications



Structure for Building Regulations

NKB report No.34
November 1978

Defined regulation
Structure for buildings
To which level regulation be enforced, and to which level it should be given to the judgment of designers.

Structure for Building Regulations, NKB report No.34, Nov. 1978, Preface

The system of rules which now governs building in the Nordic countries is made up of legislation, regulations and other building rules. In the action program of the Nordic Council of Ministers for the Nordic co-operation which the building sector is stated that the system of rules should in the first place be structures into a limited number of levels characterizing the purpose of the regulations from the comprehensive objective of the statute down to the technical solution. In this way co-operation would be facilitated even if the administrative system varies from country to country.

Performance based design(2)
performance based specifications

Nordic 5 Leave	New Zealand	Australia	UK	Canada	
Goal	Objectives	Objectives	Goals	Objectives	
Functional Requirements	Functional Requirements	Functional Requirem.	Functional Requirements	Functional Requirem.	Mandatory Requirem.
Operational Requirements	Performance Requirements	Perform. Requirem. / Deem to Satisfy			
Verification Methods	Verification Methods		Performance	Acceptable Solutions	Supporting Documents (Guidance)
Acceptable Solutions	Acceptable Methods		Technical Sol.		
			Alternative Approaches		

(CIB,1998)

Performance based design(3)
Performance Matrix

VISION 2000

Performance Based Seismic Engineering of Buildings

(SEAOC 1995)

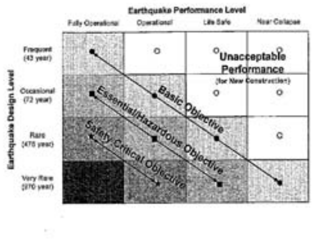


Figure 2-2: Recommended Performance Objectives for Buildings

A tool for dialogue between the owner and the designer on performances of a buildings

Performance-based design

A design methodology for designing a structure exclusively to satisfy performance requirements regardless of the structural format, structural material, design procedure or construction method. This design methodology explicitly presents the objectives of the structure and the performance requirements to achieve the objectives, defines the performance criteria to provide the performance requirements (functions) and provides the functions satisfactorily by securing the performance requirements throughout the working life of the structure. Similar terms include performance-based design, performance based specification, performance-expressing design and performance-oriented design.

Comprehensive Design Code

- Describing basic rules of design code, e.g. concepts, terminologies and procedures.
- A code for code writers

code PLATFORM

Information Exchanges

International Codes and Standards e.g. ISO2394

Base Design Code A (Railway)

Base Design Code B (Highway)

Base Design Code C (Port and Harbor)

Unified Concepts

Objectives of Code PLATFORM

- Provide a framework of a structural design code based on performance based concept.
- Define structure to define performance requirements.
  Objective – Performance Requirements – Performance Criteria
- Define the elements of Performance Criteria
  Limit states – design situations – time
- Performance verification procedure
  by performance concepts vs. by codes

Drafting Body(2001-2002)

Ministry of Land and Transportation

Contract

JSCE

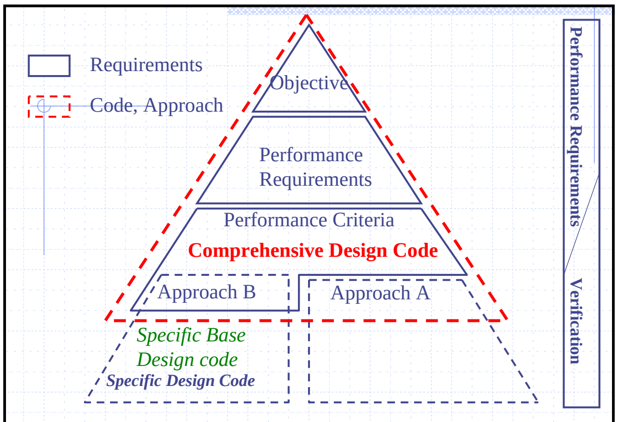
Contract

Consultant (Secretariat)

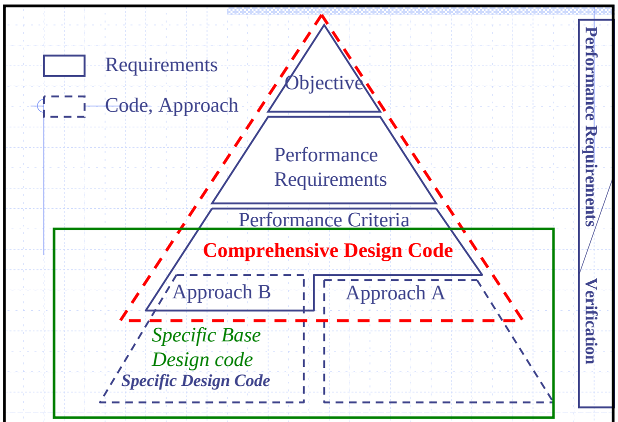
Committee on investigating and drafting a comprehensive design code (25 members)

Chair Osamu Kusakabe
General Secretary Yusuke Honjo

Scholars and Engineers from various
field: steel, concrete, geotechnical, seismic, wind, reliability etc.



Hierarchy of Requirements and Verifications



Verification Approaches

Description of Performance Criteria

Limit states + Magnitude of Action + Importance of Structures

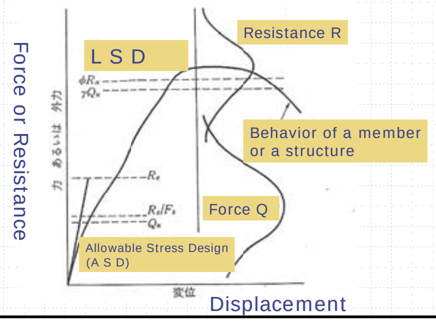
Damage to a Structure

Magnitude of Actions

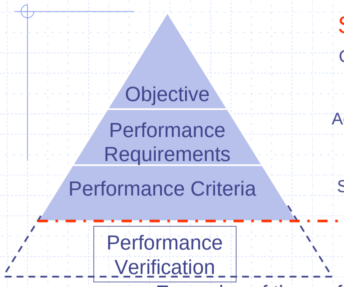
	Serviceability Limit State	Repairable Limit State	Ultimate Limit State
High freq. Low impact	◎○△		
Medium freq. Med. Impact	◎ ○	△	
Low freq. High impact		◎	○ △

Note: ◎ Important Structure ○ Ordinary Structure
△ Easily Repairable Structure

Limit State Design Concept:
The concept Eurocodes are based



Performance based specification
Structure of Port and Harbor Facilities



Standards: Mandatory

Objectives of the facilities

Accountability

Specifications for Verification

Not Mandatory

Examples of the performance verification methods and common values for design will be presented in the Annexes.

Story Two:
The other side of the story.

Government

1995 WTO/TBT agreement enforced

1998 Three year plan for Deregulation

2001 Three year plan for regulation reform promotion

2003 revision work for TSPHS started and SHB started.

2007 TSPHS completed, SHB revision underway.

Engineering Society

1997 JGS committee for PBD started

2001 1st draft of Geo-code 21.

2003 revision work for TSPHS started and SHB started.

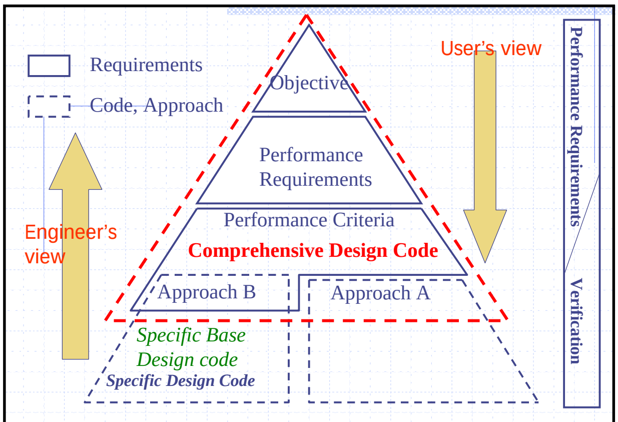
2003 MLT/JSCE code PLATFORM ver.1 published

2004 Geo-code 21 published

2007 TSPHS completed, SHB revision underway.

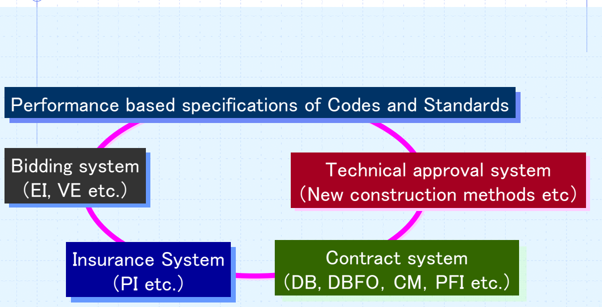
Conclusion

- PBD is NOT engineer driven, it is government policy driven.
- PBD is user/administrator oriented approach, not engineer oriented approach.
- Because of these reasons, it has become popular in very short period of time.



Hierarchy of Requirements and Verifications

Systems to support PBD



(quoted from Horikoshi et al., 2006)

감사합니다. 多謝　ありがとうございます。

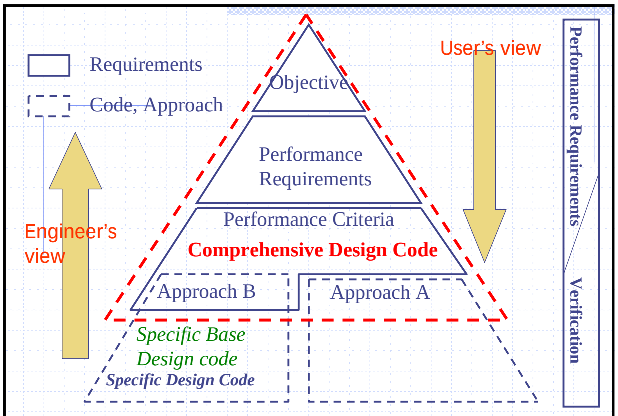
Benefits of Performance Based Design Codes

- Higher accountability and transparency to the users of the codes. Easier to understand the intention of the code writers to the users.
- Easier to harmonize the design codes under different social and legal systems.
- Construction cost reduction is expected by introduction of new technologies?
- Easier to keep consistency of the description of the design code.

Remained Issues of PBD codes

- How to find an interface between the top down approach of users and administrators, and bottom up approach of engineers or code writers.

  (User's thinking vs. Engineers' thinking)
- A social system is required to judge performance of structures based on PBD.
- Judgment for flaw (=defect) in the design when done by PBD.



Hierarchy of Requirements and Verifications

Table of contents

Table of Contents

Comprehensive Design Codes Development in Japan

- **code PLATFORM ver.1 (JSCE, 2003)**

  Principles, guidelines and terminologies for structural design code drafting founded on performance based design concept ver. 1.

  (Japanese Society of Civil Engineers, 2003)
- **Geo-code 21(JGS, 2004)**

  Principles of Foundation Design Grounded on Performance Based Design Concept

  (Japanese Geotechnical Sciety,2004)

Purposes of Comprehensive Design Codes development

- Propose an ideal design code based on performance based concept.
- Harmonize design concepts and terminologies in major Japanese design codes.
- Dispatch our technology to the world by a single voce.

Hierarchy in performance description of a structure (1)

Objective, Performance Requirements and performance criteria

- Objectives: The objective is the final social requirement of a structure with respect to one specific performance (e.g. structural performance) described in the general terminologies.

For examples, 'buildings shall provide sufficient safety to the residence at the time of earthquake events so that they are preserved from serious injuries and loss of lives' or 'Marginal operation of functions of a structure is preserved'.

Hierarchy in performance description of a structure (2)
Objective, Performance Requirements and performance criteria

- Performance requirements: The performance requirements describes the functions of a structure that should be provided to achieve the stated objective by general terminologies.

Example: 'A structure shall not collapse during an earthquake' or 'Damage to a structure shall be controlled to an extent whereby marginal operation is preserved.'.

Hierarchy in performance description of a structure (3)
Objective, Performance Requirements and performance criteria

- Performance Criteria: The performance criteria specify the details that are necessary to fulfill the functional statements. In principle, they should be quantitatively verifiable in structural design.

Performance Requirements is given by a Performance Matrix

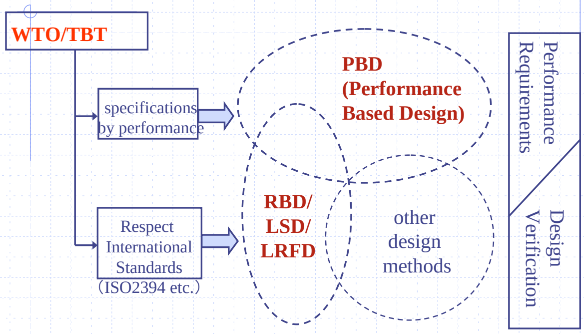
= Limit states + Magnitude of Action + Importance of Structures

Hierarchy in Verification Methods(1)

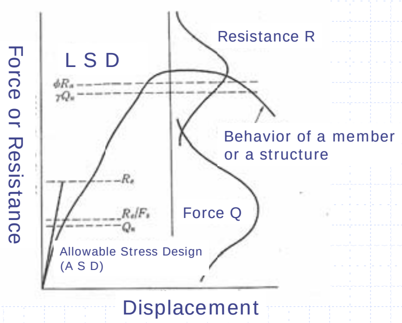
- A Comprehensive Design Code that stands on top of both Approaches A and B
- Approach A: Fully performance based design approach.
- Approach B: A code for code writers. Limit State Design (ISO2394)

It is believed that the Limit State Design Method is one of the most suitable method to realize Performance Based Design (PBD).

WTO/TBT agreement, PBD and RBD



Limit State Design Concept:



Events calendar

1995 WTO/TBT agreement enforced
1997 JGS committee for PBD started
1998 Three year plan for Deregulation
2001 1st draft of Geo-code 21.
2001 Three year plan for regulation reform promotion (revision work for TSPHS started.)
2003 MLT/JSCE code PLATFORM ver.1 published
2004 Geo-code 21 published
2007 TSPHS completed

Government Policy for deregulation (1)

Headquarter for Administrative reform (Head the Prime Minister)
'Three years plan for Deregulation (1998-2000) '
March, 1998 the cabinet decision

1) All economic regulation should be eliminated in principle. The social regulations should be minimized. All regulation should be eliminated or deregulated.
2) Rationalization of regulation methods. For example, tests can be outsourced from the private sector.
3) Simplification and clarification of the contents of the regulations.
4) International harmonization of the regulations.
5) Speed up of the regulation related procedures.
6) Transparency of the regulation related procedure.

Government Policy for deregulation (2)

'Three years plan for regulation reform promotion'
March, 2001 the cabinet decision(2001-2003)

1) Realization of sustainable economic development by promotion of economic activities.
2) Realization of transparent, fair and reliable economic society
3) Secure diversified alternatives for life styles.
4) Realization of economic society that is open to the world.

Government Policy for deregulation (3)

In order to realize such objectives, promotion of essential and active deregulations in various administrative services should be planned.

In the filed of standards and accreditations, the following basic policy was enforced.

- Essential reviews on standards and accreditations to check the necessity of the involvement of the government.
- In cases the administration involvements are still required, the roles of the administration should be minimized, and self-accreditation or self-maintenance of the standards and the accreditations by the private sectors should be promoted.
- The international harmonization of standards, the performance based specifications and elimination of multiple test procedures should be promoted.

Revision of Port and Harbor Law

Article 56 Item 2-2

(Before revision)

Those port and harbour facilities, such as navigation channels and basins, protective facilities for harbours and mooring facilities, should comply with the law that specifies such matter if such a law exists. In addition, their construction, improvements and maintenance should comply with `Technical standards of port and harbour facilities' that is specified as a ministerial ordinance by the ministry of land and transportation.

(After revision)

Those port and harbor facilities, such as navigation channels and basins (they are termed facilities covered by TSPHF), should comply with the law that specifies such matter if such a law exists. In addition, construction, improvements and maintenance concerning performances of the facilities covered by TSPHF should conform with `Technical standards of port and harbor facilities' that is specified as a ministerial ordinance by the ministry of land and transportation.

Background of Revision

International Standards
- ・ISO2394 General principles on reliability for structures, (1998)

↑

Comprehensive Design Codes
- ・Bases for design of civil and building structures (MLT, 2002)
- ・Code Platform ver.1(JSCE, 2003)
- ・JGS-4001-2004 (Geo-code 21)

↑

Specific Design Codes

Design of Port and Harbor Structures

Harmonized and Consistent with the International Codes and the Comprehensive Codes.

Allowable Stress Design with a Safety Factor (Conventional Design Method) ⇒ Reliability Based Design Dynamic Analyses (New Design Method)

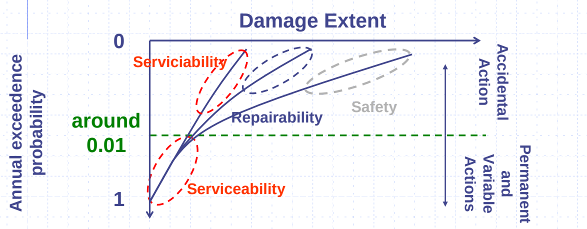
Background in Administrative Aspects

- 'Three years plan for promotion of regulation reform' March, 2001, the cabinet decision
  → For Codes and Standards,
  Harmonized to International Standards,
  Performance based Specification
- Ministry of Land and Transportation,
  Program on Restructuring of Public Works Costs,
  March, 2003 →
  - Revision of Common specifications for civil works
  - Review of Highway Bridge Specifications
  - Revision of Technical Standards for Port and Harbor Facilities to performance based.

Performance Requirements

		Definition
Basic Requirements		Performance of structural response (deformation, stress etc.) against actions.
	Serviceability	The functions of the facility would be recovered with minor repairs.
	Repairability	The functions of the facility would be recovered in relatively short period after some repairs.
	safety	Significant damage would take place. However, the damage would not cause any lives loss or serious economic damages to hinterland.
Other Requirements		Performance requirements on structural dimensions concerning usage and convenience of the facilities.

	Definition	Performance Requirements
Persistent Situation	Permanent actions (self weight, earth pressures) are major actions.	Serviceability
Transient situation	Variable actions (wave, level 1 earthquake) are major actions.	Serviceability
Accidental situation	Accidental actions (Tsunami, level 2 earthquake) are major actions.	Serviceability, Repairability and safety



Summary of Basic Performance Verification Methods

Allowable Performance Verification Methods

- Reliability Based Design (RBD) Method
- Numerical methods (NM) capable of evaluating structural response properly.
- Model tests.
- Methods based on past experiences.

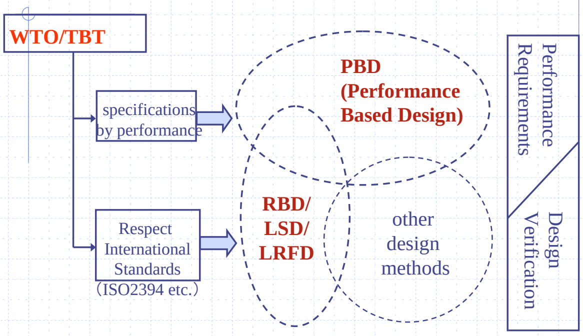
Design situation	Major Actions	Recommended performance verification procedures
Persistent situation and Transient situation	self weight, earth and water pressures, live load, wave, wind, ship etc.	RBD
	Level 1 earthquake	◆Non-linear response analysis considering soil-structure interactions. ◆RBD ◆Pseudo-static procedure (e.g. seismic coefficient method)
Accidental situation	Level 2 earthquake, Tsunami, ship collision etc.	Numerical procedure to evaluate displacements and damage extents.

Conclusion

PBD and RBD are the international standards. (Impact of WTO/TBT)

（1）The design codes are to be based on PBD for describing performance requirements, and the design verification should be based on RBD/LSD/LRFD.

WTO/TBT agreement, PBD and RBD



Conclusion

(2) The Technical Standards on Port and Harbour Facilities has been revised April 2007 based on PBS concept and LSD. The comprehensive design codes that have been developed in the professional societies played some important role.

(3) Design codes are just a part that realize performance oriented design of structures. Other parts need to be developed in parallel.

Events calendar

1995 WTO/TBT agreement enforced
1997 JGS committee for PBD started
1998 Three year plan for Deregulation
2001 1st draft of Geo-code 21.
2001 Three year plan for regulation reform promotion
(revision work for TSPHS started and SHB started.)
2003 MLT/JSCE code PLATFORM ver.1 published
2004 Geo-code 21 published
2007 TSPHS completed

Revision of Port and Harbor Law

Article 56 Item 2-2

(Before revision)

Those port and harbour facilities, such as navigation channels and basins, protective facilities for harbours and mooring facilities, should comply with the law that specifies such matter if such a law exists. In addition, their construction, improvements and maintenance should comply with `Technical standards of port and harbour facilities' that is specified as a ministerial ordinance by the ministry of land and transportation.

(After revision)

Those port and harbor facilities, such as navigation channels and basins (they are termed facilities covered by TSPHF), should comply with the law that specifies such matter if such a law exists. In addition, construction, improvements and maintenance concerning performances of the facilities covered by TSPHF should conform with `Technical standards of port and harbor facilities' that is specified as a ministerial ordinance by the ministry of land and transportation.

Attachment

First Draft of

"Glossary of Terminologies for Design Code"

Glossary of Key Terms for Structural Design Codes founded on Perfomance based Design Concept
Completed by JSCE (May 2008)

code PLATFORM	Terminology defined in 'Principles, guidelines and terminologies for structural design code drafting founded on the performance based design concept ver.1.0 (code PLATFORM ver.1.0)', March 2003, JSCE.
ISO2394	Terminology that is defined in ISO2394 (3rd version. 1998) and should be in accordance with the definitions in and revisions to ISO2394.
JSCE2001	Terminology defined in 'Guidelines for Performance-based Design of Civil Engineering Steel Structures', JSCE, October 2001.
Geo-code 21	Terminology defined in 'JGS 4001-2004 Principles for Foundation Design grounded on a Performance-based Design Concept (Geo-code 21)', completed English transration in March 2006.
MLIT2002	Terminology defined in the comprehensive design codes based on 'Bases of Design for Civil and Building Structures', Japanese Government, Ministroy of Land, Infrastructure and Transportation, October 2002.
ISO13822	Terminology that is defined in ISO13822 (1st version. 2001) and should be in accordance with the definitions in and revisions to ISO13822.
ACMC2006	Asian Concrete Model Code

#	Category	Term	Definition	Reference	See also
	General	**Structure**	Organized combination of connected parts designed to provide some measure of rigidity	ISO2394	
	General	**Structural element**	Physically distinguished part of a structure. EXAMPLES: Column, beam, plate.	ISO2394	
	General	**Structural system**	Load-bearing elements of building or civil engineering works and the way in which these elements function together.	ISO2394	
	General	**Life, lifetime, life period**	The period that begins with the construction of a structure and ends with the discontinuance of its use and its removal for one reason or another. Life is classified into physical, functional or economic life.	JSCE2001	
	General	**Life cycle**	Total period of time during which the planning, execution and use of a construction works takes place. The life cycle begins with identification of needs and ends with demolition.	ISO2394	
	General	**Quality**	A characteristic of a product that is represented using a quantitative indicator. Experimental values of quantitative indicators can be obtained in a predetermined inspection or test. One example is the Charpy impact value.	JSCE2001	
	General	**Reliability**	Ability of a structure or structural element goes fulfill the specified requirements, including the working life, for which it has been designed.	ISO2394	
	General	**Failure**	Insufficient load-bearing capacity or inadequate serviceability of a structure or structural element.	ISO2394	
	Design codes and design methods	**Comprehensive design codes**	Comprehensive design codes are that describe the basis of the design civil structures and buildings within a country or region. It is not a code for designing individual structures, rather, it provides common items such as a mean to specify the performance of the structures, the unification of terminologies, the introduction of safety margins for the design specifications, the format of verification, the standardization of the information transfer among concerned bodies, fundamental check lists for the design, etc. It is a code on the highest level of the design code system hierarchy that covers both Approach A and Approach B. It can be thought of as “a code for code writers,” but contains more basic and useful information than just that required by code writers.	Geo-code 21	
	Design codes and design methods	**Basic specific design codes**	Basic specific design codes are codes that specify the structural performance criteria of structures by regulating agencies such as central government agencies/local government authorities/the owner. It is likely that some recommendations for verification methods and acceptable methods for use with Approach B may be provided.	Geo-code 21	
	Design codes and design methods	**Specific design codes**	Specific design codes are codes that detail the performance criteria of specific structures which may be limited to a specific use or to a certain region, etc. The specification shall be based on the basic specific design code that is ranked above this code. Certain acceptable verification procedures can be attached to this code	Geo-code 21	
	Design codes and design methods	**Performance-based design**	A design methodology for designing a structure exclusively to satisfy performance requirements regardless of the structural format, structural material, design procedure or construction method. This design methodology explicitly presents the objectives of the structure and the functions to achieve the objectives, defines the performance required to provide the functions and provides the functions satisfactorily by securing the performance requirements throughout the working life of the structure. Similar terms include performance-based design, performance-expressing design and performance-oriented design.	JSCE2001	

#	Category	Term	Definition	Reference	See also
	Design codes and design methods	**Performance-based design codes**	A performance-based design is a code whose specifications on structures have not been give by prescriptive means, but by outcome performances based on the requirements of society and/or the client or the owner.NOTE:Reference 6) defines the design method that identifies the relationship between the level of performance required to meet the functional requirements of the structure and the level of action used for verifying the achievement of the requirements as the performance-based or -expressing design method.	Geo-code 21	
	Design codes and design methods	**Specification-based design**	A design methodology for designing a structure using the specified types and sizes of structural materials, analysis procedure, etc. Many of the existing design standards are applicable to this type of design.	JSCE2001	
	Design codes and design methods	**Pre-verified specification**	The specification that exemplifies a “solution” that is considered to satisfy performance requirements. It is applied in the case where no performance verification methods can be explicitly presented. Examples include specifications for structural material and their size for which no relationship is available to performance requirements, analysis methods that do not directly verify the performance requirements considered valid based on the past practice and verification methods using resistance estimation equations. Other terms available are pre-verified criteria and approved design. The term pre-verified specification is used because it is more appropriate than pre-verified criteria as the specification covers existing analysis methods or estimation equations specified in various standards.	JSCE2001	
	Design codes and design methods	**Reliability-based design**	A design methodology that involves the stochastic verification of the probability of a structure reaching a limit state.	JSCE2001	
	Design codes and design	**Target reliability level**	The level of reliability required to satisfy performance requirements	ISO13822	
	Design codes and design methods	**Limit state design**	A design methodology that explicitly defines the limit states to be verified. In most cases, the partial safety factor design method at level I of the reliability theory is adopted as the verification format. The term partial safety factor design is therefore sometimes used to mean the limit state	JSCE2001	
	Design codes and design methods	**Partial factors format**	Calculation format in which allowance is made for the uncertainties and variabilities assigned to the basic variables by means of representative values, partial factors and, if relevant additive	ISO2394	
	Design codes and design methods	**Partial factor design format**	The partial factor design format is a format in which several partial factors are applied to various sources of uncertainties in the verification formula in order to ensure a sufficient safety margin; it is usually classified into the following two approaches.	Geo-code 21	
	Design codes and design methods	**Material factor approach (MFA)**	MFA is a type of partial factor format in which partial factors are applied directly to the characteristic values of basic variables.	Geo-code 21	
	Design codes and design methods	**Resistance factor approach (RFA)**	RFA is a type of partial factor format in which partial factors are applied to resistances.	Geo-code 21	
	General terms on design methodology	**Design work life**	Assumed period for which a structure or a structural element is to be used for its intended purpose without major repair being necessary.	ISO2394	
	General terms on design methodology	**Structural integrity (structural robustness)**	Ability of a structure not to be damaged by events like fire, explosions, impact or consequences of human errors, to an extent disproportionate of the original cause.	ISO2394	
	General terms on design methodology	**Reliability class of structures**	Class of structures or structural elements for which a particular specified degree of reliability is required.	ISO2394	

#	Category	Term	Definition	Reference	See also
	General terms on design methodology	**Required performance matrix**	A matrix indicating the grade of performance that should be provided to a structure and the grades of assumed external forces. The design engineer selects performance that should be provided to a structure from the matrix according to the significance of the structure. Reference 2) proposes required performance matrices concerning earthquakes, fatigue and wind.	JSCE2001	
	General terms on design methodology	**Assessment**	Total set of activities performed in order to find out if the reliability of a structure is acceptable or not.	ISO2394	
	General terms on design methodology	**Pre-evaluation**	The verification made in the structural planning and design phases to evaluate whether the required performance is satisfied or not when fabricating, erecting, using, dismantling or re-using a structure	JSCE2001	
	General terms on design methodology	**Post-evaluation**	The verification of required performance after the fabrication and erection of a structure such as the quality inspection during the fabrication and erection of a structure, and the inspection and investigation while the structure is in service or at the time of damage to the structure due to an accidental external force.	JSCE2001	
	Terms on performance description	**Objective**	The reason for building a structure expressed in general terms. The term owners/users should preferably be used as the subject of sentences.	code PLATFORM	
	Terms on performance description	**Performance requirement**	The performance that a structure should possess to achieve its objectives, expressed in general terms.	code PLATFORM	
	Terms on performance description	**Performance criterion**	The performance requirement described specifically to enable performance verification. Performance criterion is defined by a combination of the limit state of the structure, action and environmental influences and time.	code PLATFORM	
	Terms on performance description	**Basic performance requirement**	The performance requirement that is essential to the achievement of the objectives of the structure. It may also be regarded as the “function” of the structure.	code PLATFORM	
	Terms on performance description	**Significance of structures**	The degree of significance of a structure that should be determined based on the benefit that the structure produces, necessity of the structure under emergency conditions and the availability of alternatives.	code PLATFORM	
	Terms on performance	**Serviceability**	Ability of a structure or structural element to perform adequately for normal use under all expected	ISO2394	
	Terms on limit state	**Limit states**	A state beyond which the structure no longer satisfies the design performance requirements.	code PLATFORM	
	Terms on limit state	**Ultimate limit state**	A state associated with collapse, or with other forms of structural failure NOTE:This generally corresponds to the maximum load-carrying resistance of structure or structural element but in some cases to the maximum applicable strain or deformation.	ISO2394	
	Terms on limit state	**Serviceability limit state**	A state which corresponds to conditions beyond which specified service requirements for a structure or structural element are no longer met.	ISO2394	
	Terms on limit state	**Restorability limit state**	A limit state under which a structure can be used continuously through restoration using applicable technologies at reasonable cost in a reasonable timeframe even in the case of damage expected to be incurred due to an assumed action. It may be regarded as one of the serviceability limit states.	code PLATFORM	
	Terms on limit state	**Irreversible limit state**	A limit state which will remain permanently exceeded when the actions which caused the excess are removed.	ISO2394	
	Terms on limit state	**Reversible limit state**	A limit state which will not be exceeded when actions which caused the excess are removed.	ISO2394	

#	Category	Term	Definition	Reference	See also
	Terms on verification	**Verification**	The determination of whether the structure satisfies the performance criteria or not. In the case of limit state design, whether equation $S \leq R$ or $f(S, R) \leq 1.0$ is satisfied or not is determined where S is the response value and R is the limit value.	JSCE2001	
	Terms on verification	**Verification approach A**	A verification approach that imposes no restrictions on the structural verification method but requires that the design engineer should prove that the structure satisfies the specified performance requirement and ensures an appropriate level of reliability.	code PLATFORM	
	Terms on verification	**Verification approach B**	A verification approach that makes verification of the structure based on the specific base design codes or specific design codes specified by an administrative organization, local public body or business that governs the structural performance of the structure, and according to the procedure shown in such codes e.g. a design calculation procedure.	code PLATFORM	
	Design examination, accreditation and others	**Design examination**	The detailed inspection of a series of design procedures from the definition of an objective to verification made by an accredited third-party organization. Upon the passage of the examination, the third-party organization certifies the design work.	code PLATFORM	
	Design examination, accreditation and others	**Accreditation**	The appointment of organizations that are authorized to carry out examinations.	code PLATFORM	
	Design examination, accreditation and others	**Certification**	The examination of a series of design procedures from the definition of an objective to verification and the issue of a certificate.	code PLATFORM	
	Design examination, accreditation and others	**Compliance**	The satisfaction of requirements	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Action**	a)An assembly of concentrated or distributed mechanical forces acting on a structure (direct actions).b)The cause of deformation imposed on the structure or constrained in it (indirect action).NOTE :In some categorizations, environmental influences are regarded as an action.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Representative value of action**	A value used for the verification of a limit state NOTE:Representative values consist of characteristic values, combination values, frequent values and quasi-permanent values, but may also consist of other values.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Characteristic value of an action**	Principal representative value NOTE 1:It is either on a statistical basis, so that it can be considered to have a specified probability of not being exceeded towards unfavorable values during a reference period, or on acquired experience, or on physical constraints.NOTE 2:Characteristic value : Representative value of parameter estimated to be most suitable to the model for predicting the limit state that is examined in design. Characteristic values should be determined based on a theory or acquired experience fully considering variations and the applicability of a simplified model.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Design values of an action, F_d**	Value obtained by multiplying the representative value by the partial factor γ_F.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Permanent action**	a)Action which is likely to act continuously throughout a given reference period and for which variations in magnitude with time are small compared with the mean value.b)Action whose variation is only in one sense and can lead to some limiting value.	ISO2394	

#	Category	Term	Definition	Reference	See also
	Terms relating to actions, action effects and environmental influences	**Variable action**	Action for which the variation in magnitude with time is neither negligible in relation to the mean value nor monotonic.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Accidental action**	Action that is unlikely to occur with a significant value on a given structure over a given reference period.NOTE:Accidental action is in most cases of short duration.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Fixed action**	Action which has a fixed distribution on a structure, such as its magnitude and direction are determined unambiguously for the whole structure when determined at one point in the structure.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Free action**	Action which may have an arbitrary spatial distribution over the structure within given limits.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Static action**	Action which will not cause significant acceleration of the structure or structural elements.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Dynamic action**	Action which may cause significant acceleration of the structure or structural elements.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Bounded action**	Action which has a limiting value which cannot be exceeded and which is exactly or approximately known.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Unbounded action**	Action which has no known limiting values.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Combination value**	Value chosen, in so far as it can be fixed on statistical bases, so that the probability that the action effect values caused by the combination will be exceeded is approximately the same as when a single action is considered.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Frequent value**	Value determined, in so far as it can be fixed on statistical bases, so that:・・the total time, within a chosen period or time, during which is exceeded is only a small given part of the chosen period of time; or・・the frequency of its exceedance is limited to a given value.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Quasi-permanent value**	Value determined, in so far as it can be fixed on statistical bases, so that the total time, within a chosen period of time, during which is exceeded is of the magnitude of half period.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Action combination**	A combination of design values used for verifying the structural reliability in a limit state where different actions are considered simultaneously. It is also referred to as load combination.	code PLATFORM	
	Terms relating to actions, action effects and environmental influences	**Environmental influence**	Mechanical, physical, chemical or biological influence which may cause deterioration of the materials constituting a structure, which in turn may effect its serviceability and safety in an unfavorable way.	ISO2394	

#	Category	Term	Definition	Reference	See also
	Terms relating to actions, action effects and environmental influences	**Load**	Action acting on the structure that is converted to a combination of mechanical forces loaded directly on the structure. It is input for calculating stress resultant, stress, displacement and other parameters using an action model for the purpose of design.	MLIT2002	
	Terms relating to actions, action effects and environmental influences	**Reference period**	A chosen period of time which is used as a basis for assessing values of variable actions, time-independent material properties, etc.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Design situation**	Set of physical conditions representing a certain time interval for which the design demonstrates that relevant limit states are not exceeded.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Persistent situation**	Normal condition of use for the structure, generally related to its design working life.NOTE: “Normal use” includes possible extreme loading conditions due to wind, snow, imposed loads, earthquakes in areas of high seismicity, etc.	ISO2394	
	Terms relating to actions, action effects and environmental influences	**Transient situation**	Provisional condition of use or exposure for the structure.EXAMPLE:During its construction or repair, which represents a time period much shorter than the design working life.	Geo-code 21	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Characteristic value of a material property**	A prior specified fractile of the statistical distribution of the material property in the supply produced within the scope of the relevant material standard.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Characteristic value of a geometrical quantity**	A quantity usually corresponding to dimensions specified by the designer.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Design value of a material property**	Value obtained by dividing the characteristic value by a partial factor γ_M or, in special circumstance, by direct assessment.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Design value of a geometrical quantity**	Characteristic value plus or minus a additive geometrical quantity.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Conversion factor**	Factor which converts properties obtained from test specimens to properties corresponding to the assumptions made in calculation models.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Conversion function**	Function which converts properties obtained from test specimens to properties corresponding to the assumptions made in calculation models.	ISO2394	

#	Category	Term	Definition	Reference	See also
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Fractile value**	The value of a random variable with a cumulative probability lower than specified.NOTE:Expressed like “x% fractile is y.”	MLIT2002	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Design value**	The design value is the value obtained by multiplying a partial factor by a characteristic value in the case of an MFA partial factor format.	Geo-code 21	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Demand, response value *S***	The physical quantity that occurs in the structure due to an external force.	JSCE2001	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Capacity, limit value of performance *R***	The limit value allowed for the response value. A physical quantity that is determined according to the type of “limit state.” If the response value exceeds the limit value, the performance requirement is not satisfied.	JSCE2001	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Statistical uncertainty**	Uncertainty related to the accuracy of the distribution and estimation of parameters	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Basic variable**	Part of a specified set of variables representing physical quantities which characterize actions and environmental influences, material properties including soil properties, and geometrical quantities.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Primary basic variable**	Variables whose value is of primary importance to the design results.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Limit state function**	A function g of the basic variables, which characterizes a limit state when $g(X_1, X_2, ..., Xn) = 0$: $g > 0$ identifies with the desired state and $g < 0$ with the undesired state.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Reliability index, β**	A substitute for the failure probability P_f, defined by $\beta = -\phi^{-1}(p_f)$, where $\cdot -1$ is the inverse standardized normal distribution.	ISO2394	

#	Category	Term	Definition	Reference	See also
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Reliability element**	Numerical quantity used in the partial factors format, by which the specified degree of reliability is assumed to be reached.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Element reliability**	Reliability of a single structural element which has one single failure dominating failure mode.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**System reliability**	Reliability of a structural element which has more than one relevant failure mode or the reliability of a system of more than one relevant structural element.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Model**	Simplified mathematical description or experimental set-up simulating actions, material properties, the behavior of a structure, etc.NOTE:Models should generally take an account of decisive factors and neglect the less important ones.	ISO2394	
	Terms relating to structural response, resistance, material properties and geometrical quantities	**Model uncertainty**	Related to the accuracy of models, physical or statistical.	ISO2394	
	Terms on performance assessment of existing structures	**Assessment**	Total set of activities performed in order to find out if the reliability of structure is acceptable or not.	ISO13822	
	Terms on performance assessment of existing structures	**Rehabilitation**	The improvement of the resistance of a structure to performance deterioration with time.	code PLATFORM	
	Terms on performance assessment of existing structures	**Upgrading**	Efforts to enhance the mechanical performance of a structure.	code PLATFORM	
	Terms on performance assessment of existing structures	**Damage**	Changes in condition of a structure that may have an adverse effect on its performance.	ISO13822	
	Terms on performance assessment of existing structures	**Deterioration**	The reduction of performance and reliability of a structure with time.	ISO13822	
	Terms on performance assessment of existing structures	**Deterioration mode**	A model of deterioration with time representing the performance of a structure as a function of time.	ISO13822	
	Terms on performance assessment of existing structures	**Inspection**	A nondestructive test conducted in the field to determine the present state of a structure.	ISO13822	
	Terms on performance assessment of existing structures	**Investigation**	The collection of data and evaluation through inspection, data surveys, loading tests and other testing.	ISO13822	
	Terms on performance assessment of existing structures	**Loading test**	A test conducted applying the load or imposed displacement to evaluate the behavior or properties of an entire structure or part thereof or to estimate load bearing capacity.	ISO13822	

#	Category	Term	Definition	Reference	See also
	Terms on performance assessment of existing structures	**Maintenance**	Total set of activities performed during the design working life of a structure to enable it to fulfill the requirements for reliability.	ISO13822	
	Terms on performance assessment of existing structures	**Monitoring**	Frequent or continuous observation or measurement of the condition of a structure or the action applied to the structure. Monitoring generally takes place over a long period of time.	ISO13822	
	Terms on performance assessment of existing structures	**Remaining working life**	The period during which an existing structure is assumed to be maintained and placed in service.	ISO13822	
		Accidental action	Action whose chance of occurrence is very small but the intensity is very high compared to the variable actions.	ACMC2006	
		Action	Mechanical force or environmental effect to which the structure (or structural component) is subjected.	ACMC2006	
		Aerodynamic shape factor	Factor to account for the effect of geometry of structure on the surface pressure due to wind.	ACMC2006	
		Aggregate	Normally inert materials such as river gravel, river sand, sea sand, crushed rock, etc. which are used as ingredients to produce concrete or mortar.	ACMC2006	
		Alkali-aggregate reaction	The reaction between alkali in concrete and the reactive substances in the aggregates.	ACMC2006	
		Analysis (Assessment)	Acceptable methods of evaluating the performance indices or verifying the compliance of specific criteria.	ACMC2006	
		Autogeneous shrinkage	Volume decrease due to loss of water in the hydration process causing negative pore pressure in concrete.	ACMC2006	
		Basic wind speed	Hourly mean wind speed or 3-second peak gust wind speed with a specified probability of exceedence, measured at 10 meters above open country terrain with few, well scattered obstructions.	ACMC2006	
		Biological degradation	The physical or chemical degradation of concrete due to the effect of organic matters such as bacteria, lichens, fungi, moss, etc.	ACMC2006	
		Bleeding	Segregation between water and the other ingredients in concrete causing water to rise up to the surface of the freshly placed concrete.	ACMC2006	
		Carbonation	Action caused by chemical reaction between calcium hydroxide in concrete and carbon dioxide in the environment, resulting in a denser surface for the carbonated concrete and reduction of alkalinity in the carbonated portion.	ACMC2006	
		Characteristic strength	Unless otherwise stated in this code, the characteristic strength of material refers to the value of the strength below which 5% of all test results would be expected to fall.	ACMC2006	
		Chemical admixtures	Admixtures which are usually used in small quantities typically in the form of liquid and can be added to the concrete both at the time of mixing and before placing to improve various concrete properties such as workability, air content and durability, etc.	ACMC2006	
		Coarse aggregate	Aggregate which has almost all its particles retained on a 5mm-size test sieve.	ACMC2006	
		Damage control	A means to ensure that the limit state requirement is met for restorability or reparability of a structure.	ACMC2006	
		Deformability	A term expressing the ability of concrete to deform.	ACMC2006	

#	Category	Term	Definition	Reference	See also
		Degree of deterioration	The extent to which the performance of a structure is degraded or the extent to which the deterioration has progressed from the time of construction, as a result of its exposure to the environment.	ACMC2006	
		Design return period	Inverse of the annual probability of exceedence.	ACMC2006	
		Design life	Assumed period for which the structure is to be used satisfactorily for its intended purpose or function with anticipated maintenance but without substantial repair being necessary.	ACMC2006	
		Design wind pressure	Potential pressure available from the kinetic energy of the design wind speed.	ACMC2006	
		Design wind speed	Wind speed for use in design. It is derived from regional basic wind speed taking into consideration the wind direction, topography, height, importance of structure, design life, size and shape of the structure.	ACMC2006	
		Deterioration factor	The factor affecting the deterioration process.	ACMC2006	
		Deterioration index	An index selected for estimating and evaluating the extent of the deterioration process.	ACMC2006	
		Deterioration prediction	Prediction of the future rate of deterioration of a structure based on results of inspection and relevant records made during the design and construction stages.	ACMC2006	
		Drag	Force acting in the direction of the wind stream.	ACMC2006	
		Drying shrinkage	Volume decrease due to loss of moisture from concrete in the hardened state which is usually serious in hot and dry environment.	ACMC2006	
		Durability design	Design to ensure that the structure can maintain its required functions during its service life under environmental actions.	ACMC2006	
		Durability grade	The extent of durability to which the structure shall be maintained in ord er to satisfy the required performance during its design life. This affects the degree and frequency of the remedial actions to be carried out during that life.	ACMC2006	
		Durability limit state	The maximum degree of deterioration allowed for the structure during its design life.	ACMC2006	
		Durability prediction	Prediction of the future degree of deterioration of the structure based on data used in its design.	ACMC2006	
		Dynamic approach	An approach based on dynamic analysis to assess the overall forces on a structure liable to have a resonant response to wind action.	ACMC2006	
		Dynamic response factor	Factor to account for the effects of correlation and resonant response.	ACMC2006	
		Early age state	The state of concrete from final setting until the achievement of the required characteristic strength.	ACMC2006	
		Environmental actions	An assembly of physical, chemical or biological influences which may cause deterioration to the materials making up the structure, which in turn may adversely affect its serviceability, restorability and safety.	ACMC2006	
		Equivalent static approach	An equivalent or quasi-static approach in which the kinetic energy of wind is converted to equivalent static pressure, which is then treated in a manner similar to that for a distributed gravity load.	ACMC2006	

#	Category	Term	Definition	Reference	See also
		Erosion	The physical degradation of the concrete surface due to abrasive actions like rubbing, water stream action, tyre friction, etc.	ACMC2006	
		Exposure factor	Factor used to account for the variability of the wind speed at the site of the structure due to terrain roughness and shape, height above ground, shielding and topographic conditions.	ACMC2006	
		Fatigue loads	Repetitive loads causing fatigue in the material which reduces its strength, stiffness and deformability. Fatigue loads are considered as variable loads.	ACMC2006	
		Fine aggregate	Aggregate which has almost all its particles passing through a 5mm-size test sieve.	ACMC2006	
		Finishability	The property of concrete at the fresh state which indicates the ease of finishing to obtain a neat surface.	ACMC2006	
		Formwork	Total system of support for freshly placed concrete including the mould or sheathing, all supporting members, hardware and the necessary bracings.	ACMC2006	
		Freezing and thawing	The effect of freezing and thawing of the pore water in concrete, causing its deterioration if repeated continuously.	ACMC2006	
		Fresh state of concrete	The state of concrete after mixing until the completion of placing.	ACMC2006	
		Function	The task which a structure is required to perform.	ACMC2006	
		Grout	A mixture of cementitious material and water with or without admixtures.	ACMC2006	
		Hardened state of concrete	The state of concrete after achieving the required strength.	ACMC2006	
		Importance	Rank assigned to a structure according to the likely overall impact caused by its failure, due to deterioration, to satisfactorily perform its functions as determined at the time of design.	ACMC2006	
		Irregular structures	Structures having unusual shapes such as open structures, structures with large overhangs or other projections, and any building with a complex shape.	ACMC2006	
		Laitance	Substances brought up to the concrete or mortar surface by bleeding water and precipitated at the surface giving a contaminated appearance.	ACMC2006	
		Limit state	A critical state specified using a performance index, beyond which the structure no longer satisfies the design performance requirements.	ACMC2006	
		Limits of displacement	Allowable deformation of structure in terms of such parameters as interstorey drift and relative horizontal displacement, to control excessive deflection, cracking and vibration.	ACMC2006	
		Long-term performance index	Index defining the remaining capacity of a structure in performing its design functions during the design life.	ACMC2006	
		Maintenance	A set of activities taken to ensure that the structure continues to perform its functions satisfactorily during its design life.	ACMC2006	
		Mechanical forces	An assembly of concentrated or distributed forces acting on a structure, or deformations imposed on it.	ACMC2006	
		Mineral admixtures	Admixtures which are normally used in large quantities in power form and are added at the time of batching in order to improve certain properties of the concrete.	ACMC2006	

#	Category	Term	Definition	Reference	See also
		Mix proportions	Proportions or quantities of the ingredient or constituent materials to produce concrete or mortar of a desired quality.	ACMC2006	
		Model	Mathematical description or experimental setup simulating the actions, material properties and behavior of a structure.	ACMC2006	
	@	**Monitoring**	Continuous recording of data pertaining to deterioration and/or performance of structure using appropriate equipment.	ACMC2006	
		Normal concrete	Concrete which is commonly used in construction; it does not include special constituent materials other than Portland cement , water, fine aggregate, coarse aggregate and common mineral and chemical admixtures; it does not require any special practice for its manufacturing and handling.	ACMC2006	
		Overall performance index	Index indicating the overall performance of the structure.	ACMC2006	
		Partial performance index	Index indicating a partial performance of the structure.	ACMC2006	
		Partial safety factor for material	For analysis purposes, the design strength of a material is determined as the characteristic strength divided by a partial safety factor.	ACMC2006	
		Performance	Ability (or efficiency) of a structure to perform its design functions.	ACMC2006	
		Performance index	Index indicating structural performance quantitatively.	ACMC2006	
		Permanent actions	Self-weights of structures inclusive of permanent attachments, fixtures and fittings.	ACMC2006	
		Plastic shrinkage	Shrinkage arising from loss of water from the exposed surface of concrete during the plastic state, leading to cracking at the exposed surface.	ACMC2006	
		Plastic state	The state of concrete from just after placing until the final setting of concrete.	ACMC2006	
		Reliability	Ability of a structure to fulfill specified requirements during its design life.	ACMC2006	
		Remaining service life	Period from the point of inspection to the time when the structure is no longer useable, or does not satisfactorily perform the functions determined at the time of design.	ACMC2006	
		Remedial action	Maintenance action carried out with the objective of arresting or slowing down the deterioration process, restoring or improving the performance of a structure, or reducing the danger of damage or injury to the users or any third party.	ACMC2006	
		Repair	Remedial action taken with the objective of arresting or slowing down the deterioration of a structure, or reducing the possibility of damage to the users or any third party.	ACMC2006	
		Restorability (or reparability)	Ability of a structure to be repaired physically and economically when damaged under the effects of considered actions.	ACMC2006	
		Robustness (or structural insensitivity)	Ability of a structure to withstand damage by events like fire, explosion, impact, instability or consequences of human errors.	ACMC2006	
		Safety	Ability of a structure to ensure that no harm would come to the users and to people in the vicinity of the structure under any action.	ACMC2006	
		Segregation	Separation of one or more constituent materials from the rest of the concrete, such as bleeding, aggregate blocking, etc.	ACMC2006	

#	Category	Term	Definition	Reference	See also
		Service life	The length of time from the completion of a structure until the time when it is no longer usable because of its failure to adequately perform its design functions.	ACMC2006	
		Serviceability	Ability of a structure to provide adequate services or functionality in use under the effects of considered actions.	ACMC2006	
		Settlement	Sinking of the concrete surface after placing due to bleeding and/or escaping of the entrapped and entrained air in the concrete.	ACMC2006	
		Shores	Vertical or inclined support members designed to carry the weight of the formwork, concrete and other construction loads.	ACMC2006	
		Special concrete	Concrete other than normal concrete including lightweight concrete, rollercompacted concrete, self-compacting concrete, fiber-reinforced concrete, anti-washout underwater concrete, etc.	ACMC2006	
		Stiff and flexible structures	Stiff structures refer to those that are not sensitive to dynamic effects of wind, while flexible ones are those that are sensitive to such effects.	ACMC2006	
		Strengthening	Remedial action applied to a structure with the objective of restoring or improving its load bearing capacity to a level which is equal to, or higher than, the original design level.	ACMC2006	
		Surface finishing	Action, such as trowelling, applied to the exposed portion of concrete to obtain a neat surface.	ACMC2006	
		Temperature cracking	Cracking caused by thermal stress which arises from differential temperatures in the concrete mass.	ACMC2006	
		Threshold level of	Minimum acceptable level of performance of a structure.	ACMC2006	
		Tributary area	Area of building surface contributing to the force being considered, due to wind actions, and projected on a vertical plane normal to the wind direction.	ACMC2006	
		Ultimate limit state	Limit state for safety.	ACMC2006	
		Variable action	Action due to a moving object on the structure as well as any load whose intensity is variable, including traffic load, wave load, water pressure, earth pressure, and load induced by temperature variation.	ACMC2006	
		Wind tunnel test	Test modeling the atmospheric boundary layer characteristics, to obtain wind speed multipliers and/or pressure coefficients.	ACMC2006	
		Workability	The term expressing the ease with which concrete can be placed, compacted and	ACMC2006	