PROPOSAL ON EARTHQUAKE RESISTANCE FOR CIVIL ENGINEERING STRUCTURES

INTRODUCTION

In Japan we continually face the threat of natural disaster, but despite this, our understanding of the forces of nature remains rather limited. It is thus imperative that we respect nature and remind ourselves of how important it is to incorporate natural disaster prevention measures, environmental preservation strategies, and economic considerations into our approaches to the development of land and the creation of urban centers. The Hyogoken-Nanbu earthquake—an earthquake of formidable power that occurred directly below a densely populated urban center with an advanced infrastructure—caused tremendous damage for three main reasons: 1) earthquake resistance of structures was insufficient; 2) infrastructure and other fundamental urban systems were deficient; 3) post-earthquake crisis management was deficient. All three of these explanations are closely linked. There is no guarantee that structures built to particular standards will be able to withstand all the assaults of nature. Therefore, in addition to reinforcement of earthquake resistance of structures, a comprehensive measure for earthquake disaster prevention should be developed from a wide view point.

The 1995 Hyogoken-Nanbu Earthquake demonstrated that we had forgotten about the devastation caused by previous earthquakes—and the danger this forgetfulness poses. Further, it revealed the need to fully understand the profundity of the damage created by a major earthquake, particularly since our urban centers are now so densely populated and have such complex infrastructures. To minimize disaster in the future, it is essential that people place a high value on disaster prevention and maintain a high level of awareness of what it entails, all of which can only be accomplished through ongoing education and training.

The single most important thing we can do to minimize the likelihood of another disaster is to thoroughly analyze why the Hyogoken-Nanbu earthquake was so devastating. This requires engineers and researchers in each relevant field to conduct detailed, broad-ranging studies based on information such as earthquake motion observation records and structural damage surveys.

This proposal is a compilation of items that the JSCE considers desirable from an academic point of view, and some of them must await future research and development before being realized. It is our sincere hope that this paper will serve the needs of various organizations working to develop earthquake disaster prevention measures.

1. EARTHQUAKES AND EARTHQUAKE MOTIONS THAT NEED TO BE CONSIDERED IN EARTHQUAKE-RESISTANT DESIGN

1.1 Need to consider near field ground motions in earthquake resistant design

The Hyogoken-Nanbu earthquake severely damaged many civil engineering structures and was caused by the activity of an inland fault which was, unfortunately, near a large urban center. Earthquake motions in near field of an active fault with a magnitude of 7, however, has not been incorporated into conventional earthquake-resistant design standards. The very strong earthquake motions of the Hyogoken-Nanbu earthquake, which had a maximum acceleration of about 8 m/s^2, a maximum velocity of about 1 m/s, and a maximum displacement of about 30-50 cm, were widely observed near the fault, the first time such observations have been made in Japan. The severity of the damage can be attributed to the extremely strong earthquake motion—forces beyond the design criterion—that directly struck aboveground structures built before the introduction of elasto-plastic design, as well as underground structures which had been considered relatively safe. Many structures built with the latest earthquake-resistant technologies, however, were not severely damaged, an indication that strong earthquake motions near a fault can be overcome through engineering.

The return period of an active fault is thought to be about 1,000 years, so through the course of history it has been rare for active faults to directly strike major urban centers and cause severe damage. Expressed in a time frame more relevant to human life, the likelihood of such a disaster occurring over a period of 50 years is roughly 5%. Since the level of risk is low, strategic judgments must be made in order to maintain the capacity of civil engineering structures to withstand earthquakes. However, there have been quite a few instances in which serious damage has resulted from inland earthquakes with a magnitude of 7 or more. Therefore, even though the risk level is low, it is still possible for strong earthquakes of this type to strike somewhere in Japan, so their potential for disaster should not be ignored. To take full advantage of the bitter experience of the Hyogoken-Nanbu Earthquake, therefore, it is necessary to incorporate the effects of earthquake motions in near field of inland faults into earthquake-resistant design considerations.

1.2 Ground motion in earthquake-resistant design

Two types of earthquake motions should be considered in assessing the aseismic capacity of civil engineering structures. The first type is likely to strike a structure once or twice while it is in service. The second type is very unlikely to strike a structure during the structure's life time, but when it does, it is extremely strong. The second type ground motion includes those generated by interplate earthquakes in the ocean and those generated by earthquakes by inland faults. The concepts behind these two types of motion have been incorporated into the existing earthquake-resistant design of some structures, and these two types of the ground motions are called "Level I earthquake motions" and "Level II earthquake motions." Objectives for and characteristics of these earthquake motions in earthquake-resistant design are as follows:

(1) Level I earthquake motions is the level in which structures are not damaged when these motions strike.

(2) Level II earthquake motions is the level in which an ultimate capacity of earthquake resistance of a structure is assessed in plastic deformation range.

Level I earthquake motions are used in conjunction with the elastic design method and are established as earthquake motions for static load analysis or elastic dynamic analysis. There are many different types of civil engineering structure, and systems of and knowledge about the design methods for each of them have been developed through experience. These systems and the knowledge accumulated should be respected.

In existing design systems of road bridges Level II earthquake motions are treated as design earthquake motions with an elastic response of 1 G on standard ground. However, since the earthquake motions in the Hyogoken-Nanbu earthquake were very destructive, a need to re-evaluate that Level II earthquake motions for very strong earthquake motions generated in the near field of inland faults.

A problem specific to direct inland earthquakes is that the relative displacement caused by the dislocation of an earthquake fault reaches the ground surface and structures straddle the fault. Using existing technology to deal with this situation is problematic because of the difficulty of specifying the exact locations of faults and the inevitability in many cases of linear structures crossing faults. Solutions to these problems require further research and development.

1.3 Level II earthquake motions

The following concepts are used to determine Level II earthquake motions.

(1) Level II earthquake motions generated by active inland faults are determined based on indentification of active faults that threaten an area and assumptions of source mechanism, through comprehensive examination of geological information on active faults, geodetic information on diastrophism, and seismological information on earthquake activity. To be able to do this, considerable effort must be put into establishing engineering methods.

(2) Since the Hyogoken-Nanbu earthquake, research in Japan on the above points has been advancing. However, the accuracy of methods for forecasting earthquake return periods and magnitudes, as well as the characteristics of the motions of earthquakes caused by active inland faults is still insufficient for establishing a basis for earthquake-resistant design. Therefore, when earthquake motions cannot be specified directly using information on an active fault, strong motion records caused by near field earthquakes, such as the

Hyogoken-Nanbu earthquake, should be used to create a Standard Level II earthquake motions.

(3) It is thought that earthquake motions that are generated in the near field by a large interplate earthquake occurring near land have different characteristics from earthquake motions generated through the movement of an inland fault. Since there are no records on very strong earthquake motions of this type, there are a lot of unknowns about the characteristics of these earthquake motions. More research needs to be done on very strong earthquakes generated by earthquake motions near interplates.

1.4 How Level II earthquake motions are expressed

Below is a discussion of how Level II earthquake motions are expressed.

(1) Level II earthquake motions are basically used for earthquake-resistant design based on damage control concepts. Therefore, the dynamic characteristics of earthquake motions should be expressed concisely, such as in the response spectrum or time history waveforms.

(2) Ground levels where earthquake motions are given

1) Earthquake motions on bedrock: Basically, Level II earthquake motions are established in bedrock. With the Hyogoken-Nanbu earthquake, it was pointed out that the irregularity of the topography in the area greatly affected local amplification effects of the earthquake motions. Furthermore, the non-linear characteristics of the surface layer, and softening of sandy ground greatly affected the amplification characteristics. To specify earthquake motions by evaluating these phenomena, it is essential to examine information on three-dimensional ground structures on bedrock, as well as to accumulate more information on topographic features and ground conditions and to conduct more research and development.

2) Earthquake motions on basement from engineering viewpoint (engineering bedrock): Earthquake motions on engineering bedrock are established by back analysis of earthquake motions observed on the ground surfaces.

3) Earthquake motions on ground surfaces: There are few records from observations of earthquake motions on bedrock and engineering bedrock, so in many cases earthquake motions on bedrock and engineering bedrock may not be able to be specified. Because of this, for now, earthquake motions are established on ground surfaces for which records of strong earthquake motions exist.

1.5 Research and development items related to earthquake motions

Effects of vertical motions: A lot of attention has been paid to the three-dimensional effects of the motions of the Hyogoken-Nanbu earthquake, particularly the vertical motions, on damage to and destruction of structures. Considerable effort has been made to clarify these effects. Thus far it has not been proven that the vertical motions were the primary cause of the destruction of major civil engineering structures. It is important to continue with detailed research on the effects of the three-dimensional characteristics of earthquake motions on the destruction of structures.

2. EARTHQUAKE-RESISTANT DESIGN METHODS

2.1 Introduction

In this section, the expected aseismic performance of civil engineering structures against Level I and II earthquake motions is discussed, and design methods for achieving this performance are proposed. Civil engineering structures are of many different types, but they may be categorized as follows. 1) Above-ground structures such as bridges, tanks, dams, towers, etc.; 2) in-ground structures such as subways, buried pipelines, tunnels, etc.; and 3) various types of foundation such as piles, caissons, etc. and soil structures such as dikes, retaining walls, etc.

It is quite difficult to define a unified aseismic performance level for these different types of civil engineering structures. Hence, in this chapter, aseismic performance and design methods are proposed separately for each category.

2.2 Required aseismic capacity and earthquake-resistant design of above-ground structures

(1) Earthquake resistance to Level I earthquakes

In principle, no damage should occur to any structure when earthquake motion of Level I occurs. Accordingly, the dynamic response during motion of this level should not exceed the elastic limit.

(2) Earthquake resistance to Level II earthquakes

Important structures and structures requiring immediate restoration in the event of an earthquake should, in principle, be designed to be relatively easily repairable; even if damage is suffered in the inelastic range. Accordingly, the maximum earthquake response of such structures must not exceed the allowable plastic deformation or the limit of ultimate strength. For other structures, complete collapse should not occur even if damage is beyond repair. Accordingly, deformation during an earthquake of this level should not exceed the ultimate deformation.

The degree of importance of structures can be determined based on the following factors:

1) the effect of structural damage on life and survival
2) the effect of structural damage on evacuation, relief, and rescue operations
3) the effect of structural damage on everyday functions and economic activities.

(3) Important issues in the earthquake-resistant design of above-ground structures and related topics for research and development

In evaluating the dynamic response of a structure to Level I earthquakes, linear multi-mode response analysis using response spectra or time history earthquake motions is recommended. Further, an investigation of the three-dimensional effects, including vertical motion, should be carried out when necessary.

In evaluating the dynamic response of a structure to Level II earthquakes, elasto-plastic time history response analysis is recommended. However, it is also acceptable to use practical and more convenient methods based on equivalent linearization analysis or design spectra corresponding to the allowable ductility factor. For structures with a low degree of static indeterminance, a rigorous verification of the ability to carry sustained loads is required, especially in the case of a Level II earthquake. Accordingly, it is desirable to investigate the accuracy of various elasto-plastic analysis methods and compare them with test results.

For any structures with a high degree of static indeterminance, including steel and concrete structures, an ultimate deformation analysis that takes into account the damage process is recommended.

In the design of most steel structures, the allowable stress method alone is used, and no investigation of load capacity or deformability is carried out. However, earthquake-resistant design should in the future include investigation of these characteristics even in the case of steel structures. In particular, it is necessary to promote research to increase the deformability of structures, such as investigations related to structural configuration and the limits of sectional stress and strain.

Since the earthquake response of short-period structures is largely determined by the effect of dynamic interactions of the foundation-ground system in the nonlinear range, research into design methods that take account of this should be promoted. It may prove possible to use a simplified procedure in which the effect of dynamic interactions is incorporated into seismic design by lengthening the natural period of the total structural system and increasing the damping coefficient.

In order to enhance the earthquake resistance of structures, introduction of new technologies such as seismic isolation and active control is recommended. Seismic isolation increases the deformability and damping capacity of relatively short-period structures, while the use of active control incorporating energy absorbing mechanisms can increase the damping capacity of long-period structures.

2.3 Required aseismic capacity and earthquake-resistant design of underground structures

The basis of earthquake-resistant design for underground structures is the stability and deformation behavior of the ground when subjected to earthquake inputs. Knowledge of three-dimensional displacement behavior, including depth-wise movements, is critical to the earthquake-resistant design of large tunnels, whether of shield or cut-and-cover type. Ground displacements along the structure axis are important in the case of extended structures of small cross-section, such as buried pipes. This means that the earthquake response of the near-surface ground should be thoroughly investigated. Since ground liquefaction and resulting ground displacement have a great influence on the earthquake resistance of underground structures, the stability of the ground under earthquake excitation should be studied in adequate detail.

(1) Retained earthquake resistance of structures

The function of structures should be retained after a Level I earthquake. In the case of a Level II earthquake, the damage should be limited such that there is no fatal damage to the structure's functions and functions can be restored within a short period.

(2) Use of flexible structures

To ensure that structures retain earthquake resistance after Level II earthquakes, it is highly recommended that structures and materials with good flexibility be used. Further, total collapse of a structure due to the collapse of a single member should be prevented by designing structural details so as to ensure brittle failure does not occur.

(3) Plans for lifeline systems

In designing trunk lines for lifeline systems such as water, sewerage, electricity, gas, and telecommunications designs best able to maintain functionality after a Level II earthquake should be chosen, taking into account the topography, ground conditions, and the city layout in the vicinity. If this is difficult for economic reasons or because of ground conditions, continued functionality (or rapid restoration) after a disaster should be ensured by selecting the most appropriate route, adopting a multi-route system, using a block system, or implementing some alternative measure.

(4) Underground structures straddling faults

When the location of an active fault is well identified, such measures as increasing the flexibilities of structures, duplicating lines, and isolation of line systems from the casing structure may be considered. However, if such measures are technically difficult to implement, operational measures including the provision of alternative systems should be considered.

2.4 Required aseismic capacity and earthquake-resistant design of foundation and soil structures

(1) Seismic stability of foundation structures

In the case of a Level I earthquake, the objective of earthquake-resistant design for a foundation structure is to maintain the original engineering function of the superstructure which the foundation supports. One principle of design is, wherever possible, to prevent soil liquefaction in ground with a high liquefaction potential by implementing suitable ground improvements.

In cases where it is judged that ground improvements would be difficult, however, the function of the superstructure should be maintained by proper design and/or reinforcement of the foundation structure and/or the superstructure itself.

In the case of Level II earthquakes, the objective of earthquake-resistant design for a foundation structure is to ensure that no serious damage occurs to the superstructure supported by the foundation. Where it would be difficult to implement ground improvements, the foundation structure should be reinforced or the whole structural system should be re-evaluated, or both, to minimize displacement of the foundation due to seismic response and lateral ground displacement, thus preventing serious damage to the superstructure.

(2) Seismic stability of quay walls, dikes, and embankments

There may be no need for seismic stability along the entire length of this type of structure from an economic viewpoint, since quay walls, dikes, embankments, retaining walls, and similar structures are long, continuous structures which can be easily repaired when slight damage occurs. It is recommended that segments of relatively high importance be isolated and designed for high seismic stability.

For Level I earthquakes, the original functions of relatively important sections of quay walls, dikes, retaining walls, and embankments should not deteriorate, maintaining the original design requirement after the earthquake. Slight damage to other less-important sections is allowable unless it would have a detrimental effect on adjacent structures. The objective of earthquake-resistant design is, however, to ensure that damage can be repaired within a short period and the whole system returned to functionality.

For Level II earthquakes, the objective of earthquake-resistant design in the case of important sections of quay walls, dikes, retaining walls, and embankments is that the damage should not seriously affect the structures they support and adjacent facilities, even if some degree of damage occurs. In the case of important structures which form an essential part of an emergency transportation route, the aim is to ensure that original functions are maintained. For ordinary sections, it is necessary to ensure that, even if damaged, there are no detrimental effects on adjacent areas, such as by secondary damage.

(3) Important issues in the earthquake-resistant design of ground improvements, foundations, quay walls, dikes, retaining walls, and embankments, and related research and development topics

If a soil mass that includes a large amount of gravel also has some sandy matrix, it may liquefy depending on its density, fine-material content, hydraulic conductivity, etc. Accordingly, present design standards and codes should be re-evaluated and, if necessary, revised to include evaluation of the possibility of liquefaction for Holocene soil deposits and reclaimed fill with a gravel content.

Recently, detailed evaluations of the liquefaction potential of relatively dense sand have been described. These recent investigations revealed that, at blow counts above about twenty as measured by standard penetration tests, resistance to liquefaction increases rapidly with rising blow count. It was also revealed that the amplitude of cyclic shear stresses required to cause soil liquefaction rapidly increases as the number of loading cycles involved increases. This recent information suggests that the present design standards and codes should be re-evaluated and, if necessary, revised to properly take into account the liquefaction potential of dense sand, particularly in the case of the high stress amplitude and relatively small number of loading cycles in a near field earthquake.

It is also necessary to improve understanding of the mechanism of liquefaction-related large ground displacement and to develop methods of predicting it.

The behavior of piles, caissons, buried structures, and other similar structures in a liquefied soil mass undergoing lateral displacement is poorly understood. It is highly important to foster research into design methods for foundations and buried structures exposed to this situation.

The seismic behavior of quay walls, dikes, embankments, and retaining walls is also poorly understood. Accordingly, there is a great need to foster studies on the development of methods for evaluating the settlement and displacement of ground, and also the dynamic earth pressure caused by an earthquake. Methods are also needed for increasing the seismic stability of ground. This requires relevant field observations, model tests, etc.

3. ASEISMIC DIAGNOSIS AND ASEISMIC REINFORCEMENT

3.1 Aseismic diagnosis

(1) Basic policies on aseismic diagnosis

Earthquake resistance diagnosis of existing civil engineering structures is in two stages: primary diagnosis using approximate methods and secondary diagnosis using detailed methods.

Primary diagnosis should be based on damage to civil engineering structures caused by the Hyogoken-Nanbu earthquake. After ground conditions and the ages, design standards, and outlines of the structural characteristics are examined, structures requiring aseismic reinforcement and those requiring a detailed aseismic capacity examination by secondary diagnosis are selected. In primary diagnosis, the following five factors are taken into the consideration: 1. effect on human life when a structure is damaged; 2. effect on evacuation, rescue, emergency medical services, and activities for preventing a secondary disaster; 3. effect on provision of basic requirements for daily life and economic activities of the area; 4. substitution of system function by providing another structure; and 5. changes in design conditions after construction.

Objects for secondary diagnosis, which is based on drawings and specifications and ground conditions, are structures judged in primary diagnosis to require a detailed examination of aseismic capacity. Secondary diagnosis is used to judge whether a structure has the required aseismic capacity to withstand Level I and Level II earthquake motions, and to select structures for reinforcement. In secondary diagnosis, the bottom line in judging the aseismic capacity of a structure is that it does not collapse even when damaged beyond repair. In secondary diagnosis, on-site measurements and testing, and surveys on the ground conditions should be conducted, and the aseismic capacity of the structure to withstand the earthquake motions through redesigning and/or numerical analysis.

(2) Establishing data bases for aseismic diagnosis

For the smooth implementation of primary diagnosis, it is urgent that data bases (design standards and age of the structure) for existing civil engineering structures be established.

If the structure is old and adequate data on it cannot be obtained, primary diagnosis should be done in a strict manner and the site surveys and tests required for secondary diagnosis should be conducted.

(3) Aseismic capacity of an overall structure

In selecting parts of a structure for aseismic reinforcement, it is necessary to thoroughly take into consideration the effects of reinforcement on the aseismic capacity of the overall structure.

(4) Earthquake disaster prevention as a system

In selecting structures for aseismic reinforcement, it is necessary to attempt to effectively improve the earthquake disaster prevention capacity of the overall system which consist of structures.

3.2 Aseismic reinforcement

(1) Basic policies of aseismic reinforcement

In aseismic reinforcement of an existing civil engineering structure, as with a new structure, both Level I and Level II earthquake motions must be taken into consideration. The in-service period of the structure should be considered the same as that of a new structure.

The target aseismic capacity of a structure for reinforcement should also be the same as that of a new structure. In short, as with a new structure, the importance of the structure and the risk of Level I or Level II earthquake motions are taken into consideration when the target aseismic capacity of the structure is established.

With some existing civil engineering structures, increasing the aseismic capacity to the level of a new structure is problematic because of difficulties with construction methods or because of financial constraints. In such cases, the importance of the structure should be carefully examined, and alternative measures, such as the establishment of a quick restoration system after an earthquake, should be adopted. In addition, issues pertaining to demolition and reconstruction should also be examined.

(2) Determining a priority for reinforcement

Determination of which structures have priority for aseismic reinforcement is based on the importance of the structure, as well as the risk of an earthquake in the area. It is also necessary to examine economic factors and the potential effects of reinforcement on the earthquake disaster prevention capacity of the overall system which consist of structures.

Clarification of the reasoning behind the process for determining which structures have priority for aseismic reinforcement is required.

(3) Aseismic reinforcement methods

Feasibility, safety, economic factors, and the effects of aseismic reinforcement on the surrounding environment must all be carefully examined when selecting an aseismic reinforcement method. Therefore, new construction methods and new materials appropriate for the structural characteristics of the structure and the environment of the site should be developed and applied.

(4) Evaluating the aseismic capacity of a reinforced structure

The aseismic capacity of a reinforced structure is evaluated with quantitative methods. This requires verification of the validity of the evaluation methods by, if necessary, conducting tests with full-size models, numerical analysis, and earthquake observations of reinforced structures. A thorough verification of evaluation methods for determining aseismic capacity is needed when a new construction method or new materials are used.

It is vital not only to evaluate the aseismic capacity of reinforced parts of a structure; it is also necessary to evaluate the aseismic capacity of the overall structure and to assess the safety against other loads such as winds and floods.

Further, it is necessary to evaluate how the earthquake disaster prevention capacity of the system consisting of reinforced structures is improved.

(5) Maintenance and management, and repair

As with new structures, reinforced structures require thorough periodic inspections. It may be necessary to conduct earthquake observations and various measurements in order to check whether the target aseismic capacity is being maintained.

3.3 Issues for future research on and development of aseismic diagno-sis and aseismic reinforcement

(1) Development of aseismic diagnosis techniques based on structural characteristics

There are many different types of civil engineering structure, and the aseismic diagnosis method used for a particular structure must be appropriate for its structural characteristics. It is necessary to establish through research and development rational and appropriate aseismic diagnosis methods for each type of civil engineering structure.

(2) Development of aseismic reinforcement techniques

There exists large number of civil engineering structures that require aseismic reinforcement. In many cases, aseismic reinforcement work must be done while a structure is being used, which necessitates strict limitations on work periods and spaces as well as restrictions related to the surrounding environment, such as vibration and noise. It is therefore urgent to develop proper aseismic reinforcement techniques that satisfy these conditions based on the characteristics of each type of civil engineering structure.

(3) Construction of data base for design documents

The construction of data base for design documents is essential for conducting appropriate and reasonable aseismic diagnosis and reinforcement, as well as for restoring earthquake-damaged structures. Each organization responsible for a civil engineering structure should put considerable effort into research on and development of construction of data bases.

4. GENERAL SEISMIC SAFETY PLAN

4.1 Land use and facility deployment for regional seismic safety

(1) Need for a seismic hazard assessment system

In Japan, open spaces formed by streets, roads, and parks are lacking in most urban areas, a result of inadequate effort to plan public facilities. Further, certain areas are densely packed with houses on small lots that do not meet present building and earthquake resistance codes. Such urban communities are less resilient to disasters as well as less comfortable to live in than those in other advanced countries.

Fundamental improvement of the urban environment is one of the most serious issues facing Japan. Since improvements are by no means possible within a couple of years, efforts must be initiated to attain them as early as possible. A "regional seismic hazard assessment system" is one key element to be taken into consideration in such efforts. This is explained below.

1) Areas surrounded by clear boundaries such as arterial roads or collector-distributor streets, rivers, and drainage channels are defined as a unit zone. The exposure to hazard is evaluated for each zone in terms of three environmental components; that is, the natural environment, the infrastructure environment, and the building environment.
2) The natural environment includes topography, geology, and soil properties. The infrastructure environment includes profiles of roads, parks, and fire cisterns. The building environment includes structural types, numbers of stories, and time since completion.
3) For each environmental component, the total exposure is evaluated for each zone and publicized, taking into account the actual state of the environment and people's awareness.
4) Use of the Geographic Information System (GIS) in the above analysis and evaluation is recommended.

Through this process of analysis, evaluation, and publication, people in the community will gain an understanding of the present exposure to hazard. This will lead to a re-evaluation of land prices, which will in turn stimulate spontaneous improvements to the community environment.

On demand from the community, local governments are expected to encourage improvements to the environment through systematic assistance including expertise planning and financial support. Further, governments are also expected to facilitate coordinating these improvements with the normal urban-redevelopment and land-readjustment projects.

(2) Review and revision of urban/regional plans and infrastructure planning guidelines

An important element in urban/regional plans has always been safety in times of disaster. However, plans have not always been well coordinated with urban/regional disaster plans.

The urban infrastructure usually consists of a hierarchy of systems, each with different size and coverage. For example, the street system consists of arterial roads, collector-distributor streets, and local streets. In the case of Japan, however, this infrastructural hierarchy has not been well established, and it is lacking in both quality and quantity. As has been discussed for years, it is necessary to improve and extend Japanese planning standards.

Further, not all the minimum requirements for public facilities—such as evacuation/rescue routes and open spaces useful in case of emergency—have yet been established. To increase the seismic safety of society, an urgent review and revision of planning standards for such facilities is needed. These standards will be also useful in the assessment system described above.

4.2 Emergency management system for disaster mitigation

Delays in rescue operations and fire-fighting aggravated the Hyogoken-Nanbu earthquake disaster, and revealed the inadequacy of current emergency management systems in Japan. Measures for disaster mitigation include several that can be implemented both pre- and post-disaster. Among them, the following require urgent consideration:

(1) Integrated use of various disaster information systems: Various disaster information systems are being constructed by both the public and private sector. However, none are intended or designed to be linked to each other. It is desirable to develop a technology for integrating these independent systems, and to carry out repeated drills prior to a disaster so as to master the integration functions.

(2) Preparing disaster management strategies: Disaster management involves serious decision-making issues such as whether evacuation vehicles or rescue vehicles should have priority, and whether use of water-dropping helicopters is appropriate in urban fire-fighting. Certain strategies for emergency management may be quite different from those used in normal situations, and may at first be considered unacceptable to the community. Through in-depth discussions prior to a real disaster, mitigation strategies that have community-wide consensus should be prepared for various disaster situations.

(3) Drill improvement: A large-scale earthquake disaster is likely to require efforts beyond the capacity of public emergency management agencies, so local communities should be asked to organize effective disaster drills that go beyond the conventional focus on evacuation and early fire fighting. These drills should be more comprehensive, encouraging people to think about what they themselves can do in such a disaster. Drill methods should be changed from the prepared-scenario type to an improvisational type aimed at improving adaptability in an emergency.

(4) Cultivation of disaster managers: Since large-scale disasters are rare, the lessons of past disasters tend to be lost without experts such as disaster managers, and disaster preparedness programs are tend to lack consistency and continuity. However, varied duties and Japan's tradition of periodic transfers tends to inhibit the cultivation of such trained experts. Disaster managers, including high-level decision makers, need to be cultivated to facilitate the early establishment of efficient disaster management systems in Japan.

4.3 Cost sharing for reinforcement and reconstruction

The earthquake resistance of the infrastructure, schedules for seismic reinforcement of existing structures, and plans for post-disaster reconstruction are closely related to cost and the cost burden. Besides cost-benefit evaluations usually performed before determining the cost burden, a number of other cost-related issues arise, as follows.

(1) As with the Hyogoken-Nanbu earthquake, the cost burden sometimes exceeds the ability of the affected community to pay. Moreover, the occurrence of such a disaster in particular community is quite low in probability.

(2) Disaster-related damage extends not only to the economic sphere, but also to human life and even mental health.

(3) Increased investment to secure a safe community may result in a lower budget for

new projects. Hence, the trade-off between the two needs to be evaluated from a socio-economic point of view.

A quantitative evaluation of the hazard mitigation achieved by disaster-related investment is important; it must be done together with the assessment mentioned in 4.1. The evaluated socio-economic effects will form the basis of planning standards for disaster preparedness.

Various legislative and financial relief measures were adopted after the Hyogoken-Nanbu earthquake without in-depth discussion. Some of these gave inconsistent relief to the various types of facilities, and left much room for improvement as regards rule standardization. Rules for financing reinforcement of existing facilities, post-disaster recovery, and reconstruction should be established, especially as regards placing an appropriate cost burden on the various regions and generations. These should take into account some of the important factors listed below.

1) Japanese funding systems to facilitate reconstruction: Every part of Japan is under potential threat from a large earthquake, though the probability of occurrence is low. Meanwhile, the related financial burden—such as the cost of investment in improved seismic safety, insurance premiums, and the cost of recovery and reconstruction—is too heavy for a local community alone to deal with. In principle, the cost burden for infrastructure recovery and reconstruction cannot but be shared by all the Japanese of present and future generations, including direct and indirect beneficiaries and administrative entities of the facilities. This burden sharing can be implemented though several approaches, such as national debt, special taxation, special funding for mandatory earthquake insurance, and rearrangements of existing budgets. By integrating all possible means, financial systems able to provide an optimum response to large-scale disasters should be urgently established.

2) National consensus on appropriate investment for disaster mitigation: The greater the safety we require of our infrastructure, the more we have to pay for its construction and maintenance. Thus, through a process of in-depth discussion among taxpayers, a national consensus on the degree of seismic safety we require of our infrastructure should be developed; this is especially critical as we approach the 21st century and the greater cost burden of the so-called "advanced-age society" becomes an issue.

3) Cost burden rules for reinforcing existing facilities: Much discussion among the private and public sectors, and the development of a consensus, is also required as regards the issue of the cost burden of seismic reinforcement work. The cost burden rules which apply to the reinforcement of a facility should not be the same as those for its construction. This is partly because the latter is usually determined without considering devastating disasters like the Hyogoken-Nanbu earthquake, and partly because a high cost burden may cause a dangerous delay in the reinforcement work. A national consensus is also needed for cost burdens of this kind.