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SOCIAL SYSTEM FOR PERFORMANCE BASED DESIGN (P.B.D.) OF BUILDING STRUCTURES -- ITS PERSPECTIVE AND KEY ELEMENTS

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SUMMARY

In order to make buildings actually performance-based-designed, new "Social System" has to be developed, which is composed of various supporting devices for Performance Based Design (PBD) practice like codes/rules, institutions, technical tools, information systems, etc.

PBD can be modeled (assumed) to be conversion between three phases of information related to structural performance: "Design Brief", "Design Criteria", and "Design Solutions."

The new Social System has to function to ensure sufficient reliability of conversion between the three phases mentioned above, as well as to support clients to concretize their needs and to prepare appropriate environment for PBD practitioners.

It needs to be developed to cover any of three types of PBD practice: "Individualized objective-oriented type", "Standardized verification method type" and "Dependent on deemed-to-satisfy solutions type."

Various elements need to be developed within the above-mentioned framework. Quality assurance, related information managing system, data base of reference technical information, independent bodies to provide related technical services, information system on engineers/organizations, and insurance system suitable for PBD practice are examples of the key elements.

INTRODUCTION

The Social System Subcommittee was established in FY 1995 as one of the subcommittees for the Comprehensive Research and Development Project on "Development of a New Engineering Framework for Building Structures" to carry out research on a new institutional framework and supporting system for performance-based design/engineering. The new social system (i.e. institutional framework and supporting system) shall ensures a performance-based "structural design practice" to be feasible and meet the needs of clients (owners of buildings). Elements of the new system include, for example, codes/rules, institutions, technical tools, information systems, etc.

Social system can be classified into two areas: firstly the one which works to satisfy the minimum requirements of regulations, such as requirements of the Japanese Building Standard Law, and secondly the other which targets much broader requirements or needs. This project examines the system which is common to both types while placing more emphasis on the latter.

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THE MODELING OF PERFORMANCE-BASED "STRUCTURAL DESIGN PRACTICE"

The Three Phases of Structural Design-Related Information

Performance-based design practice can be defined as "an act or process to convert one phase into another among the three phases of design-related information: "Design Brief", "Design Criteria", and "Design Solutions." The information on structural performance in each phase can be defined as shown in table 1, and is converted from one phase into another by performance-based structural design practice.

Table 1: Three Phases of Design-related Information

	Typical Contents	*Information on Structural Performance*
Phase 1: Design Brief	1. Clients' needs and expectations - Safety / security levels & quality - Market value / utilities, etc. - Budget, term of work 2. Social requirements - Laws, bylaws, customs, etc. 3. Site conditions, characteristics of the area, etc. 4. Policy of the designer, engineer and/or the organization	**Requirements for Structural Performance** 1. Needs and expectations for structural performance - Safety level - Security level (damage, property, cost of repairs, etc.) - Quality level of structure (prevention of crack, etc.) - High market value / utility (e.g. security of household goods, sustainability of business, etc.) - Reasonable cost of management (e.g. insurance premiums, maintenance & management costs, etc.) - Reasonable construction cost, etc.
Phase 2: Design Criteria	1. Basic policies for architectural design, floor and spatial plan, disaster prevention plan, equipment and environmental plan, etc. 2. Target of each design/plan item 3. Target cost / term of work	**Design Criteria for Structural Performance** 1. Target performance for structural performance - Setting up design criteria using indices (e.g. response value) which are technically measurable. 2. Basic policies for structural planning, performance verification, etc. - Structural planning: to be developed originally or selected from the menu, etc. - Performance verification (methods, verification criteria): to be developed originally or selected from the menu, etc.
Phase 3: Design Solutions	1. Plans (floor & spatial plan, architectural plan, structural plan, equipment plan, etc.) 2. Specifications 3. Other information to be transmitted	**Design Solutions for Structural Performance** 1. Structural plan (various plans) 2. Specifications - Materials, construction method, etc. - Required ability (workmanship) - Specifications for quality control, conditions for supervision, etc. 3. Various information to be transmitted - Questions and answers, notification table for design intention, notification table for design quality, etc.

The Detailed Process for Performance-Based "Structural Design Practice"

Performance-based "structural design practice" consists of the following processes. (N.B. Some of the processes may be repeated, whilst some processes may be omitted.)

a) While a client and a project manager (a chief engineer or an architect may also serve as a project manager) are clarifying general "design brief" through consultation, the "requirements (needs and expectations) for structural performance" of the client are being consolidated through discussions between the client and a structural engineer.

b) While the project manager is clarifying overall "design criteria", the criteria for structural performance is being formulated by the structural engineer. These criteria include "target performance" and the basic policy for the corresponding "structural planning" as well as "performance verification". In general, when formulating "design criteria" for structural performance, architectural "design criteria" (such as basic span) often function as given conditions.

c) Once "design criteria" for structural performance have been formulated, they are presented to a client and an agreement between the two parties on the criteria (to which design output should conform) is reached. Common "target performance" is thereby reached.

d) With the mutually agreed "design criteria" being taken into consideration, a structural plan is then drafted (drafting of "design solutions"). Then, "performance verification" on the structural plan is carried out to examine whether "target performance", set as the "design criteria", is satisfied or not. These two acts are repeatedly carried out, if necessary, and finally "design solutions (design documents) " is drawn up as the result (output) of structural design. Through this process, the structural performance, which the "design solutions" realize, is clarified to be presented to the client. (N.B. This process may be divided into two processes, namely "basic design" and "working drawing" stages. However, in the remainder of this paper, they are treated as one process. That is, "design solutions" are synonymous with the output of "working drawing".)

e) When an agreement on the "design solutions" has been reached with the client, they are conveyed to the production or construction process. At this time, the methods and necessary measures which enable the structural performance to be realized in a completed building have to be transmitted, too. These methods and measures (e.g. construction method, specifications for quality control and supervision, etc.) need to be clarified through the process of drafting "design solutions".

CLASSIFICATIONS OF PERFORMANCE-BASED "STRUCTURAL DESIGN PRACTICE"

The process for performance-based "structural design practice" is greatly affected by the conversion forms as well as the "judgement grounds" on which conversion is based. Based on the differences in the "conversion forms" and the "judgement grounds", performance-based "structural design practice" can be classified into some groups.

Differences in "Conversion Forms" and "Judgement Grounds"

a) Prior to clarification of the "design brief," information on clients' needs, existing regulations, other various conditions, etc. is collected and analyzed. At this stage, there are still no processes to be called as "conversion," and we find little difference in "processes" which affects the types of "design practice."

b) Conversion from "design brief" into "design criteria (target performance) " means to convert from a highly abstract concept (i.e. a concept with more or less sensuous needs and expectations such as "a building can even resist against an unusually big earthquake") into a concrete and definite concept (i.e. a concept which enables us to carry out conformity verification such as "the limit of story deformation against given load conditions"). At this stage, we can classify the conversion process, taking the differences in conversion forms and judgement grounds into account, under three patterns as shown in Table 2.

Table 2: Patterns for 1st Conversion Process (between Design Brief and Design Criteria)

Pattern 1-a	In accordance with the contents defined in the "design brief", the original "target performance items" are set up. (They may include not only the items for "safety against loads" but also other various items for "target performance" such as floor deflection, vibration, response acceleration, etc.)
Pattern 1-b	Corresponding to the "needs and expectations" categories, those which are most likely to be related to the contents defined in the "design brief" are selected from the "list of target performance items" which has been prepared beforehand (in combination with the "performance verification method"). (E.g. "allowable limit stress", "story deformation angle" which are already incorporated in the menu in combination with "standardized calculation methods", etc.)
Pattern 1-c	From the pre-determined menu of the "construction methods" (structural plan of materials, parts, dimensions, etc.) for which target performance of each item has been already evaluated and approved, the one which is most likely to satisfy the contents defined in the "design brief" is selected.

c) Conversion from "design criteria (target performance)" into "design solutions" consists of mainly two processes, namely, "structural planning" and "performance verification (conformity verification to the target performance)." There are three possible patterns of these processes in terms of types of "structural planning" and "performance verification" as shown in Table 3.

Table 3: Patterns for 2nd Conversion Process (between Design Criteria and Design Solutions)

Pattern 2-a	For the method of "performance verification", any optional method is selected or developed and applied. For the "structural planning", a unique method may be set up, without relying on any precedent examples.
Pattern 2-b	From the menu of the methods of "performance verification", one method is selected. A structural plan is formed in such a way that it is within the applicable range of the selected verification method.
Pattern 2-c	In a case where a specific "structural plan" has been selected at the stage of conversion into "design criteria" as mentioned in Pattern 1-c, "structural planning" and "performance verification" are not carried out because "design solutions" have already been selected.

d) A combination of the three patterns listed in Table 2 and the other three patterns in Table 3 provides the classifications of "performance-based structural design practice".

Classifications of Performance-Based "Structural Design Practice"

As examined above, performance-based "structural design practice" can be classified into various patterns. Among possible combinations, the following are the three major patterns (see Table 4).
Please note that the classifications listed below represent only typical patterns, and actual "structural design practice" generally lies somewhere in between the three patterns, or it may be a mixture of them. Also, even in relation to the same building, different patterns may be adopted for different parts or different performance items.

Table 4: Three Typical Types of Performance-Based "Structural Design Practice"

Type A: "Individualized Objective-Oriented" Type (a combination of 1-a and 2-a)	As for the "target performance items", those which are unique to the project concerned are set up. As for the method for "performance verification", a unique one is selected or developed and applied. As for the "structural planning", an original technique is developed and applied.
Type B: "Standardized Verification Method" Type (a combination of 1-b and 2-b)	As for the "target performance items", those found in the menu are selected. As for the method of "performance verification", one method is selected/applied from the menu available. "Structural planning" is executed within the applicable range of the previously selected verification method.
Type C: "Dependent on Deemed-to-Satisfy Solutions" Type (a combination of 1-c and 2-c)	In the menu for "construction methods" (which give examples of solutions in a prescriptive manner), the one which is most likely to satisfy the contents and items defined in the "design brief" is selected. Unlike the other types, "structural planning" and "performance verification" are not carried out.

TARGETS OF THE "NEW SOCIAL SYSTEM" FOR PERFORMANCE-BASED "STRUCTURAL DESIGN PRACTICE"

The Roles of the New System

As a result of the analysis concerning the performance-based "structural design practice" stated above, the following four points should be the main roles expected of the new social system (institutional framework and supporting system).
The following three are those mainly provided to a client in the process of "structural design practice," while the last one (3.1.4) is to be provided mainly to a structural engineer.

Offering support to clients to clarify the "requirements (needs and expectations) " of structural performance

With respect to a client’s "requirements (needs and expectations) " about structural performance of a building, it is necessary to establish some sort of system which can help a client to precisely understand the relationship between his "structural performance requirements" and the "effects and values" which his requirements would add to his building. (Or, in other words, the "demerits and risks" which would be brought about by not requiring

any structural performance). This process can help a client to clarify his "requirements (needs and expectations) " of the project.
Elements constituting the system are, for example, as follows.

a) A market-system where structural performance levels and social/economic values are linked.
   - Insurance system whose premiums are determined taking the level of structural performance into consideration
   - A system of structural performance evaluation which is connected to market value of the building.

b) A system which can help a client to further understand "structural performance" and its relating "effects and values" (or" demerits and risks").
   - The methodology and auxiliary tools which can secure the provision of professional services (in particular, a methodology which can secure the provision of direct or indirect advice by a structural engineer).
   - Information system which enables a client to judge the qualifications and reliability of a professional who gives him information and advice.
   - Statistical data (e.g. the data concerned with the relationship between structural performance and the market value of buildings, and the correlation between structural performance and the risks of disasters/loss of properties) and other technical information such as minimum performance levels required by society. Communication tools between a client and an engineer including common measures, verification methods, etc. are also necessary.

The provision of reliability in converting "requirements (needs and expectations)" into "target performance"

The "requirements (needs and expectations)" of a client for structural performance are clarified and consolidated through communication with a structural engineer. Then, they, together with other given conditions, are converted into "target performance" through technical interpretation and appropriateness examinations by the engineer, and finally they are established as "design criteria", which the structural design details, namely "design solutions" must achieve.
Since such technical interpretation is carried out on a highly sophisticated engineering basis (especially when design practice type is "A" in Table 4), it is generally very difficult for a client to perfectly understand what is going on. Therefore, in order for a client to be assured that the engineer’s conversion results are reliable and that the output ("design criteria") can be used as the basis for the next stage of structural design practice, some sort of system which helps the engineer and client to reach an agreement should be established. The following are some examples of the elements which constitute the system:

a) The methodology and auxiliary tools which provide the grounds for judging whether the conversion processes by an engineer were performed in a manner/method that could secure the appropriate output, and/or provide other grounds for judging whether the output of his work is appropriate with respect to the purposes. (In particular, it is important to provide the grounds for judging whether the technical tools used by the engineer are appropriate, he has enough judging ability, he doesn't misunderstand the facts, or he doesn't intentionally neglect the conditions, etc.)
b) The methodology and auxiliary tools required to help all the persons concerned reach an agreement on the converted "target performance" as part of "design criteria" and lead to the structural design practice to the next stage.
c) Information on the professional abilities and competence levels of engineers/organizations, which is necessary to apply the above mentioned methodology and auxiliary tools.
d) Evaluation and certification services by an independent body which accredit appropriateness of the technical methods or pertinence of the grounds which were used for conversion or judgement.

The provision of reliability of integrity of "target performance" and "design solutions"

By consulting the previously set up "target performance", detailed examinations are carried out on the structural plan and the construction methods. Thus, the proposed "design solutions" are verified as to whether it satisfies the "design criteria" and the "target performance". These processes are carried out by making full use of professional technology and knowledge as well as professional tools, especially when design practice type is "A" in Table 4. To ensure that "potential performance" which is to be achieved by the "design solutions" is closely integrated with not only "target performance" but also the "requirements (needs and expectations) " of a client, these processes are of crucial importance.
Since the management of these processes is carried out on a highly sophisticated engineering basis (especially when design practice type is "A"), it is generally very difficult for a client to perfectly understand what is going

on. Therefore, in order for a client to be assured that the engineer's conversion results are reliable and that the output ("design solutions") can be used as the basis for the next stage (production and construction), some sort of system which helps the engineer and client to reach an agreement should be established. The following are some examples of the elements which constitute the system:

a) The methodology and auxiliary tools which provide the grounds for judging whether the conversion (structural planning and performance verification) processes by an engineer were performed in a manner/method that could secure the appropriate output, and/or provide other grounds for judging whether the output of his work is appropriate with respect to the purposes. (In particular, it is important to provide the grounds for judging whether the technical tools used by the engineer are appropriate, he has enough judging ability, he doesn't misunderstand the facts, or he doesn't intentionally neglect the conditions, etc.)
b) The methodology and auxiliary tools required to help all the persons concerned reach an agreement on the converted "design solutions" and lead to the production/construction stage.
c) Information on the professional abilities and competence levels of engineers/organizations, which is necessary to apply the above mentioned methodology and auxiliary tools.
d) Evaluation and certification services by an independent body which accredit appropriateness of the technical methods or pertinence of the grounds which were used for planning and verification.

Providing a structural engineer with a proper environment for carrying out his job

In order for a structural engineer to carry out the performance-based "design practice" on a stable basis, a certain system which guarantees the following items must be established.
- He can earn decent economic return for the level and reliability of his service.
- He can manage the risk which might arise in the course of his work within the proper limits so that it doesn't exceed his ability and liability.
- He can obtain support in acquiring the knowledge, the grounds for his judgement, and economic ability (namely, liability for his responsibility)

The examples of the elements which constitute the system are as follows.

a) Methodology and auxiliary tools which clearly define the role and responsibility of a structural engineer. (To clarify the range of the engineer's responsibility in connection with the contract with a client, to define the engineer's responsibility in connection with other structural engineers, architects, equipment design engineers, the person in charge of construction, product/material suppliers, etc.)
b) Methodology and auxiliary tools which allow a structural engineer to claim proper level of fees for the service he provides.
c) Insurance or other support tools to his ability to assume his liability which may arise as he provides his service.
d) Support to acquire and/or update his knowledge and technical abilities which he may need as he provides his service.
e) The source of information to acquire and update the knowledge and technical abilities.
f) Technical information, tools, etc. which he can refer to or utilize in his professional practice.
g) The services of independent bodies for evaluating and authorizing the characteristics and reliability of technical information and tools.

CONCLUSIONS -- KEY FUNCTIONAL SYSTEM ELEMENTS OF THE NEW SYSTEM

The "New Social System" consists of several system elements, each of which corresponds to a particular function that the new system is deemed to perform. These system elements can be classified into 7 types (listed in Table 5) in terms of their functions. While the design practice type "A" often needs a full set of system elements listed below, types "B" and "C" tend to require fewer elements.

Table 5: Seven Key Functional System Elements of the New Social System

F01: Quality assurance scheme for structural design practice and related information managing system
(to be provided mainly for design practice type A) - Methodology and auxiliary tools that can provide grounds for judging the reliability of the output of each process, namely, the outputs of "design brief: requirements (needs and expectations) ", "design criteria: target performance", and "design solutions: possessing performance" respectively. - Methodology and auxiliary tools that can clearly define the information on structural performance which have been agreed and confirmed at each process, namely, the "design brief: requirements (needs and expectations)", "design criteria: target performance", and "design solutions: possessing performance" respectively. Moreover, the methodology and auxiliary tools should be provided as the means for tracing back the relationship and integrity between each information, whenever necessary.
F02: Data base of reference technical information and technical tools
(to be provided for design practice types A, B and C) - A system for information and knowledge in which reference information is stored and managed. In the management of all other functional system elements, engineers and other people concerned are able to have access to this information and knowledge base whenever they need for technical and professional reference materials, for judgement grounds, for tools for their work, for comparison purpose, etc.
F03: Independent bodies to provide related technical services
(to be provided for design practice types A, B and C) - A system which provides evaluation or re-verification by an independent body, with respect to quality assurance scheme stated in F01, for validity of the work (interpretation, conversion, planning, verification, etc.) done by a structural engineer. The system is also assumed to have a function to determine the reliability of performance certification service stated in F06, as well as to reduce the risks of engineers when they make judgements and decisions in the course of their work. - In connection with F02, a system which evaluates and certifies pertinence and reliability of various sorts of technical reference information and technical tools (i.e. performance verification method) is also to be provided.
F04: Information system on abilities and qualifications of engineers/organizations and system to support them to develop their knowledge and ability
(to be provided mainly for design practice type A, but some part is also available for types B and C) - An information system which helps a client select structural engineer/organization and which also provides information to judge technical/liability abilities of engineers/organizations that constitute very important elements to manage the quality assurance scheme stated in F01 and the standard guide stated in F05. - A system supporting engineers to acquire and/or update their knowledge and technical.
F05: Standard guide of design practice and model contract documents
(to be provided mainly for design practice type A, but some part is also available for types B and C) - A system which helps to define the range of roles and responsibilities of the structural engineers and other persons concerned including architects, other engineers and clients. It also helps to define the scope of the roles and responsibilities of each structural engineer in charge of different kind of work. It functions as the set of rules for applying the methodology and auxiliary tools related to the quality assurance scheme and information managing system stated in F01. It also includes the methodology for calculation of fees.
F06: Performance certification service
(to be provided mainly for design practice type A, but some part is also available for types B and C) - A system to enable clients to enunciate the performance (i.e. the level and contents) of their buildings, which can be linked with the market value of the buildings including premiums for insurance scheme that are referred to in F07.
F07: Insurance system suitable for PBD practice
(to be provided mainly for design practice type A, but some part is also available for types B and C) - Insurance systems such as liability insurance for engineers to support their liability capability, a property (damage) insurance scheme linked with the level of structural performance of a building, and a performance guarantee insurance scheme, etc.