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Integrated Research on Methodological Development of Urban Diagnosis for Disaster Risk and its Applications

Norio OKADA, Hirokazu TATANO, Yoshimi HAGIHARA, Yoshiyuki SUZUKI, Yasuhiro HAYASHI, Michinori HATAYAMA, Jens HARTMAN*, Takeshi NAGAE*, and Hidemaru SHIMIZU*

* COE Researcher, DPRI, Kyoto University

Synopsis

As a part of DPRI-COE research activities, our IMDR Division has conducted an extensive methodological research on integrated disaster risk management, with a focus on "urban diagnosis." This paper outlines the major research achievements made within this framework. First the definitions of key concepts and methodological framework are explained briefly. Then representative research activities conducted by our Division team are specifically described and further research efforts to be made in the remaining phase of the COE research project are addressed.

Keywords: Risk Management, Urban Diagnosis, Methodology

1. Introduction

As a part of DPRI-COE research activities, our IMDR Division has conducted an extensive methodological research on integrated disaster risk management, with a focus on "urban diagnosis." Okada has taken initiative in developing a common research perspective and as well as its methodological framework, whereas the rest of members have conducted specific research activities within this framework. The framework has also been discussed and modified though mutual discussions within the IMDR Division. The following gives an outline of the whole dimension of related research outputs performed in our Division.

2. Definition and Conceptual Models for Integrated Disaster Risk Management and Urban Diagnosis

The prototype scheme of risk management is shown in Fig.

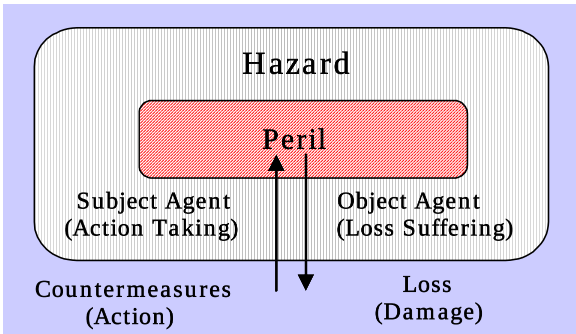

Fig.1 Prototype for Risk management

(1) The key thing is a clear distinction made between the notion of "danger" and that of "damage." The first trigger event of the occurrence of danger is called "peril" and surrounding factors that may either promote or inhibit subsequent events to be triggered by the peril are referred to as "hazard." As a final outcome, damage may or may not be caused. In Fig. 1 damage is restated as "loss." (2) In the intermediate process of a peril resulting in loss, "subject agents" are committed to take an action and to interact with both the peril and hazards. "Object agents" are also there to suffer loss. Thus the occurrence of loss can be interpreted as the

output of subject agents taking "actions" and interacting with both the peril and hazard, and eventually attacking respective object agents. We note that subject agents (SA) and object agents (OA) are clearly identifiable; SA has the capacity to exercise their actions, and take responsibility for its inherent results. OA is expected to have capacity to accept (a part of) the loss if it has been committed to action-taking (decision-making) in one way or another. (In this case OA is also SA.)

(3) The most conventional model for this prototype risk management scheme is "private management" model that is characterized by the equivalence of both subject and object agents. This basic model operates by the "principle of (self-) responsibility." In contrast "public management model" assumes a society, community or region, which consists of multiple agents and most commonly a government or an entity of public interest. Here the subject and object agents may not always be identical. Some are governmental (public sector), non-governmental such as private sector, NGO and even citizens and individuals. Moreover SA and OA are not always a priori identifiable and thus not so self-evident. We need to set up and determine the boundary for those "stakeholders" belonging to its communication platform. As explained later this is part of the reason why we need a participatory approach.

(4) Another key concept that intrinsically characterizes risk management is "unknowns" and "uncertainties" (non-deterministic factors) inherent in the occurrences of the peril, hazard and loss. The theory of probability and statistical approach finds its vital application to modeling uncertain events. However it is even truer that people need to challenge "unknowns" and "inexperienced" events which need to be figured out and anticipated with viable imagination, based on the body of scientific knowledge, and the accumulation of extensive experience available up to date, with an assistance of tools and medias that can best support our imagination.

3. Introducing Risk Management to Disaster Management: A Variant of the Prototype Scheme

As depicted by Fig. 2, what makes essential difference between disaster prevention and a generic form of risk management is that the former is characterized by the notion of region or city as a common (public) space, whereas the latter not. Additionally disaster is featured by unwelcome events triggering disaster, and object agents (and their assets and belongings) are characterized by the manner they are distributed (or concentrated) over space, and also by how vulnerable they are in responding to triggered events.

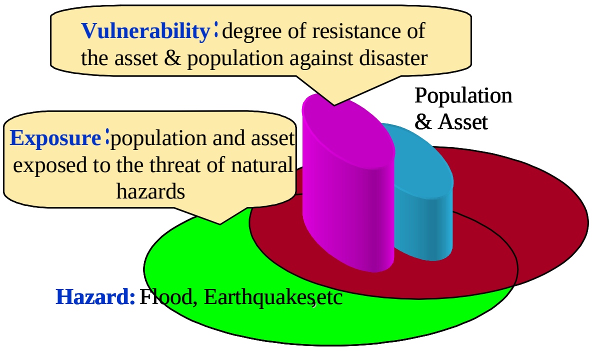

Fig. 2 City Space as Overlaps of Hazard, Exposure and Vulnerability

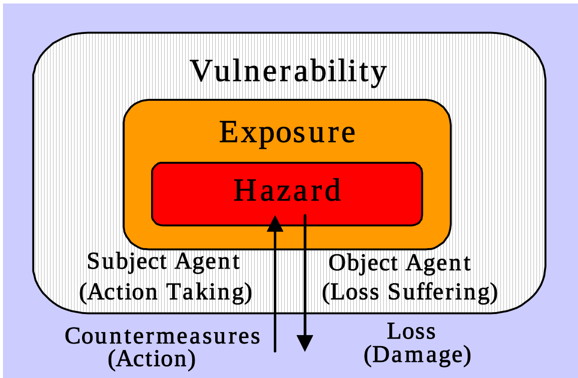

Fig.3 Variant of Prototype Scheme for Disaster Risk Management

Fig. 3 illustrates a variant of the above-stated prototype scheme for risk management (Fig. 1), with specifics of disaster management well incorporated. It is noted that "peril" in Fig. 1 corresponds to " hazard" (with a focus on its original meaning of unavoidable natural hazardous event) in Fig. 2, and likewise "hazard" in Fig. 1 corresponds to either of "exposure" and " vulnerability." Here "exposure" refers to the "spatial distribution or frequency of an involved object agent exposed to the hazard." The term "vulnerability" means the extent the object agent is vulnerable to the forces of the hazard and the degree of exposure.

This type scheme has significance in the following:

i) "Disaster" is differentiated from "hazard" and the former occurs only when the hazard results in the occurrence of the latter, i.e., loss (damage).
ii) "Disaster" is an outcome of risk management where unknowns and uncertainties are unavoidably inherent.
iii) "Disaster" is caused and promoted by the degree and patterns of vulnerability and exposure of involved object agents spatially and temporally distributed over a common region, city or local community.

4. Pre-disaster Risk Management vs. Post-disaster Risk Management

We now think of a time stream of risk management that divides itself into pre-disaster (pre-event) and post-disaster (post-event) management. The former is a proactive management in anticipation of probable disaster. The latter is a retroactive management and classified into the phases of "immediately after", "in the middle of " and "practically after", respectively corresponding to "emergency management", "crisis management" and "recovery and restoration management." Usually the performance of retrospective management is largely constrained by time resources and information available real-time. Therefore decision has to be made immediately and linked directly to its actual practice. Decisions linked to practice characteristically make them "irreversible." This feature of "irreversibility" as well as "limitedly short span of time", together with a "scanty amount of information" all constrain emergency and crisis management.

The interrelationships between pre-disaster and post-disaster risk management merits attention. Community's preparedness before disaster and people's familiarization with emergency tools and equipments in everyday life are known to be pretty effective in the event of emergency management. In this relation people's cohabitation patterns (a kind of exposure characteristics) have been found in close linkage with community's search and rescue (SAR) capacity, as pointed out by Kajitani et. al. (2003).

5. Process of Risk Management as a PDCA Cycle

The process of risk management should be viewed as a cyclic process as illustrated by Fig. 4 (this is a common scheme of risk management process as adopted first by the EqTAP project and then by the DPRI-COE project.) Alternatively Fig. 5 that illustrates the schematic process of PDCA, i.e., Plan-Do-Check-Action Cycle, describes the pith of this cyclic process. We make a point that this process is not self-closed within the cycle of planning as information processing (note that this part corresponds to the echelons of "identify risk" through "evaluate risk" in Fig. 4) . Importantly the process is required to extend beyond "planning" down to "doing," "checking," and "action", eventually leading back to "establish risk" or "context building" for planning and management. This PDCA cycle should apply more to a chain of both proactive (pre-disaster) risk management and retroactive (post-disaster) risk management. This also means that the gap between the two modes of risk management should be filled in and that the phases of "CHECK" and "ACTION" on the part of end-users of disaster management ought to be handed with their initiatives. As mentioned later we will refer to this activity centered on these phases of risk management as "diagnosis"; particularly "urban diagnosis" when cities are focused.

The connotation behind this is our stress on distinguishing "planning without these preceding phases paved by those involved in planning" from "planning with theses phases of urban diagnosis."

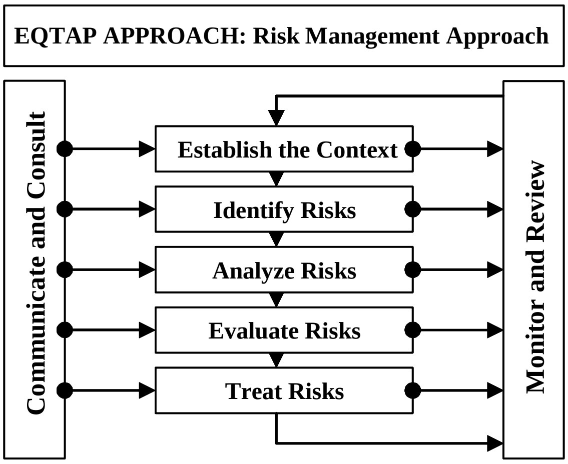

Fig.4 EqTAP-adopted Risk Management Process

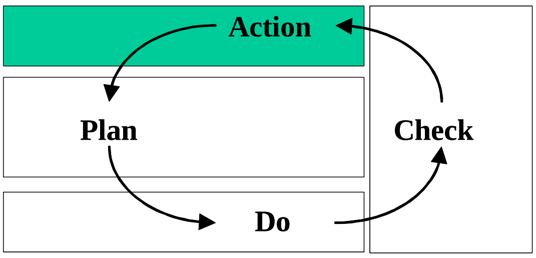

Fig. 5 PDCA Cyclic Process

6. Anticipatory Approach Based on the PDCA Cycle Process

Suppose that our future outlooks are highly uncertain and unknown but our best knowledge tells us that we should (and could) work out a "preparatory countermeasure as a hypothesis" and start out with it. Such being the case, we can make this approach systematic by basing our risk management on the PDCA Cycle Process. This approach is called "anticipatory approach" or "precautionary approach." If this cyclic process intends to induce innovative organizational or socio-cultural scheme to evolve, a system- ecology approach called "adaptive management" may well serve for the purpose. In this case a preparatory countermeasure as a hypothesis is referred to as a "policy" to test empirically (see Fig. 6).

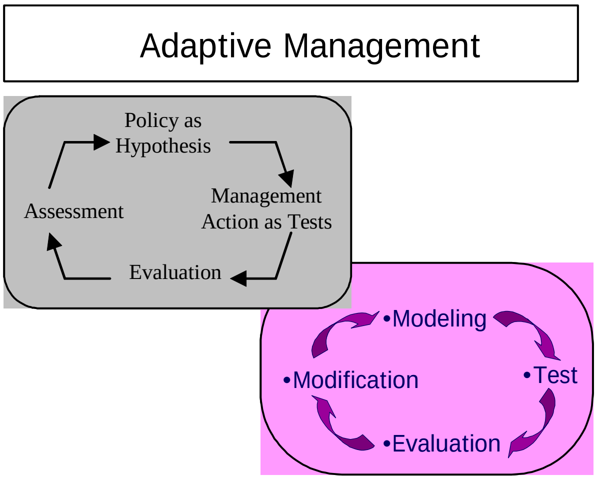

Fig. 6 Process of Adaptive Management

A typical example is the case of the Tonankai twin earthquake disaster that is scientifically predicted to take place in the Pacific Metropolises of Tokai and Nankai Regions in Japan with a probability of ca. 0.95 in 50 years. A great deal of governmental initiatives is currently taken to best prepare for this eminent earthquake. We need to give a challenge to this earthquake risk by anticipatory approach. A question here is: what should we set up a policy as a hypothesis?

An ongoing research challenge made by the authors with us a focus on Nagoya City is relatively convincing. So far crucial themes identified are (a) how to set up a communication platform for the implementation of integrated disaster risk management, (b) which level of governance may fit for which type of platform building in terms of geo-space, jurisdiction and expertise (all put together as "decision common space" as to geography, jurisdiction and common knowledge and technology"), and most importantly and difficultly, (c) who can gradually grow into independent and responsible stakeholders though most of those taking part initially may not necessarily be identical to stakeholders in the real sense of the term in English. This means that the adaptive process of implementing multi-participant decision-making and practices under a variety of disaster risk is hypothetically expected to make them eventually become stakeholders. Later we will take up this question from the viewpoint of socio-cultural backgrounds and human climate, which are considered to override at meta-level, the communication platform and its practice and process of integrated risk management in a specific form.

7. Urban Diagnosis

A lesson learned from the 1995 Hanshin-Awaji Earthquake Disaster is that we need to switch our mind to manage this kind of low-frequency/ high impact disaster that could hit the heart of a densely populated metropolis. We need to manage such catastrophic risks in a more integrated manner

i. Disaster management needs to be linked up more closely and consistently with urban planning and management.
ii. Disaster management should extend more to include the phase of pre-disaster and the time mode of everyday life
iii. Disaster management is required to deal with multiple hazards as well as combined and chained consequences triggered by the occurrence of a hazard.
iv. Disaster management cannot be fulfilled only by the government sector but needs to be participated by the NGOs, private companies, citizens and residents.

Fig. 7 depicts a five-storied pagoda model for viewing a city (region or community) as a vital complex system. The top layer corresponds to "living activity" level, the second to the level of "land-use and built-environment," the third to "infrastructure," the forth to "social environment," and the fifth (bottom) to "natural environment." Notably, as we step up, the speed of change becomes higher. Much of disaster risk is commonly latent and spatially/temporally distributed across the city. Moreover social hazards may lie in ambush over niches between different layers in the spatial/temporal system of the pagoda.

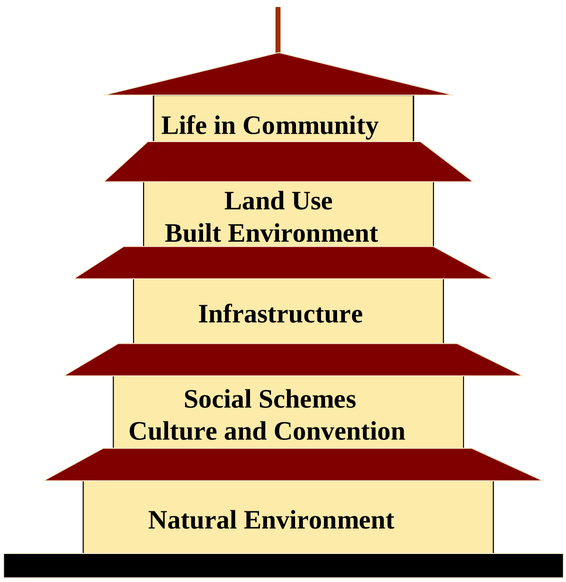

Fig.7 City as a five-layer vital system (Pagoda Model)

In the event of a catastrophic disaster, such spatial/temporal risks will become exposed and in the absence of due awareness of these risks, damage will become much more immense than the case in which disaster risks were properly managed. If we make analogy with management of health risks to a human body, the methodology of comprehensively examine spatial/temporal risks can be interpreted as the methodology of diagnosis of a city as a human body. From this viewpoint let us call it the methodology of "urban diagnosis."

All of the above listed four items point to the need for conducting urban diagnosis for disaster risk management. Note that urban diagnosis principally finds its proper place not so much in "Plan" but in "Do", and more in "Check" and "Action" in the PDCA Cyclic Process. This is because we need to monitor and check up the status-quo conditions before and after a treatment (countermeasure or policy) has been actually introduced as a hypothesis. Importantly the outputs of urban diagnosis should basically be made open to public and prognosis ought to be made to re-start another round of the PDCA Cyclic Process. Then a revised prescription and treatment is developed and selected with "informed consent." Thus the procedure repeats itself until a process-tested treatment has been empirically identified and exercised.

8. Socio-economic Performance Criteria as Measurements for Urban Diagnosis

As mentioned above, urban diagnosis calls for collaborative work among participants and thus inevitably necessitates an agreed-upon common measurement with which to make diagnosis and to figure out needed directives for improvement. Let us call such common measurements "socio-economic performance", with an implication that they should address what their choices open to them mean to them as well as what differences it would make to their life in society, if selected.

It has so far been shown that the practice of urban diagnosis requires a variety of socio-economic performance criteria addressing the needs and values of prospective different stakeholders. This may well justify the significance of model performance criteria that have been developed in our COE research activities (as well as their preceding international research projects such as EqTAP) and that have relevance to respective echelons (levels) of the five storied pagoda model as illustrated in Fig.7

9. Economic Analysis of Catastrophic Risk (H.Tatano et. al. 2003, S.Tsuchiya et. al., 2003)

9.1 Economic Impacts of Catastrophic Event in a Regional Economy(H.Tatano and N.Okada, 2003,)

Natural catastrophe in an economy makes discrete downward jump of its production capacity. This is because some portion of capital accumulated in the economy is destroyed by the disaster. Tatano et.al. (2000) described economic losses due to natural catastrophic event consists of "stock losses" and "flow losses". The stock losses are the lost value of stocks in the economy, i.e., value of destroyed capitals. The flow losses are the secondary losses due to shift of the economic growth path caused by the disaster. These two elements of the losses are interconnected with the effort of restoration investment after the event. If no investment for restoring destroyed stock could be done, i.e., no investment for accumulation of capital, the economy would stay in the same level or worse. As to avoid such losses, investment for destroyed capital is executed in the real world. Therefore, observed losses as flow in the real world is lost value of product by the destroyed capital minus net benefit of rest restoration investment of them.

Reducing both of stock losses and flow losses is important to design effective disaster risk management strategies. Mitigation investment contributes to reduce damages in stock and risk financing arrangement and the restoration policy after disaster affect the levels of production and economic growth path of the economy. This study focuses on anti-disaster risk management policies in a regional economy: mitigation and risk transfer restoration policies. At first, roles of mitigation and restoration are discussed in disaster risk management. In the second, based on a multi-regional general equilibrium model which takes account of disaster risk, mitigation policies are discussed. In the third, the optimal restoration path after a catastrophic event is discussed, based on the analysis completed by use of endogenous economic growth model that consists of two regions which have two types of capital, i.e., infrastructure and private capital. In the forth, design methodology of catastrophic insurance schemes under constraints of insurers' sustainability is developed. A hybrid design model which consists of earthquake damage simulation and stochastic optimization calculation to solve the above problem is formulated. A numerical experiment illustrates its applicability for real world problem by designing earthquake insurance structure of the pilot area.

9.2 The Optimal Maintenance of Infrastructures under Natural Disaster Risks

Recent earthquake disasters have repeatedly demonstrated the seismic vulnerability of infrastructure, especially highways, lifelines and so on. Although much attention has been paid on the preventive maintenance of infrastructure, there are few studies dealt with natural disaster risk. Particularly, the following aspects in such a large-scale infrastructure management as far as the authors know. Specifically, a) several natural disasters, in particular earthquakes, have non-stationary random events; b) there are financial constraints on maintenance cost whereby preventive maintenance takes a certain amount of time. Despite of their importance, these features have been neglected for either simplicity or computability in the past literature.

This study proposes a framework for dynamic evaluation and management of infrastructures facing natural disaster risk involving the above important aspects explicitly. In this study, the optimal maintenance problem is formulated as a stochastic impulse control problem in a continuous time-state framework. By applying the Dynamic Programming (DP) principle, the optimality condition of the problem is represented as a variational inequality problem (VIP). Several another analyses reveal that the VIP reduces to a standard-form linear complementarity problem (LCP) via certain function transformation techniques. This LCP also can be interpreted as a free boundary problem, which divides the time-state space into two domains corresponding to the optimal strategies, say, ‘full maintenance’ and ‘suspending the maintenance’.

These analyses enable us to develop an efficient algorithm exploiting the recent advances in the theory of complementarity problem. In order to develop the numerical method, the LCP is reformulated in a discrete time-state framework. An efficient algorithm is developed, which connects a successive calculation for the finite difference approach for partial differential equations and a merit function approach for the LCPs. This algorithm is applied a simple model as a illustrative example, in which as the catastrophic intensity increases (i.e. the recurrence interval decreases), the administrator intends to 'fully maintain' frequently.

10. Natural and Social Environmental Disaster Mitigation (Y.Sato and Y.Hagihara, 2003, D.Kamiya et. al., 2003)

10.1 Social Research and Analysis on Arsenic Contaminated Drinking Water in Bangladesh (S.Yamamura et.al., 2003)

In recent years, arsenic contamination of drinking water becomes serious problem in Bangladesh. Many institutions from foreign countries support people in Bangladesh by means of making wells, giving arsenic removal devices and so on. But, in fact, many of them are not acceptable by the people, because they can not understand how to keep them or their effectiveness for arsenic. And some devices are too inconvenience to use in their daily lives. We carried out interview to people at two villages in Bangladesh in order to clear the relation between arsenic problems and their social environment, and to consider acceptable alternatives adapted there. Then, the model of deterministic function of drinking water satisfaction is set up and the model of unhappiness function is proposed.

10.2 Historical Transition on Waterside and Regional Disaster Prevention Capacity for Risk Communication

About the time at Hanshin-Awaji Earthquake, the Hanaore, Nishiyama, and Obaku fault that pass through urban area in Kyoto city have been activate, so it is necessary to act against the huge disaster in the urban area, Kyoto city. Especially from the experience of Hanshin-Awaji Earthquake, waterside natural open-spaces are essential not only for providing natural amenities, but also for evacuation in the case of earthquake disasters in urban area. In this research, we explain waterside historical transition in urban area, Kyoto city. Through the analysis of questionnaire survey intended for senior person living in the target area, we consider the way to increase regional disaster prevention capacity based on community activity to implement disaster mitigation functions which waterside natural open-spaces have.

10.3 Roles of a Third Party in the India and Bangladesh Conflict over the Ganges Water Resources (M.Sakamoto and Y.Hagihara, 2003)

The graph model for conflict resolution is used to formally analyze an ongoing conflict between India and Bangladesh over the regulation of the Ganges River in order to illustrate the crucial role a Third Party can play in resolving the dispute. Because a Third Party can assist in resolving a dispute in a variety of ways, a general systems approach to conflict management with a Third Party is devised. The strategic analysis of the India/Bangladesh conflict using the graph model clearly shows that one can determine, in advance, exactly how a Third Party can influence potential resolutions to the dispute.

10.4 Evaluation of Earthquake Risk in Water circulate Network by Safety

In this paper, earthquake risks in water circulate network are classed. Two earthquake risk evaluation indexes by safety are made. One index is considering possibility of arrival and the other is considering danger degree.

These indexes are applied to right area of the Yodo River as a case study. Finally actual condition is compared with alternative applying condition, in order to show validity of indexes. This alternative is waterfront recreation model utilizing of reclaimed water in sewage treatment plant.

11. Earthquake Disaster and Seismic Performance Evaluation of Wooden Houses

(H. Murakami, et. al., 2003, Y. Hayashi et. al., 2003)

11.1 Damage Investigation of Wooden Houses in Northern Miyagi Earthquakes

We have performed the investigation of earthquake damage on wooden houses from the Northern Miyagi earthquakes of July 26, 2003. First, the peak ground velocities in the most heavily damaged area are estimated from the toppling ratios or displacements of tombstones. Then, from a survey of the damages in three towns, it is found that the damage ratio of one-story houses is much higher than that of two-story houses. This damage trend is analyzed and explained by using the method of equivalent-performance response spectrum. Finally, seismic performances of 21 typical houses are compared based on the response limit strength design method. From these studies, it is recognized that hanging walls are very important. Consequently, it is pointed out that in order to improve the method for seismic performance evaluation of existing buildings in the local area, the loading capacity should be verified through experiments using real scale specimen.

11.2 Seismic Performance Evaluation of Wooden Frames

Shaking table tests were carried out for wooden frames with three different seismic resistant elements as well as the same frame without any additional structural elements. The structural elements are plaster walls used in traditional wooden houses and wooden braces and plywood walls used in modern wooden houses. Hysteretic behaviors of these frames are investigated based on the test results. Important characteristics of the hysteretic behaviors, which are critical for the seismic performance, are discovered and compared between the four frames. Constitutive models are proposed to represent hysteretic restoring forces analytically using the test results, and apply to the different frames for simulating their dynamic behaviors. It is found both experimentally and analytically that, among the four frames, the traditional wooden frame with plaster walls has both a large maximum restoring force and a high deformability; therefore, it has the best seismic performance.

11.3 Seismic Performance of Two-Storied Wooden Frames by Full-Scale Shaking Tests

The objectives of this study are to evaluate the seismic performance of wooden frames with various seismic resistance elements by shaking table tests and to develop the evaluation method for the seismic performance of whole wood houses. The shaking table tests of full-scale wooden frames with various seismic resistance elements were also carried. The basic specimen is two-storied post-and-beam wooden frame and is 5880mm in height, 5460mm in width and 3640mm in depth. As the seismic resistance elements used widely in Japan, wooden brace, plastered mud wall, plywood wall are examined. Each specimen has only one seismic resistance element installed. In total, four specimens were tested. The seismic performance of the wooden frames simply evaluated by a calculation method using seismic response spectra is verified from the experimental results. It is found that the restoring force-deformation relationships of wooden frames in wide range of deformation are traced and the maximum displacement responses are estimated. The proposed evaluation method is applied easily to the seismic reinforcement design of existing wooden houses as well as the seismic design of new houses.

12. Conclusion

To conclude, further research efforts are mentioned to fulfill the major objectives of our collaborative studies in the remaining phase of the COE project.

i) The proposed research perspective of integrated disaster risk management needs to be further refined and examined through continued application to the real-world cases as conducted by each of the IMDR research members.

ii) Particularly methodological efforts should be made to enrich the inventory of tools, models and information media with which to carry out urban diagnosis in actual situations of urban disaster risk management.

iii) More coordinated crosscutting research practices will lead to the refinement of the proposed methodology and its accompanying techniques. It is also hoped that policy-making scenarios need to be developed by inviting potential stakeholders in our modeling process.

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災害リスクに対する「都市診断」科学の構築とその応用に関する総合的研究

岡田憲夫・多々納裕一・萩原良巳・鈴木祥之・林康弘・畑山満則・
Jens HARTMAN*・長江剛志*・清水秀丸*

*京都大学防災研究所 COE研究員

要旨

総合防災研究部門では，21世紀COEプログラムにおける研究活動として「都市診断」に着目した総合的な災害リスクマネジメントの方法論の確立についての研究を行ってきた．本稿では，この枠組みのもとで行われた主要な研究結果を示す．まず，全体のキーとなるコンセプトと方法論的な枠組みについて簡単に説明し，次に各分野で行われた代表的な研究活動について概要を示す．最後に，21世紀COEプログラムの残りの期間で行うべき研究課題についての考察を行う．

キーワード:リスクマネジメント，都市診断，方法論