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Development of a basic specific design code on performance based specification concept: The Technical Standards for Prot and Harbor Facilities (2007)

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ABSTRACT: There have been movements in Japan to develop a serious of comprehensive structural design codes that can harmonize all the major Japanese structural design codes. This movement is much motivated by the rapid development and popularisation of international and regional structural design codes such as ISO2394 and Structural Eurocodes, as well as of the performance based specification concept especially after the conclusion of WTO/TBT agreement in 1995. In proposing such efforts, it is much contemplated to propose a concept that can harmonize all the major Japanese structural design codes that have been developed rather separated way due to many historical reasons. The performance based specification (PBS) (or the performance based design (PBD)) and the limit state design (LSD) are the two concepts we introduced to achieve this aim. 'Principles for Foundation Designs Grounded on a Performance-based Design Concept' (nick name 'Geo-code 21') by JGS (Japanese Geotechnical Society) and 'code PLATFORM ver.1' by JSCE (Japan Society of Civil Engineers) are proposed along this line. In April 2007, the new version of the Technical Standards for Port and Harbour Facilities (TSPHF) has been published. This is one of the major Japanese civil structural design codes. In the new version of TSPHF, the performance based specification concept and the reliability based design method are the two major concepts of the revision. This paper reports the background and the process of this revision in connection with the previously published code PLATFORM ver.1 and Geo-code 21.

1 INTRODUCTION

1.1 Background

Movements to establish a series of comprehensive design codes that are able to harmonize major civil engineering codes are emerging in Japan about a decade ago. These activities are much motivated by the conclusion of WTO/TBT agreement in 1995 and the rapid development and popularisation of international and regional structural design codes including ISO2394 and Structural Eurocodes.

In WTO/TBT agreement,

which actually consists one of the basic policies on economy and trade of the Japanese government, it is stated that

'where technical regulations are required and relevant international standards exist or their completion is imminent, Members shall use them, or the relevant parts of them, as a basis for their technical regulations' (Article 2.4).

It also addresses that

'wherever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or descriptive characteristics' (Article 2.8).

Based on these requirements, there are considerable work going on for the major Japanese structural design codes to revise them from the traditional descriptive specifications to performance based specifications, and from working (or allowable) stress design codes to the limit state design codes.

The impact of close completion of Structural Eurocodes (most probably before 2010) is also very pronounced in Japan. As it is clearly stated in Eurocode 0 that main purposes of establishing Eurocodes are

(1) promote construction industries with in EU region by unifying the market, and

(2) strengthen the competitiveness of EU construction industry against non-EU.

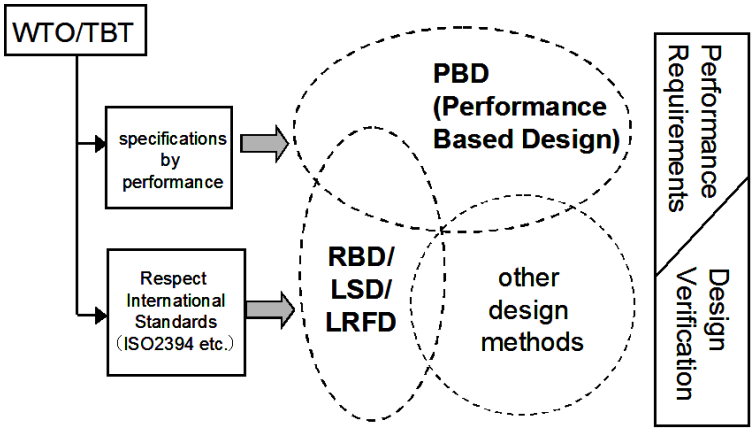

Fig.1 WTO/TBT agreement, PBD and LSD/RBD

The works to draft Eurocodes stated sometime in 1970's, and they have taken almost 40 years to complete this series of documents which provides a set of rules for design of civil and building structures thereby eventually replace present design rules that are different from on countries to another in EU and EFTA countries.

It is the essence of LSD (Limit State Design) to clearly identify a state that separates a structure from undesirable to desirable situation in design verification. Because of this characteristic, LSD is, at least, one of the most suitable design methods to carry out PBD/PBS. The relationships among WTO/TBT, PBD/PBS and LSD in the current design framework are illustrated in **Fig.1**. It is our belief that the specifications of performance of the structures would be described based on the concept of PBD/PBS, whereas the verification of design would be based on LSD/RBD for all the major design codes in the world.

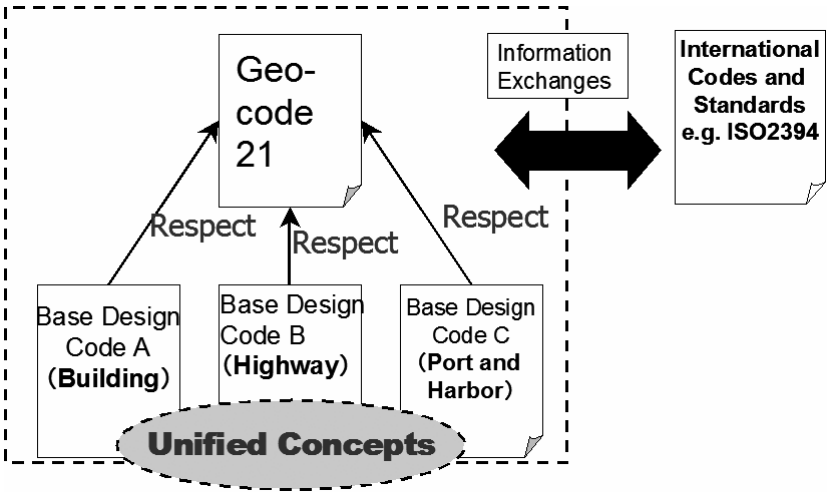

Fig.2 Concept of the comprehensive design code

1.2 Establishment of Comprehensive Design Codes in Japan

In order to cope with the situations explained in the previous section, movements to establish a series of comprehensive design codes have been started in Japan. One of the initial works of this kind of movements started in 1997 at JGS (Japanese Geotechnical Society) as drafting of 'Geocode 21'[*], a proto type comprehensive foundation design code that can harmonize all the major foundation design codes in Japan. The comprehensive design codes stand at the top hierarchy level in all the structural design codes in Japan to give concepts, framework and terminologies for structural design codes as indicated in **Fig.2**. It is not intended to be legally enforced but as agreements among the professions (more specifically, the code writers) to draft structural codes based on the rules, terminologies and concepts established by the comprehensive design codes. Therefore, it is thought that it is most appropriate for professional societies such as JSCE (Japan Society of Civil Engineers) and JGS (Japanese Geotechnical Society) to publish such codes.

In proposing the code, it was much contemplated to propose a concept that can harmonize all the major Japanese foundation design codes that have been developed rather separated way due to many historical reasons. The performance based specifications for describing requirements and the limit state design for design verification are the essential two concepts that have provided bases for this comprehensive design code. By doing so, we intend to dispatch the Japanese foundation design technology to the world by a single voice. In the past six years of the research period, we have drafted the main text that consists of 8 chapters and appendixes of this code, which was published as a design standard of JGS (JGS-4001-2004) in 2004. The official name of the code is *Principles for Foundation Designs Grounded on a Performance-based Design Concept.*

Chapter 0 'Bases of structural design' in Geo-code 21 is drafted to propose a comprehensive design code for all civil and building structures. This idea has attracted interests of some officers at the Ministry of Land and Transportation (MLT) of the central government, and JSCE has contracted a research project form the MLT to draft such comprehensive code between 2001 and 2003. The outcome of this research activity is 'code PLATFORM ver.1', *Principles, guideLines And Terminology for structural codes drafting founded on the perFORMance based design concept*.

In this paper, the contents of 'code PLATFORM ver.1' is briefly presented. More through explanation on these codes can be seen in Honjo (2006) and Honjo et al. (2005). Furthermore, the recently developed Technical Standards for Port and Harbour Facilities (TSPHF, 2007 version) is going to be introduced emphasizing the contributions of the comprehensive design codes to TSPHF.

[*] 'Geocode 21' is a nick name of this design code. This name has been used from the beginning of the project. The final official name of the code is *Principles for Foundation Designs Grounded on a Performance-based Design Concept* and the official number of the code is JGS-4001-2004.

Table 1 Table of contents of code PLATFORM ver.1

1. Definitions of terminologies
1.1 General terms
1.2 Terms on design methodology
1.3 Terms on action and environmental influence
1.4 Terms on structural response, resistance, material property and geometrical quantity
1.5 Terms on performance assessment of existing structures

2. General
2.1 Scope
2.2 Framework of design code

3. Performance requirements of structures
3.1 Objectives of structures
3.2 Performance requirements
3.3 Performance criteria
3.3.1 Definitions
3.3.2 Limit states of structures
3.3.3 Actions, environmental influences: magnitude and their combinations
3.3.4 Time
3.3.5 Significance of structures

4. Verification procedures

4.1 Allowable verification procedures
4.1.1 General
4.1.2 Designers
4.2 Verification approach A
4.3 Verification approach B

5. Structural design report

2 CODE PLATFORM VER. 1

2.1 Table of contents

Presented in **Table 1** is the table of contents of *'code PLATFORM ver.1'*. Many terminologies are defined in the first chapter. It was a policy of the drafters of this code to minimize the number of newly defined terminologies as much as possible, and tried to use those defined in the authorized documents such as ISO 2394 (ISO,1998). Newly defined words did not exceed more than ten. Chapter 1 serves as a glossary of terminologies in drafting a new structural design code.

Chapter 2 specifies the scope and the framework of a structural design code. It gives the outline of performance requirements description structure and verification procedures that are described in more detail in the following chapters.

The main body of the document is Chapters 3 and 4 that respectively describe objectives, performance requirements and performance criteria of a structure, as well as verification approaches that should be conformed by any structural design codes.

The last chapter, Chapter 5, specifies the contents of a structural design report that need to be reported form a designer to an owner. This is to clarify the information flow concerning design works and responsibility of each party involved in this activity.

2.2 Main features

In 'code PLATFORM ver.1', an ideal design code to harmonize all major design codes in Japan is pursued. Since the code is free from any legal constraints, it was considered appropriate to look for new generation of code that can be used in the next several decades. None of the Japanese major structural design codes could be drafted with such freedom due to the various constraints, and this is a great advantage of this code. The scope of the code includes all categories of structures.

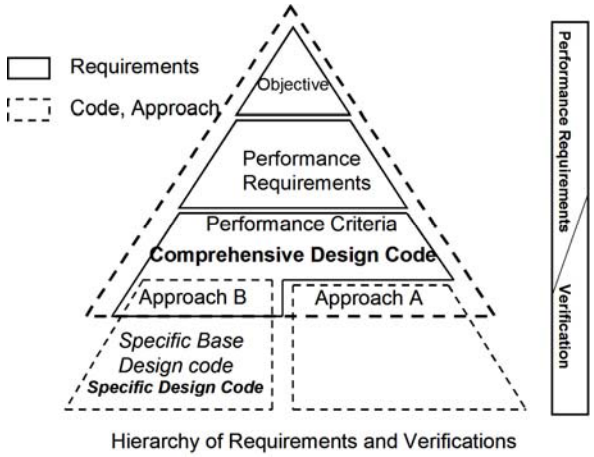

Fig.3 Hierarchy of performance requirements, verification and codes

(1) Performance requirements description structure

The performance requirements for structures are hierarchized in order to increase transparency and accountability of the code so as to improve dialogs between citizens and code writers on structural performances of infrastructures. The hierarchy structure is presented in **Fig.3**, which consists of the three layers, namely Objectives, performance requirements and Performance criteria defined respectively as follows:

Objectives: Objectives are final social requirements to a structure for one of its specific performance (e.g. structural performance) described in general terminologies.

Performance requirements: Performance requirements describe functions of a structure that should be provided to achieve the stated objectives by general terminologies.

Performance criteria: Performance criteria specify details that are necessary to fulfill the performance requirements. In principle, they should be quantitatively verifiable in structural design, and should be defined based on four factors: limit states (e.g. damage levels of the structure), magnitude and frequency of an action or their combinations, time and the importance of the structure.

The three level representation of performance requirements on a structure is widely accepted including well know Nordic five levels (NKB, 1978).

(2) *Design verification procedures and LSD*

Two verification procedures are introduced in *'code PLATFORM ver.1'*, namely Verification approach A and B, as shown in Fig.3. Verification approach A is the fully performance based design approach where designers are only given the performance requirements of the structures; and requested to verify their design, where the results would be checked, for example, by an accredited organization or a committee.

On the other hand, Verification approach B is a verification procedure based on design codes: these codes may be established for each category of structures (e.g. highway bridges, buildings etc.) by the authorities who are either owner or one responsible for the administration and safety of the category of structures. In Verification approach B, *'code PLATFORM ver.1'* is to be used as a code for code writers.

In both Approaches A and B, LSD is recommended to be used for verification. which ISO2394, *General principles on reliability for structures*, is founded on (ISO, 1998). It is presumed that LSD is one of the most suitable methods to realize PBD/PBS.

It should also be known that the Ministry of Land and Transportation (MLT) of the Japanese government has established a based of design code for civil and building structures in 2002 (MLT, 2002). The reason for establishing such a document was that due to many historical reasons, the concepts and the terminologies on LSD had not been harmonized among civil and building structures as well as among steel, concrete, wood and geotechnical structures. The document has succeeded in the harmonization to some extent, but the contents are just limited to LSD and are very similar to those of ISO2394. It is not inappropriate to say that this is Japanese version of ISO2394.

3 DEVELOPMENT OF TSPHF (2007)

3.1 Japanese Government Policy on Technical Standards and Accreditations

Since 1995 (this is the year WTO/TBT agreement has come into effect.), the Japanese Government has taken the policy of deregulation of various laws and rules on economic activities and trades. In March 1998, 'Three year plan for deregulation' was determined as a cabinet decision, where the following tasks were stated:

(1) All economic regulations should be eliminated in principle. The social regulations should be minimized.
(2) Rationalization of regulation methods. For example, tests can be outsourced to 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.

Following the above plan, 'Three years plan for regulation reform promotion' was determined as a cabinet decision in March, 2001, which consisted of the objectives as below:

(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.

In order to realize such objectives, promotion of essential and active deregulations in various administrative services were planned. In the filed of standards and accreditations, the following basic policies were 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 examination procedures in accreditation processes should be promoted.*

The third item had very strong impact on the revision of design standards and codes of civil structures. The Ministry of Land and Transportation (MLT) started a program on Restructuring of Public Works Costs in March, 2003, which includes tasks as below:

- Revision of Common specifications for civil works
- Review of Highway Bridge Specifications

- Revision of Technical Standards for Port and Harbour Facilities to performance based. The revision of Technical Standards for Port and Harbour Facilities (TSPHF) has started around this time making the harmonization of the standards to the international agreement.

3.2 Revision of TSPHF

Based on the background explained in the previous sub-section, the Port and Harbour Law was revised at the parliament, whose proclamation was in September 2006, and enforcement on 1 April 2007. The item that influenced the revision of the standards is presented in Table 2, which is Article 56 Item 2-2. In the revision, the performance of facilities are regulated rather than prescribing the specifications of design details.

Table 2 Revision of Port and Harbour 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, improvement 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 harbour facilities, such as navigation channels and basins, protective facilities for harbours, and mooring facilities (they are termed facilities covered by TSPHF), should comply with the law that specifies such matter if such a law exists. In addition, construction, improvement and maintenance concerning performances of the facilities covered by TSPHF should comply with `Technical standards of port and harbour facilities' that is specified as a ministerial ordinance by the ministry of land and transportation.

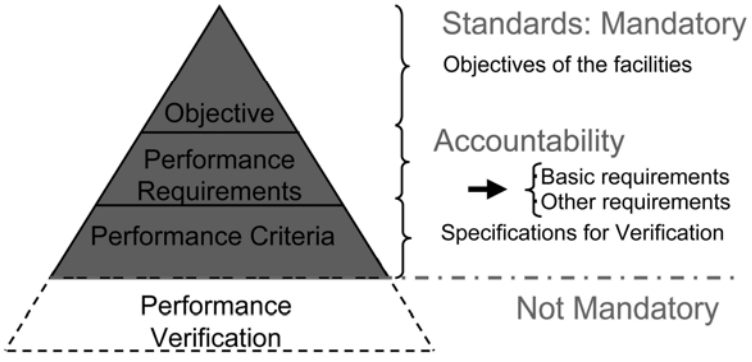

Fig.4 Performance based specifications of TSPHF

Based on the revised Port and Harbour Law, TSPHF was fully revised. The main points of the revision are summarized from two aspects here, namely the system of the performance based specifications, and the performance verification. The comprehensive design codes that had been established in the past (MLT, 2002; JOCE, 2003; JGS, 2004) gave bases for the revision of this technical standards.

(1) System of the performance based specifications

The basic system of the TSPHF is that the required perfomrances of the structures are given as mandetory items in the three levels, i.e. objectives, performance requirements and performance criteria, whereas the performance verification methods are not mandetory but are given in the annex or in the reference documents as some of the possible methods (Fig.4).

The objectives state necessity of the structures, whereas the performance requirements state the functions of the stuructures that need to be immplemented in the structures to satisfy the objectives in plain language from a view point of accountability. The perfomance criteria restates the performance requirements from technical view points, thus make each performance requirement verifiable.

Table 3 Performance requirements in TSPHF

Classification		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.

The performance requirements are classified into the basic requirements and other requirements (Table 3), where the former specifies structural performances against various actions and their combinations, and the latter gives structural dimensional requirements coming from the usage and conveniences. The basic requirements are further classified into serviceability, repairability and safety requirements as defined in Table 3.

Table 4 Summary of the basic requirements

Design Situation	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

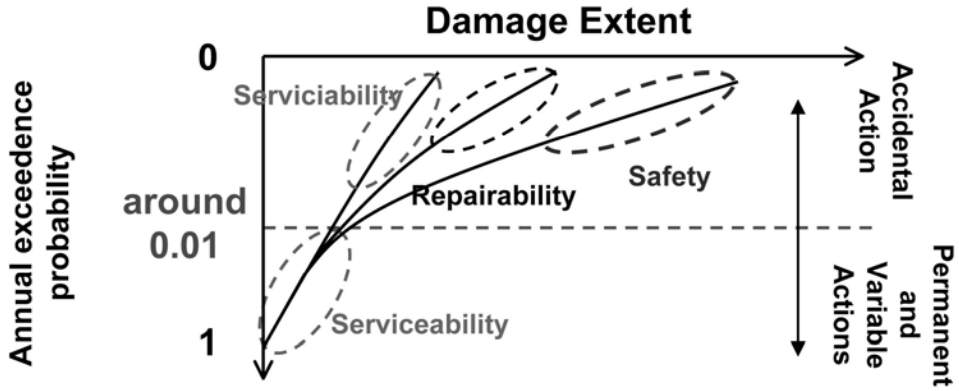

Fig.5 Classifications of performances, actions and frequency

The basic requirements should be combined with the actions considered in the design, which are summarized in Table 4. The combinations of performance requirements and actions are termed design situations, where performance verification on the structure should be carry out for each design situation. The actions are classified into accidental and permanent / variable actions taking the annual occurrence rate of about 0.01 (i.e. the return period of 100 years.) as a threshold value. For both permanent and transient design situations, serviceability need to be satisfied, whereas in the accidental situations, either of the three performance requirements need to be satisfied depending of the importance and functions of the structure under design. This concept is further illustrated in Fig.5. It should be noticed that the performance of a structure may not be able to be verifiable in the accidental situation in some cases.

The objectives and the performance requirements are prescribed in the MLT (the Ministry of Land and Transportation) ministerial ordinance part of the TSPHF, whereas the performance criteria are specified in the MLT declaration part of the TSPHF that defines the details of the TSPHF. In this way, the hierarchy of the performance specifications are kept.

(2) Performance verification

In order to harmonize the TSPHF to the international standards such as ISO2394, and introduce the newly develop verification methods using more sophisticated design calculation methods such as seismic response analyses, the following verification methods are introduced in the revised TSPHF:

Table 5 Summary of basic performance verification methods

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.

- Reliability based design (RBD) methods, mainly Level I partial factor approach.
- Numerical methods (NM) capable of evaluating structural response properties.
- Model tests.
- Method based on past experiences.

The performance verification implies design procedures to verify for the structures to satisfy the specified performance requirements and/or the performance criteria. In principal, the revised TSHPF does not specify any concreter allowable values for strength nor displacement. So as the tolerable failure probability, safety indices nor characteristic values on basic variables in the design. These are all under the decision of designers.

However, it is considered necessary to provide standard verification methods together with the minimum tolerable limit values for the design in order for the users of the revised TSPHF to understand the intentions of the code writers. For this purpose, it is judged appropriate to provide these information in the form of annex and supporting documents.

As an example, design of break water in persistent situation where a case the major action is wave, it is recommended to employ RBD based on force equilibrium. Level I RBD is adopted, and recommended partial factors are provided in tables in the annex. In case of a caisson-type break water on rubble embankment, the serviceability is required for the wave force of 50 years return period (a variable action), the partial factors are provided which are determined based on the annual failure probability of 0.01 or below for sliding, overturning and bearing capacity failure.

4 CONCLUSION

The purpose of this paper was to introduce the revision of the Technical Standards for Port and Harbour Facilities (TSPHF) which has just been revised April 2007 focussing on the contributions of the comprehensive design codes that have been developed in the past several years mainly by the professional societies such as JSCE and JGS.

It is considered that TSPHF is one of the first cases of revision of design codes based on the performance based design/specification concept. Other design codes are expected to follow the similar path for the revision. The comprehensive design codes such as MLT (2002); JOCE (2003) and JGS (2004) have been and expected to contribute considerably to these activities.

Finally, it should be emphasized that the development of PBD based design codes are just a part of activities to realize the truly performance oriented design of structures. As illustrated in Fig. 6, balanced development of other systems is inevitable for enhancing the dissemination of performance-oriented design, and maximizing its advantages. It is also important that these systems be developed international harmonization in the scope (Horikosi, Honjo and Iizuka, 2006).

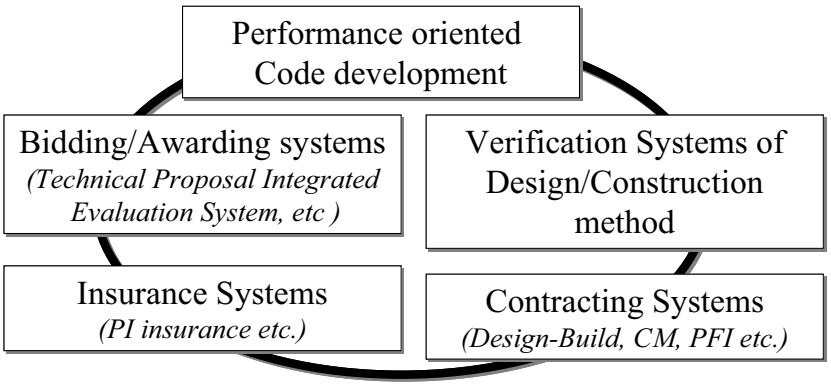

Fig.6 Systems promoting performance-based design (after Horikosi et al., 2006)

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