New trend toward performance-based design in the construction industry

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ABSTRACT: More than 10 years have passed since performance-based design was introduced into the construction industry along with a set of expectations. As the new concept is gradually adopted by Japanese design codes, the performance and quality of public works produced at minimum cost is becoming a major concern. This paper describes 1) the current situation of the Japanese construction industry; 2) new contracting and bidding systems employed in Japan that are oriented more toward performance and quality without compromising cost; and 3) results of investigation on performance-based design in European countries. A significant portion of the contents is based on the activities of the JSCE (Japan Society of Civil Engineers) Committee on ‘Performance-based design of soil structures’ chaired by Prof. Atsushi Iizuka of Kobe University. The Japanese construction market has become increasingly competitive. Designs that satisfy required performance and quality at minimum cost and risk are key factors for survival.

1 INTRODUCTION

More than 10 years have passed since the importance and advantage of performance-based design was introduced into the construction industry. Nowadays, Japanese engineers are very familiar with the term ‘performance-based design’. Designers and contractors expected more flexible application of new design and construction methods for public works. The public sector expected more cost-effective construction by setting the required performance of individual structures based on importance. Despite these expectations, however, the application of performance-based design in public works is still limited.

At present, some of the large Japanese projects are based on design-build contracts. Design-builders must take more risks to achieve the required performance. Risk sharing related to geotechnical conditions is always a difficult issue between the client and the design-builder. Insurance systems that cover such risks are not fully developed due to difficulty in determining the insurance premium.

This paper presents 1) the current situation of the Japanese construction industry after the bubble economy; 2) new contracting and bidding systems in Japan that are oriented more toward performance and quality without compromising cost; and 3) results of investigation on performance-based design in European countries.

A significant portion of the present paper is based on the activities of the JSCE (Japan Society of Civil Engineers) Committee on ‘Performance-based design of soil structures’ chaired by Prof. Atsushi Iizuka of Kobe University. The committee was organized in 2004 to discuss the applicability of performance-based design to soil structures such as embankments, reclaimed islands, and dams. The following three working groups were set up in the committee:

WG 1: Drafting a comprehensive geotechnical design code for soil structures,
WG 2: Studying performance evaluation methods for soil structures, and
WG 3: Investigating systems to support performance-based design for soil structures.

The first author chairs WG 3. The committee consists of more than 30 researchers and engineers from
governments and universities, as well as consultants and contractors.

2 JAPANESE CONSTRUCTION INDUSTRY

This chapter presents the latest data on the Japanese construction industry, in order to clarify the
current situation. Since the end of the bubble economy from the late 1980s to the early 1990s, the
Japanese construction industry has experienced what is probably its most difficult time.

Figure 1 shows changes in the proportion of construction investment to GDP (Gross Domestic
Product) in Japan. The changes in Japanese GDP are also included in the figure. The current
Japanese GDP is about 505 trillion yen, with a very limited increase over the last 10 years.
Construction investment fell to 10.6% of the GDP, nearly half the peak value.

Figure 2 shows the total domestic investment in construction, which has dropped to 53 trillion yen
from a peak value of 84 trillion yen in 1992. These two figures show how the Japanese construction
market has shrunk due to financial difficulties of both the government and private sectors.

Figure 1. Japanese construction investment compared with GDP
(JCECA: Japan Civil Engineering Contractors’ Association, 2006)

Figure 2. Changes in construction investment in Japan (JCECA, 2006)

Figure 3 shows the number of registered construction companies and the number of employees in the
construction industry. In spite of the shrinking domestic market, the number of companies has not
changed accordingly. Figure 4 also shows the number of employees working for the top 35 Japanese
contractors. Low profitability has led to a decrease in the number of employees. Figure 5 shows
changes in the ordinary profit ratio of the construction industry, compared with that of the overall industry. The ratio is defined as the proportion of ordinary profit to turnover. Although the profitability of the overall industry has already recovered to the level of 1990, that of the construction industry is still very low. Figures 3, 4 and 5 indicate that the Japanese construction market has become increasingly competitive.
In contrast to the domestic market, the number of overseas orders for Japanese contractors has recently increased, as shown in Figure 6. Note that the proportion of the turnover from overseas markets is still much smaller compared with that from domestic markets.

![Figure 6. Changes in overseas orders for Japanese contractors (JCECA, 2006)](image)

The following trends in the Japanese construction industry can be seen from the above data:

1) The Japanese domestic construction market has become increasingly competitive. Severe price wars have led to client concerns over maintaining the quality of public works, which has led to the application of new contracting and awarding systems as shown below.

2) Due to the low profitability of the construction industry, the number of employees has been decreasing. Maintaining technology levels related to design and construction is also a big issue among contractors.

3) Some of the top contractors have expanded their markets to overseas; other contractors have had no choice but to enter the fierce competition, or to change their business. The increase in overseas projects has resulted in designers, consultants, and contractors shifting toward performance-based design in order to avoid or reduce potential risks in the target projects. Performance-based design can be an important key to the success of a project.

3. INTRODUCTIONS OF JAPANESE CONTRACTING SYSTEMS

In April 2005, regulations for promoting quality assurance in public works came into effect under the Quality Assurance Act. The act sets forth the concept of public procurement based on overall evaluation, combining price and the technical expertise of the contractor, to assure the quality of public works projects. Under the new system, the following items must be considered:

1) Technical capability of bidders must be examined at each bid tender,

2) Adoption of technical proposals from private sectors must be considered, and

3) For effective utilization of a technical proposal, necessary measures such as mutual dialog, and estimation of ceiling price based on the proposal, must be considered.

In the new system, designers and contractors make more effort to achieve the required performance of structures at minimum cost with minimum risk. Following are the new systems currently employed in Japan:

1) **Design-Build System**
   In principle, different firms carry out the design and construction of public works. However, at present, some of the projects employ the design-build system.

2) **Value Engineering (VE) System**
This system was introduced as a means to improve project quality (value) while reducing the cost. It can be adopted at the tendering phase or at the post-contract phase. In the post-contract VE phase, half the cost savings achieved through the use of VE is often returned to the contractor.

3) Technical Proposal Integrated Evaluation System
In this system, public-sector clients call on bidders to submit technical proposals in addition to price bids for a particular public works project. The client then evaluates each bid considering both the price and the technical proposal, reviewing factors such as quality, time schedule, design, and safety of construction work.

4) Performance Requirement Ordering System
This system has been employed for paving works since 1998. Maximum traffic noise is often stipulated as a required performance. Pavement performance one year after completion of the work is also specified.

5) PFI (Private Finance Initiative)
Seven years have passed since the enactment of the PFI Act in Japan in 1999. By September 2005, as many as 212 projects were implemented through the PFI Act. The total amount of private sector spending exceeded 1.4 trillion yen according to the Research Institute of Construction and Economy (2006).

Table 1. Classification of Japanese contracts, bidding, and awarding systems

<table>
<thead>
<tr>
<th>Type of contracts</th>
<th>Blanket ordering contract</th>
<th>Traditional contract</th>
<th>Design-build contract</th>
<th>Construction management (CM) contract</th>
<th>PFI (Private Finance Initiative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of aimed structures</td>
<td>Performance based ordering system</td>
<td>Prescription based ordering system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bidding system</td>
<td>Open competitive Bidding System</td>
<td>Designated competitive Bidding System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Competitive negotiation System</td>
<td>Discretionary contract System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awarding system</td>
<td>Technical proposal integrated evaluation system</td>
<td>Price bidding system</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Adoption of new systems to increase quality and performance of target structures

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical proposal integrated evaluation system</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>34</td>
<td>472</td>
<td>617</td>
<td>426</td>
</tr>
<tr>
<td>Value engineering (VE) system at tendering phase</td>
<td>35</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>19</td>
<td>74</td>
<td>491</td>
<td>689</td>
</tr>
<tr>
<td>Value engineering (VE) system at post-contract phase</td>
<td>101</td>
<td>134</td>
<td>282</td>
<td>320</td>
<td>1,638</td>
<td>2,081</td>
<td>2,272</td>
<td>1,954</td>
</tr>
<tr>
<td>Construction management</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Design-build contract</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>14</td>
<td>15</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>Performance requirement ordering system</td>
<td>-</td>
<td>2</td>
<td>14</td>
<td>28</td>
<td>53</td>
<td>179</td>
<td>(73)</td>
<td></td>
</tr>
</tbody>
</table>

( ) in the table indicates the number of contract that adopts Technical proposal integrated evaluation system.

(Ministry of land and infrastructure and transport, 2004)
Table 1 shows the classification of Japanese contracts, bidding, and awarding systems, and Table 2 shows the number of applications each year. The Technical Proposal Integrated Evaluation System and the Value Engineering System are especially increasing in number. The Japanese awarding system is changing from the Price Bidding System to the Technical Proposal Integrated Evaluation System.

In the Technical Proposal Integrated Evaluation System, the following items can be considered in the bidding stage:

1) Cost-related items, such as construction cost, maintenance cost, life-cycle cost, and compensation,
2) Performance-related items, such as earthquake resistance and settlement, and
3) Socially requested items, such as environmental preservation, securing of traffic flow, safety measures, energy savings, and recycling.

Figure 7 shows an example of the awarding procedure based on the Technical Proposal Integrated Evaluation System. The procedure was applied to the removal work for a bridge that crossed over a national highway. Since this highway was a major road with heavy traffic, securing the traffic flow was a major evaluation point. In the project, a minimum requirement was set that traffic closure during construction would be, at most, 8 hours during the night. Bidders considered their plans to minimize the traffic closure time at minimum cost based on their experience and technology.

It should be noted that, in Japan, the ceiling price is estimated by the client before the tendering stage, based on the accountancy law. This ceiling price is not open to bidders before tendering. For the estimation, the client must carry out detailed design using the most conventional design and construction methods. (During the European investigation described later, it was discovered that the Japanese ceiling price system is unique.)

In accordance with the proposals from several bidders, the client quantitatively evaluates the plans. For example, a quantitative evaluation is made based on the following equation:

\[
\text{Evaluation value} = \frac{\text{basic points} + \text{additional points}}{\text{bidding price}} = \frac{(90 + \text{shortened time of traffic closure} \times 1.43 \ (=10 \text{ points/7hours}))}{\text{bidding price}}
\]

where the minimum requirement is that traffic closure is less than 8 hours in a day, whereas the target condition is 1 hour for traffic closure. If 8 hours traffic closure is achieved, basic points of 90 are automatically given.
An example of the evaluation is plotted in Figure 7 in which it can be seen that bidder A was successful and bidders B, C, and D were not successful. The bidding price must be lower than the pre-estimated ceiling price. Any proposal such as C in which the cost exceeds the ceiling price cannot be awarded. The gradient of the evaluation line indicates the cost performance of the proposal. The cost performance of bidder A is the highest below the ceiling price.

4. PERFORMANCE-BASED DESIGN FROM DIFFERENT VIEWPOINTS

As mentioned in the introduction, the technical committee on ‘Performance-based design of soil structures’ was established in 2004 by the JSCE. Through discussions in the committee, it was clearly recognized that expectations for performance-based design differed depending on members’ professional affiliation, as shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Expectations for performance-based design from different viewpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>From viewpoint of designers &amp; contractors</td>
</tr>
<tr>
<td>-Increased flexibility in applying advanced design methods</td>
</tr>
<tr>
<td>-Increased flexibility in applying new materials and construction methods on the condition that required performance is met</td>
</tr>
<tr>
<td>-Promotion of application of new technology and construction methods beyond prescriptive codes</td>
</tr>
<tr>
<td>-Increased motivation in research and development</td>
</tr>
<tr>
<td>-Reduction of total construction cost with consideration given to required performance</td>
</tr>
<tr>
<td>-Transfer of risk from clients to contractors, i.e., clients need only be concerned about the outcome of construction works</td>
</tr>
<tr>
<td>-Reduction in labor and costs for supervision and administration</td>
</tr>
<tr>
<td>-Promotion of consideration of performance according to life-cycle cost of structure</td>
</tr>
</tbody>
</table>

Designers and contractors tend to expect more flexibility in performance-based design, whereas public-sector clients tend to expect better performance and quality at reduced cost.

The concept of performance-based design may be implemented generally in design-build contract systems, or PFI systems. A report by the RICE (Research Institute of Construction and Economy) also points out an important aspect of performance-based contracts, as shown in Figure 8. In performance-based design, since the client’s main concern is the outcome of the construction rather than the detailed construction procedures, risks that clients took in the conventional contracts are generally transferred to the design-builders. This means that the risk to design-builders will increase.

Designers/Contractors

Clients

Total procurement cost

Cost increase to deal with risks

Total cost reduced

Figure 8. Specification based contract and performance-based contract
(Research Institute of Construction and Economy, 2004)
as a trade-off for flexibility in the design and building processes. In such a case, design-builders must carefully evaluate the cost increase for dealing with potential risks. Having the technical ability for accurate risk evaluation is a key factor in a successful contract.

The discussions above reveal the presence of a few unsolved issues. The following is a list of points that require clarification:

1) Who should be responsible for checking and validating applied design methods that are outside the scope of described design codes?
2) Verification of design and construction methods often takes time. How can design verification efficiency be achieved to prevent the interruption of project/construction progress?
3) How can verified design methods be applied/validated in the international construction market?
4) How should the inspection methods for performance requirements be described, and how can objectivity be assured?
5) Who should inspect the required performance after operations start?
6) How should the penalty be decided for failure to achieve the required performance?
7) Until when should the required performance be inspected?

It was not easy to find clear answers to the above essential questions from the current Japanese contracting systems. The objectives of WG 3 in the committee were therefore established as finding the correct/ideal answers to the above questions, and to announce the findings and possible answers to the relevant engineers. One way to find the answers was to conduct an investigation in European countries.

5. INVESTIGATION OF EUROPEAN SYSTEMS

The need to obtain information from European countries was recognized in the JSCE Committee, since performance-oriented codes such as Eurocode have been implemented in European countries. Although North America was another region of interest, the committee decided to dispatch an investigation team to Europe first.

Table 3 lists the members of the investigation team. Most of them belong to ‘WG 3: Investigating systems to support performance-based design for soil structures’. The members are from a wide variety of organizations, i.e., universities, governments, and contractors.

Table 4 shows the investigation schedule. A total of 12 days was spent visiting 8 organizations in the UK, France, and Germany. Organizations were classified into consultants, public sector, research institutes, contractors, and certification bodies. A two- or three-hour meeting was held at each organization.

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenichi Horikoshi</td>
<td>Taisei Corporation (Leader of group)</td>
</tr>
<tr>
<td>Atsushi Iizuka</td>
<td>Kobe University (Chair of committee)</td>
</tr>
<tr>
<td>Yusuke Honjo</td>
<td>Gifu University</td>
</tr>
<tr>
<td>Kenji Matsui</td>
<td>Public Works Research Institute</td>
</tr>
<tr>
<td>Takashi Nagao</td>
<td>Ministry of Land, Infrastructure and Transport Government</td>
</tr>
<tr>
<td>Soji Shindo</td>
<td>Ministry of Agriculture, Forestry and Fisheries</td>
</tr>
<tr>
<td>Yukio Arai</td>
<td>Tobishima Corporation</td>
</tr>
<tr>
<td>Fuminao Okumura</td>
<td>Railway Technical Research Institute (Nov. 17 and 18 only)</td>
</tr>
<tr>
<td>Yukikazu Tsuji</td>
<td>Gunma University (Nov. 18 and 21 only)</td>
</tr>
</tbody>
</table>
Table 4. Schedule of investigation and organizations visited for meetings

<table>
<thead>
<tr>
<th>Country</th>
<th>Date, 2005</th>
<th>Organization</th>
<th>Type of organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>Nov. 17</td>
<td>Geotechnical Consultant Group</td>
<td>Consultant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dr. Jan Hellings &amp; Associates Ltd.</td>
<td>Consultant</td>
</tr>
<tr>
<td></td>
<td>Nov. 18</td>
<td>ARUP</td>
<td>Consultant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Highways Agency</td>
<td>Public Sector</td>
</tr>
<tr>
<td>France</td>
<td>Nov. 21</td>
<td>CERMES ENPC-LCPC</td>
<td>Research Institute</td>
</tr>
<tr>
<td>Germany</td>
<td>Nov. 23</td>
<td>Züblin</td>
<td>Contractor</td>
</tr>
<tr>
<td></td>
<td>Nov. 25</td>
<td>DIBt (Deutsches Institut für Bautechnik)</td>
<td>Certification Body</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GuD consult.</td>
<td>Consultant</td>
</tr>
</tbody>
</table>

During the investigation, the members realized that the term ‘performance-based design’ was not well known in Europe. Therefore, the definition of performance-based design was always the first issue of discussion at each organization.

‘Design system which allows high degree of flexibility in design method to satisfy clearly-described required performance of structures’.

The following example and discussion points were sent to each organization well in advance to ensure an efficient and productive meeting.

In the current prescriptive-based code, it is described that ‘the gradient of embankments shall be 1:1.5.’ However, in the performance-based design system, it can be written as ‘designers may decide the gradient of embankments so that performance requirements (e.g. safety against hydraulic failure and overall stability) for embankments shall be met.’ Then the following concerns may arise among designers:

1) Who (or what organization) should approve whether the innovative design deviated from conventional prescriptive manners meets the performance requirements or not, and how this procedure can be done?
2) Who take the responsibility when an unforeseen accident happens? Should the designers need to be insured?
3) How design and construction risks are covered, and how these risks are shared between clients and designers/contractors?

Discussion points sent to each organization

1. Bidding and Contracting Systems applied for public works (as basic information before main topics)
   1) Bidding and contracting systems for public works (Design-build contract, negotiations, awarding system, PFI etc.)
   2) Relationships between clients, consultants, and contractors
   3) Defect liability period
   4) Qualifications required for designers

2. ‘Performance Based Design’ and ‘Design Build Contract’
   1) Implementation of performance based design (in bidding systems, contracts, and codes)
   2) Advantages and disadvantages
   3) Applicability to soil structures (embankment, slope, reclaimed land etc.) (Examples?)
   4) Soil investigation (before & after bidding, decision & responsibility, unexpected soil conditions)
5) Design accuracy and detailed modelling such as finite element methods
6) Current situation of Eurocodes (recognition among designers)

3. Authorization of new design method and new construction technology
   1) Authorization systems and procedures
   2) Responsibility owned by authorization body
   3) Roles of third-party institution in authorization systems
   4) Mutual recognitions among different countries

4. Risk management related to ‘Performance Based Design’
   1) Evaluation of risks and risk allocations between clients and contractors
   2) Inclusion of risks in construction prices
   3) Penalty when performance is not achieved, and insurance system to cover the risks

5. Investigation in the UK

The following summarizes the findings in the UK:

1) The policies of limited government and adoption of private sector activities by Prime Minister Margaret Thatcher were well understood. Consulting engineers play an important role, since the number of in-house engineers is small in a small government.
2) Some contractors have a design section and can accept design-build contracts by themselves. Others may have a partnership contract with a consulting company, or use outsourcing.
3) Clients, consultants, and contractors sometimes have a partnership contract.
4) Due to the fact that the British Standard has a part for flexible application, there is enough room for consulting engineers’ activities.
5) Traditional methods, design-build contracts, early contractor involvement contracts, and design, build, finance & operate (DBFO) contracts are the major types of contracts in the UK.
6) PFI and DBFO systems suit long-term maintenance of roads, using the private sector’s financial ability and technology. These systems enable more flexible design and construction, and promote technology development.
7) It seems that contractors, especially large ones, prefer design-build contracts over conventional contracts even though it means taking more risks.
8) Lawyers are busier under the performance-based system or the design-build system; once a problem occurs, the time and money for solving it can be enormous.
9) Designers are covered by professional indemnity insurance. The premiums seem to be higher than those in Germany.

Figure 9 is a good example of typical risk sharing between clients, designers, and contractors in the UK. It can be understood that as flexibility in design increases from ‘Traditional’ to ‘DBFO: Design, build, finance & operate’, the risk to contractors increases.

Figure 10 shows a typical example of the relationship between clients, design-build contractors, and consultants. Consultants can be an employer’s agent as well as design checkers, which clearly shows the importance of the role of consultants in the UK.

5.2 Investigation in France

In France, we visited only one institution (CERMES ENPC-LCPC). Therefore, the information we obtained is limited. The following is a summary of what we learned in France:

1) The UK and France have a more centralized administration system than the other European countries.
2) In France, the role of the government is decreasing.
3) The European Construction Directive governs the construction system.
4) Designers generally belong to clients, or contractors, and individual designers are not insured; instead, companies are insured.

5) Responsibility for each engineering work is usually clearly defined. (There is a problem with everyone trying to avoid taking responsibility.)

6) No matter what the construction system is, information sharing among clients, designers, and contractors is considered very important.

7) In France, only the standards for seismic design and fire design are mandatory, others are not. For example, EC 8 is mandatory, but EC 7 is not. DIN is considered to be a law in Germany.

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**Figure 9. Risk-sharing pattern for each type of contract**

(Information obtained at Geotechnical Consultant Group)

**Planning, Preliminary Design, & Bidding Stage**

- **Client**
- **Employer's Agent**

**Design & Build Stage**

- **Client**
- **Design Build Contract**
  - **Employer's Agent**
  - **Designer**
  - **Checker**
  - **Safety Auditor**
  - **Consignment Contract**
  - **Subcontractor A**
  - **Subcontractor B**
  - **Subcontractor C**

**Figure 10. Relationship between client, design-build contractor, and checker in the UK**

(Suzuki, 2004)
5.3 Investigation in Germany

The following summarizes the findings in Germany:

1) Clients handle the preliminary design, and contractors handle the detailed design.
2) Independent design checkers play an important role in design verification procedures.
3) DIN does not allow any interpretations, and does not use expressions such as ‘should be’. However, DIN is not conservative, and provides for the availability of flexible and competitive designs.
4) Designs according to DIN are important in terms of design insurance. Designers must take more risks when designing structures beyond the scope of DIN criteria.
5) Insurance companies cover organizations rather than the designers.
6) Consultants are asked by the clients or contractors to verify their work to win a lawsuit. If the lawsuit is unsuccessful, the financial loss can be huge since they are not covered by insurance.

Figure 11 shows the typical relationship between clients and contractors in Germany. Clients are in charge of preliminary design, and awarded contractors are in charge of final detailed design. The preliminary design and final detailed design are checked by independent engineers. Independent checkers, which are appointed by state government, number only about 50. In the sense that contractors often make detailed designs, designers and contractors are not entirely separate.

5.4 Summary of investigation

The overall impression obtained from the investigation is as follows:

1) Traditional contracts still exist; however, design-build contracts and PFI contracts are increasing in number. PFI is especially popular in the UK.
2) Although the actual term ‘performance-based design’ may not be popular in European countries, the performance of structures is always considered by designers in their contracting systems, such as design-build and PFI.
3) Consideration of performance is necessary in order for designers and contractors to minimize their risk, which means that performance-based design is one of the risk management methods for designers and contractors.
4) Consultants probably play a more important role in Europe than in Japan. Lawsuits are also more popular in European countries. Again, consultants play an important role in such lawsuits.
5) Contracting systems, insurance systems, relationships among clients, designers, and contractors, all differ from one country to another, although design codes such as Eurocode have been
developed in harmony. Although the difference in systems will become smaller with time, Eurocode operation will progress with different supporting systems. The unification of these systems may take a longer time.

6. SUMMARY

Japan’s construction industry faces a number of important challenges brought on by fierce competition. Design and construction technology to satisfy performance requirements at minimum cost is a key factor for a successful business, along with effective use of the new types of contracts.

As illustrated in Figure 12, performance-oriented code development, as well as balanced development of other systems, is inevitable for enhancing the dissemination of performance-based design, and maximizing its advantages. It is also important that these systems be considered based on global standards.

Figure 12. Systems promoting performance-based design

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We express our sincere appreciation to all members of the JSCE Committee on ‘Performance-based design of soil structures’, as well as to the investigation team to Europe. We also express our sincere gratitude to those in each European country who assisted the European investigation team with gracious hospitality.

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Photographs taken during investigation in European countries

Geotechnical Consultant Group

Dr. Jan Hellings & Associates Ltd.

ARUP & Highways agency

CERMES ENPC-LCPC

CERMES ENPC-LCPC

Züblin

DIBt (Deutsches Institut für Bautechnik)

GuD consult.