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JGS comprehensive foundation design code: Geo-code 21

JGS comprehensible code de design des foundations: Geo-code 21

Y. Honjo
Department of Civil Engineering, Gifu University, Gifu, Japan

Y. Kikuchi
Port & Airport Research Institute, Yokosuka, Japan

M. Suzuki
Shimizu Corporation, Tokyo, Japan

K. Tani
Department of Civil Engineering, Yokohama National University, Yokohama, Japan

M. Shirato
Public Works Research Institute, Tsukuba, Japan

ABSTRACT

A proto type comprehensive foundation design code which can harmonize all the major foundation design codes in Japan is proposed in this study. This study is much motivated by the rapid development and popularization of the limit state design based design codes in the world, including ISO2394 and Eurocodes, as well as of the performance based design concept especially after the conclusion of WTO/TBT agreement in 1995. In proposing the code, it is much contemplated to propose a concept which can harmonize all the major Japanese foundation design codes that have been developed rather separated way due to many historical reasons. *A comprehensive design code* is a concept we proposed to achieve this aim. By doing so, we intend to dispatch our foundation design technology to the world by a single voice. This code just has been established as one of JGS Standards under the name '*Principles for Foundation Design Grounded on Performance Based Design Concept*'.

RÉSUMÉ

Un comprehensible proto type de design des foundations qui peut harmoniser avec tous les codes de design de foundations principales au Japon est propose dans cette etude. Elle est essentiellement mue par le developpement et la generalization rapides des codes de design bases sur les codes de design des pays dans le monde, incluant ISO2394 etEurocodes, de meme que le concept du design base sur la performance particulierement après la conclusion du Traite WTO/TBT en 1995. Lors de notre proposition de ce code, nous avons bien examine de proposer un concept pouvant harmoniser avec tous les codes de design des foundations nippones capitals qui ont separemment ete developes pour beaucoup de raisons historiques. Un proto type code de design comprehensible est un concept que nous avons proposee pour atteindre cet objectif. En le faisant ainsi, nous avons l'intention de transfere dans le monde notre technologie de design des foundations par une simple voix. Ce code a ete etabili comme l'un des Standard JGS sous le nom "Principes pour le Design du Fondement Base sur le Concept du Design a la Performance".

1 INTRODUCTION

Movements to harmonize major civil engineering design codes are emerging in Japan recently. These activities are much motivated by the conclusion of WTO/TBT agreement in 1995 and the rapid development and popularization of international and regional structural design codes including ISO2394 and Structural Eurocodes.

In WTO/TBT agreement, 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 design (PBD), and from working (or allowable) stress design codes to the limit state design (LSD) 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.*' 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 one country to another in EU and EFTA countries.

It is the essence of LSD 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. The relationships among WTO/TBT, PBD and LSD in the current design framework are illustrated in Fig. 1.

In order to cope with the situations explained above, movements to establish a series of comprehensive design codes have been started in Japan. One of the initial works of this started in 1997 at JGS (Japanese Geotechnical Society) as drafting of so called 'Geocode 21', a proto type comprehensive foundation design code that can harmonize all the major foundation design codes in Japan that have been developed rather separated way

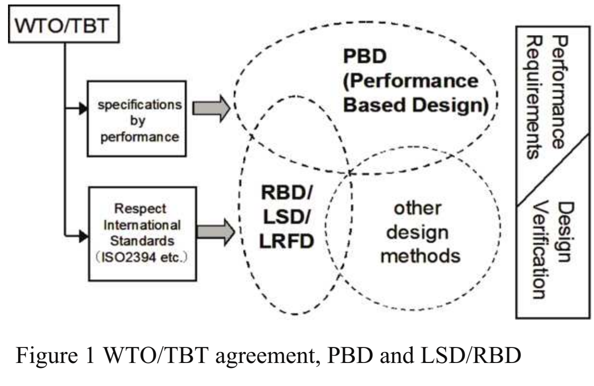

Figure 1 WTO/TBT agreement, PBD and LSD/RBD

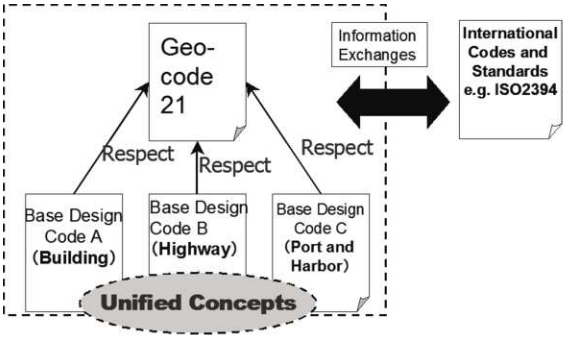

Figure 2 Concept of comprehensive design code

due to many historical reasons. By doing so, we intend to dispatch the Japanese foundation design technology to the world by a single voice.

The comprehensive design code stands at the top hierarchy level in all the foundation design codes in Japan to give concepts, framework and terminologies for foundation 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 the codes based on the principles, terminologies and concepts established by these comprehensive codes. Therefore, it is thought that it is most appropriate for a professional society such as JGS (Japanese Geotechnical Society) to publish such codes. This code just has been established as one of JGS Standards under the name '*Principles for Foundation Design Grounded on Performance Based Design Concept*' in earily 2005. Through out this paper, this code is termed Geo-code 21, which is a nickname we have given to this code since the start of this work in 1998.

2. CONTENTS AND PURPOSES OF GEO-CODE 21

2.1 *Contents of Geo-code 21*

Presented in Table 1 is the table of contents of Geo-code 21. Chapter 0 is drafted to propose a comprehensive design code for all civil and building structures. We needed to draft such chapter because there was no such code in Japan at that time.

The ver.2 of Geo-code 21 has been translated into English, and is available in the Proceeding of IWS Kamakura pp. 401-457 (JGS, 2002). This draft can be seen in the home page given in the reference.

2.2 *Harmonization of Japanese foundation design codes*

Geo-code 21 is drafted pursuing for an ideal foundation design code in Japan. That is to say, the code is aiming at systematizing and harmonizing the major foundation design codes in Japan that have been developed rather independently due to some historical and legal reasons.

In proposing such code, it is neither meaningful nor successful to try to develop a code at the same level to the existing major design codes: An advanced concept is definitely required in proposing such a code. The performance based design concept is employed as the backbone of this code, and is used to harmonize the major design codes on a ground that is different from that of the present major design codes are based.

Table 1 Table of contents of Geo-code 21

0. BASES OF STRUCTURAL DESIGN
0.1 Scope of application
0.2 Objective
0.3 Functional statements
0.4 Performance requirements
0.5 Acceptable verification methods
0.6 Verification by Approach A
0.7 Verification by Approach B
0.8 Documents related to design and construction
0.9 Revision of the present code
0.10 Definitions of terms and notations

1. BASES OF FOUNDATION DESIGN
1.1. Scope of the design code
1.2. Objectives of foundations
1.3. Functional statements
1.4. Performance requirements
1.5. Design of foundations
1.6. Verification by Approach A
1.7. Verification by Approach B
1.8. Seismic design of foundations
1.9. Foundation design report

2. GEOTECHNICAL INFORMATION
2.1. Scope
2.2. Objective
2.3. Interpretation of geotechnical information
2.4. Relationship between geotechnical investigation and structural design
2.5. Procedure of geotechnical investigation
2.6. Other matters

3. DESIGN OF SHALLOW FOUNDATION
3.1. Scope
3.2. Objective
3.3. Functional statements
3.4. Performance requirements
3.5. Investigation of ground and surrounding conditions
3.6. Matters to be considered in design
3.7. Analysis of shallow foundation
3.8. Verification
3.9. Execution

4. DESING OF PILE FOUNDATION
(Sections are omitted here)

5. DESIGN OF COLUMN TYPE FOUNDATION
(Sections are omitted here)

6. DESIGN OF RETAINING STRUCTURE
(Sections are omitted here)

7. DESIGN OF TEMPORARY STRUCTURE
(Sections are omitted here)

Annex:
A An example of comprehensive design code:
B Comments on seismic design of foundations
C Comments on geotechnical information for foundation design
D Determination of characteristic values from a small number of samples
E Comments on shallow foundation design
F Comments on pile foundation design
G Comments on column type foundation design
H Comments on earth retaining structures design
I Comments on temporary structures

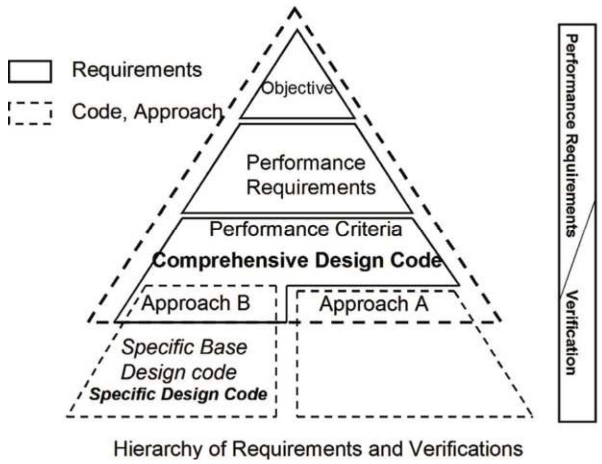

Figure 3 Hierarchy of performance requirements, design verification and codes

The comprehensive design code is fully performance based design code; but at the same time, it can be looked at as *'a code for code writers*'.

The aims of this code are as follows:

- To define means to specify the structure performances.
- Unification of terminologies.
- Methods and formats to introduce the safety margin to various limit states in design.
- Standardize characteristic value determination in geotechnical design.
- Standardize information flow (i.e. documents preparation) among owner, designer, constructor, geotechnical investigator and others.
- The limit state design (LSD) concepts is introduced for design verification.

For all the major design codes in Japan, it is principal that the design changes from the next day a revised code is enforced for the category of structures under the control of that code because of the legal background. It is too strong constraint for a code to introduce new concepts. For this reason, it is our experience that all the new concepts introduced to the codes are creepingly deformed, stripped of its essential contents in the process of drafting, and finally enforced with no substances.

It is not expected that Geo-code 21 is to be used in the actual design from the day it is issued; it is rather pursuing an ideal code which all the code should finally merge into it in the near future. It is expected that various foundation design codes in Japan to accept the concepts and the formats etc. proposed in this code, and finally mildly harmonized to this code in a certain time interval.

3. MAJOR CHARACTERISTICS OF GEO-CODE 21

3.1 *Performance based design*

One of the distinguished features of Geo-code 21 that is very different from Eurocodes and other ISO codes is introduction of PBD concept.

The performance requirements of foundations are hierarchized in order to increase transparency and accountability of the code. The hierarchy structure of Geo-code 21 has already been presented in Fig. 3. It consists of the three layers, namely Objective, performance requirements and Performance criteria. The definitions of these three levels are given 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. 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 expected to a structure is preserved'.

Performance requirements: Performance requirements describe functions of a structure that should be provided to achieve the stated objective by general terminologies. For examples, 'A structure shall not collapse during earthquake' or 'Damages to a structure shall be controlled to an extent where marginal operation is preserved'.

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

Levels of performance criteria of a structure should be determined based on the magnitude and the frequency of load the structure is exposed to during its service life, and the importance of the structure. In Geo-code 21, three performance criteria levels are proposed (Honjo and Kusakabe, 2002).

3.2 *Diversification and standardization of design verification methods*

There seems to be two large trends in structural design codes development in the world: One is the diversification or the increase of freedom in the design which has gained momentum from the conclusion of WTO/TBT where use of the performance based specifications on all industrial products has been agreed.

The other trend is the standardization or the unification such as ISO and Eurocodes that attempt to standardize and unify all design verification methods in a region or the world. It is requited to account for these two trends (i.e. the diversification and the standardization) simultaneously in developing a new code, although these two trends sometimes look contradictory to each other.

In order to account for these two trends at the same time, two different approaches in the verification of structural performance, namely Verification approach A and B, are proposed in Geo-code 21(Fig.3). Verification approach A is the fully performance based design approach where designers are only given the performance requirements of the structures; the designers are requested to verify their design, and the results would be checked by authorized organizations *et al*.

On the other hand, Verification approach B is 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, Geo-code 21 is to be used as *a code for code writers*.

We believe that even for the fully performance based design, i.e. Verification approach A, there do exist a number of principle points designer should check for each discipline of structure (e.g. foundations, concrete and steel structures etc.). In the comprehensive design code, these points are listed, and it is expected the code is used as a checklist in the examination of the design at the authorized organizations.

In Verification approach B, Geo-code 21 would be used as *a code for code writers*. There are a couple of layers of hierarchy of codes under this code (Fig. 3). The Specific Base Design Code is the major design code of each category of structures; for example, Specifications of Highway Bridges could be one of this category of code.

3.3 *Limit state design based code*

Geo-code 21 is based on ISO2394, *General principles on reliability for structures*, which is founded on LSD and the reliabil ity design concepts. The notations and the terminologies are defied in accordance with ISO2394 as much as possible. It is presumed in Geo-code 21 that LSD is one of the most suitable methods to realize PBD.

4. CHARACTERISTIC VALUES OF SOIL PARAMETERS

The most important role of design codes is to determine the safety margin (or elements) in design by balancing uncertainties involved in actions, resistances and calculation models in order to sufficiently satisfy the various performance requirements of a structure during its service life (Ovesen, 1989).

In geotechnical design, the geotechnical parameter values are different from a site to another, and they are estimated based on site investigations, laboratory testings or past experiences. It is very different from design of concrete or steel structures that the material parameter values are specified based on industrial standards and controlled in the manufacturing processes. Therefore, in order to introduce equal margin of safety to all the designed structures in geotechnical design, it is necessary and inevitable for all designers to understand in what sense a soil parameter value (i.e. a characteristic value) are a representative value of the ground. If there is no common understanding among the designers, the safety margin introduced in the design may differ from one structure to another.

We found that most of the design codes exist in Japan and abroad are quite insufficient in this aspect probably due to the fact that most of the design codes are written under the hegemony of structural engineers and not under that of geotechnical engineers.

In Geo-code 21, the definition of the characteristic value of a soil parameter is given as follows:

(1) REQ The characteristic values of geotechnical parameters are the representative values carefully estimated as the most appropriate ones for the foundation-ground models for design calculations taking into account variations of various sources.
(2) REQ These representative values of geotechnical parameters are principally the averages of the measured values. These averages are not mere mathematical averages, but taking into account estimation errors associated with statistical averaging. Moreover, these values must be determined as careful estimations of averages exercising due consideration on geologic/ geotechnical as well as experiences in similar past projects, and based on comprehensive interpretation of different kinds investigation techniques and testing methods

The most significant point here is that the characteristic value is defined as a mean value of a geotechnical parameter. By doing so, it is preventing for designer to arbitrarily include safety margins in the determination of a characteristic value by taking a conservative value. On the other hand, it is encouraged to introduce the engineering judgments that are most important element in geotechnical engineering by certifying the goal (i.e. to estimate the mean value of a geotechnical parameter).

The other important reason we employed the mean values to design is that it facilitate designers to get a "feel" of actual behavior of their design up to the last stage of their design work. This aspect is more important in geotechnical design where interactions of a structure and ground are very complex and the reduction (or increase) in soil parameter values may not always introduce more safety to the design. For example, in design of a laterally loaded pile, reduction of horizontal subgrade reaction coefficient may lead to increase in deformation, whereas, a larger value may result increase the stress in the pile.

5. A CHECKLIST FOR DESIGN

Geo-code 21 is a comprehensive foundation design code that is fully founded on PBD concept. Within this framework, we made the following points our policies while drafting chapters of a particular type foundation:

- It was the aim of such chapters to create a checklist designing foundations based on the state of the art knowledge. The information contained in such a checklist should be neither too much nor too little. This checklist is useful in both designing foundations based on PBD and drafting a foundation design code for a particular category of structures, i.e. a specific base design codes.
- In this checklist, we tried to avoid quantitative descriptions and to use only the qualitative descriptions as much as possible. This is to secure sufficient room for the designers and the code writers to introduce their own engineering judgments in their activities.
- This code can be used as a textbook in advanced undergraduate and graduate classes, which is one of the aims we intended from the beginning of drafting the code.
- We are including some typical concrete foundation design methods in the appendixes of the code. These methods are simplified versions of the actual design methods used in Japanese major foundation design codes. The aim here is to show some of the possible design methods to the readers, and we think it especially helpful for the outsiders who are not familiar with the Japanese foundation design practice.

6. CONCLUSION

As stated in the introduction of this paper, Geo-code 21 is scheduled to be published from Japanese Geotechnical Society as one of JGS standards in earily 2005. It is entitled '*Principles for Foundation Design Grounded on Performance Based Design Concept*'. Once this code is respected by the code writers of various foundation design codes, and the codes are written based on the concept stated in this comprehensive code, the harmonization, transparency and accountability of the codes shall be much improved. The English version of the code will also be published in 2005. We do hope this code will provide better understandings on Japanese foundation design for geotechnical engineers who are not familiar with our practice.

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