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VERIFICATION OF APPLICABILITY OF DAMAGE ASSESSMENT TRAINING SYSTEM

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SUMMARY

Building damage assessment for issuing victim certificate influenced most of the rebuilding of the livelihood in the long term in the 1995 Hanshin-Awaji earthquake disaster case, because the victim certificate issued by the local government based on the extent of each victim's housing damage was required to receive most of the individual assistance measures. However, a considerable number of victims were dissatisfied with the results of the assessments. This required re-visits by government officials for damage assessment, and the disaster responders became overloaded. Furthermore, in 1998, the Victims' Livelihoods Rebuilding Support Act was implemented. On the basis of this law, 1 million yen (approximately 10 thousand dollars) as the maximum was subsided to those who suffered damages due to natural disaster. Therefore, the result of the assessment is required to be more objectively. There are two important issues to facilitate the assessment: (1) establishing an efficient management system for the assessment to enhance the performance of the tasks, and (2) developing the human resources for conducting the assessment.

From this background, a Damage Assessment Training System (DATS), which was designed reflecting the above issues of (1) and (2) was developed. This Paper verifies the applicability of this system to contribute to expedite the work involved in disaster response.

The training is conducted by repetitive judgment using both more than 14,000 photographs of damaged buildings and damage pattern charts, which provide visual illustrations by schematics of building damage patterns. These photographic images are linked to the GIS database. The validity of this system is checked through the operations and the applicability of the damage pattern charts and the effectiveness of tarring are also confirmed.

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INTRODUCTION

Many damage surveys for buildings are carried out for various purposes after an earthquake disaster in Japan. One of them is *Housing damage assessment*, which is conducted by the government and the result of this assessment provides a basis for the issuance of the victim certificates. In the case of the 1995 Hanshin-Awaji earthquake disaster, the victim certificate, which were divided into four levels as major damage, moderate damage, minor damage and no damage, was used as criteria for assessing the eligibility for most of the individual assistance measures launched by the private as well as the public sector. As a consequence, *Housing damage assessment* influenced most the rebuilding of the victims' livelihoods over a long time period. Furthermore, in 1998, the Victims' Livelihoods Rebuilding Support Act was implemented, triggered by the Hanshin-Awaji earthquake disaster. On the basis of this law, 1 million yen (approximately 10 thousand dollars) as the maximum was subsided to those who suffered damages due to natural disaster, according to the annual income of the victims and the extent of their housing damages. Thus, the relationship between *Housing damage assessment* and the rebuilding of the victims' livelihoods has become closer. In this regard, this assessment may be considered as the survey that requires high accuracy and fair judgment.

Moreover, in *Housing damage assessment*, it is anticipated that this assessment be conducted for all the housings in the afflicted area in the case of a large-scale earthquake disaster because the authorized certificates has to be issued based on the results of this assessment. In this case, it will be difficult for limited human resources to carry out the assessment with construction specialists only, as in the case of the Hanshin-Awaji earthquake disaster. Consequently, a situation is anticipated, in which people without expertise, such as local government officials, must conduct the survey. Therefore, there are two important issues to facilitate the assessment: (1) establishing an efficient management system for the assessment to enhance the performance of the tasks, and (2) developing the human resources for conducting the assessment.

As relevant matters of above mentioned issue (1), in 2001, the national government reviewed and improved the standard for *Housing damage assessment* established in 1968 in response to the social demands regarding objectivity of the assessment. The Guideline for the Application of the Standard for the Assessment of Damages on Housings by a Disaster was also developed by the national government. The assessment items and the method for evaluating the damage level are unified nationwide by this guideline. However, description on developing human resources, for example, the training environment, method and tools are not found in the guideline.

With respect to the above issues, the authors' research groups (1) proposed an effective process for *Housing damage assessment* (Horie *et al*. [1]) and (2) are developing a Damage Assessment Training System (DATS) to train the disaster responders (Horie *et al*. [2]). The proposed assessment process consists of two stages to implement the opposing requirements, which are swiftness and exactness: the first stage involves a prompt survey by visual inspection from the outside of houses; the second stage involves a detailed survey including the interior to convince to victims. The idea of the proposed assessment process in the assessment system has been adapted in the guideline by national government, as described in the next chapter. Thus, how to conduct the assessment by visual inspection efficiently and how to be satisfy the victims with the result are the key points. In order to reach a consensus with the victims, it is also important to lead to objective result. The DATS, which reflects the proposed process, is being developed to bring a unified viewpoint among the investigators by repetitive training even if they are not experts in building structure.

First of all, this paper introduces the computer simulation system for building damage assessment, which is designed for the development of DATS. Secondary, the validity of this system is checked by experts of building structure according to three assessment methods: a) the classification method using a building damage pattern chart, b) the damage assessment method developed by the national government, and c) the damage assessment method developed by the local government.

IMPROVED STANDARD FOR HOUSING DAMAGE ASSESSMENT BY THE NATIONAL GOVERNMENT

Improvement Points

The former standard for *Housing damage assessment*, which was established in 1968, became inadequate under the actual circumstances such that the Committee for the Reviewing of Standard for the Assessment of Damages on Housings by a Disaster was inaugurated in December 2000 in the Cabinet office and improved the standard. The improved standard is shown in **Table 1**. The evaluation of the fundamental function for the residence is respected more in this new standard. In other words, the economic damage of housing is also evaluated as well as the structural damage. However, evaluating the extent of economic damages for each house is difficult in practice. Therefore the percentage of loss is calculated by multiplying a component ratio by a damage ratio on each part of damaged housing such as a roof and column.

Table 1: Improved standard by the national government

Damage Level	Description
Major Damage	**Houses which have been destroyed.** Specifically, cases where the area of the section of the dwelling that collapsed, burned down or washed away is at least 70% of the dwelling, or where the amount of economic damage to the main structural part of the dwelling expressed by the percentage of loss is at least 50% of the value of the dwelling.
Moderate Damage	**Damage to the houses is considerable, but if repaired it can be used again as it was originally.** Specifically, where the area of the section ranges from 20% to less than 70% of the dwelling, or if the amount of economic damage to the main structural part of the dwelling expressed by the percentage of loss is at least 20% but less than 50% of the value of the dwelling.

Assessment Process

In the Guideline for Application of the Standard for the Assessment of Damages on Housings by a Disaster, the standard assessment method is explained with the purpose of operating this new standard exactly and smoothly. The flow of assessment by the guideline consists of three stages as shown in **Figure 1**. Up to the second stage, the extent of the damages is evaluated by visual inspection from outside the housing. If the victims are dissatisfied with the results by visual inspection up to the second stage and apply for resurvey, a more detailed survey including interior such as floor and ceiling is carried out in the third stage. Moreover, in principle, an appointment is required in advance since the presence of residents is mandatory. Therefore, the survey in the third stage entails more time-consuming and extensive work, such that reducing the amount of resurvey becomes a key point to expedite *Housing damage assessment*. Thus, the visual inspection from outside up to the second stage should be performed quickly and objectively.

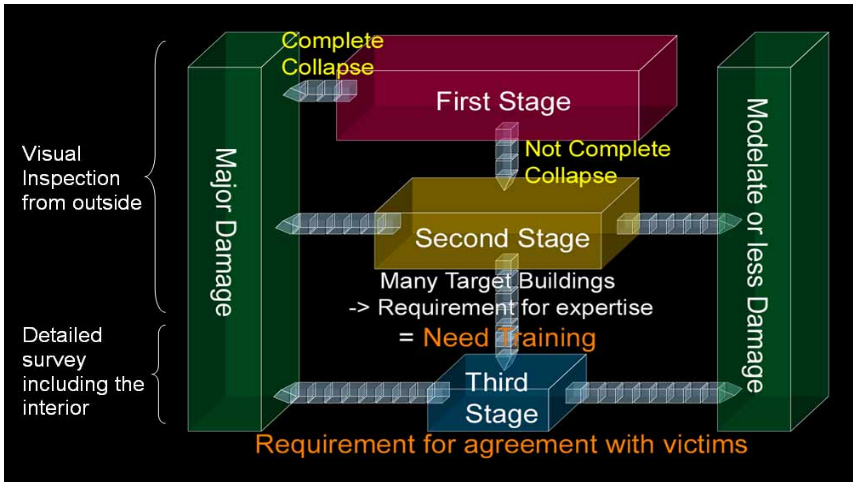


Figure 1: Flow of assessment method improved by the national government

EFFECTIVE INSPECTION METHOD FROM OUTSIDE OF HOUSE IN DAMAGE ASSESSEMENT TRAINING SYSTEM

A Proposal for Damage Assessment Method using Building Damage Pattern Chart

To evaluate the extent of building overall damage from outside quickly and objectively, the authors proposed the application of damage pattern charts, which provide visual illustrations by schematics of building damage patterns (Horie *et al*. [1]). The pattern chart for superstructure damages due to seismic ground motion was proposed by Okada and Takai [3] as shown in **Figure 2**. It was derived from the European Macroseismic Scale 98 (Grunthal G. [4]) and developed from the classification of building damage patterns using photographs taken in Hokudan Town, Awaji Island in the Hanshin-Awaji earthquake disaster. The authors also proposed the pattern chart for wooden-housing affected by liquefaction (Horie *et al*. [5]).

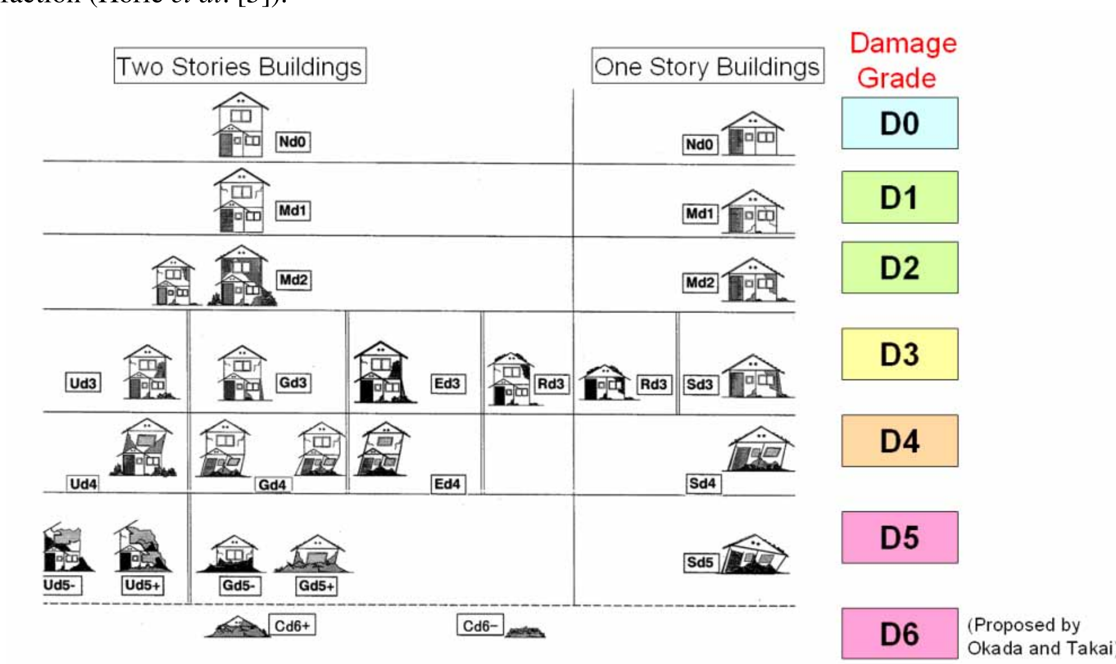


Figure 2: Building damage pattern chart for superstructure damages of wooden buildings

Visual Inspection System in Damage Assessment Training System

The product image of visual inspection system in DATS is shown in **Figure 3**. The Training in the DATS is conducted by repetitive judgment using abundant digital photographs of damaged buildings and damage pattern charts mentioned above.

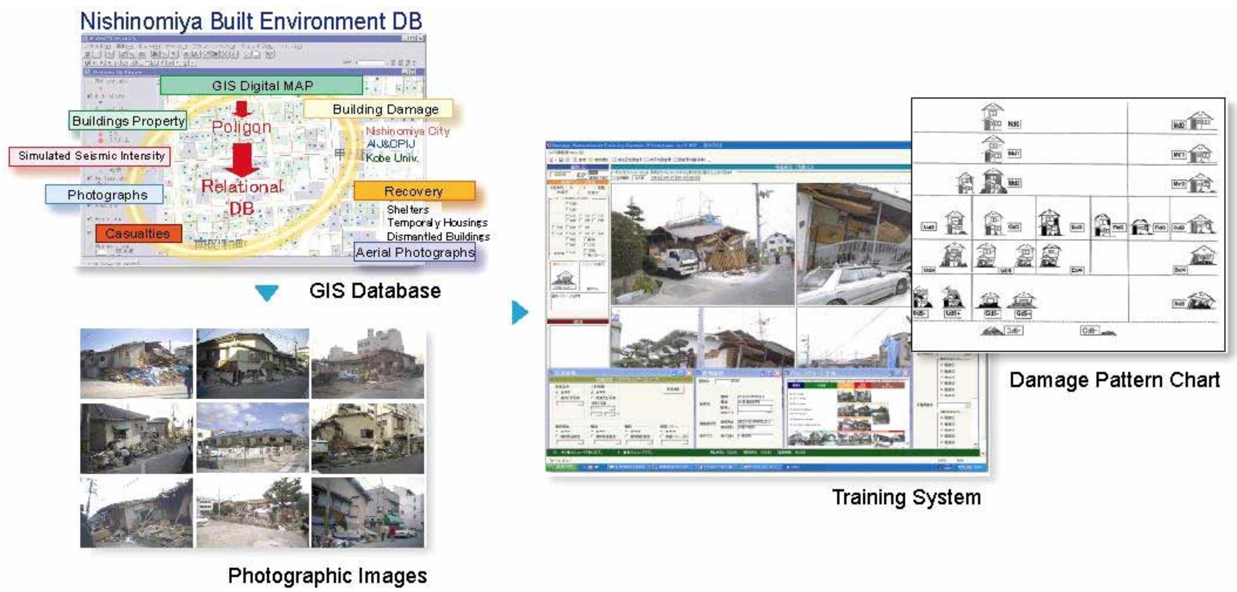


Figure 3: Product Image of Visual Inspection System in Damage Assessment Training System

The digital photographs were taken in the 1995 Hanshin-Awaji earthquake disaster. These photographic images are linked to the Nishinomiya GIS database (Lu *et al*. [6], Kohiyama *et al*. [7]), which was developed by the authors' research groups and archives the digital data on the disaster process in Nishinomiya City, where was one of the most severely damaged areas in the Hanshin-Awaji earthquake disaster. The database contains 11,426 damage photographs.

The use of the damage pattern charts is expected to facilitate damage assessment and reduce errors in the judgment due to differences in the viewpoint among investigators even if carried out by disaster responders in local government who have no expertise in building structure. However, it was not verified whether the proposed charts reflected the damage assessment standard launched by the national government regarding the economic damage in order to implement the actual *Housing damage assessment*. This issue is discussed later using a computer simulation system for building damage assessment developed by the authors.

Development of Simulation System for Damage Assessment of Buildings

As a component of the DATS, the simulation system for damage assessment of buildings has been developed. The constitution of the simulation system is shown in **Figure 4**. First, the database of photo images was constructed. The relationships among the data in the Nishinomiya database were retained. Therefore, each photo images are linked to building information such as construction year, structure type, story and actual result of building assessment. Next, a system capable of referring to both the building information and its damage images on the computer display was developed by linking to the photo images database. Furthermore, assessment forms corresponding to various survey methods were associated to a function, which enables simulation of damage assessments by inputs such as damage situation and the percentage of losses based on each survey method. An example of display and functions are shown in **Figure 5**.

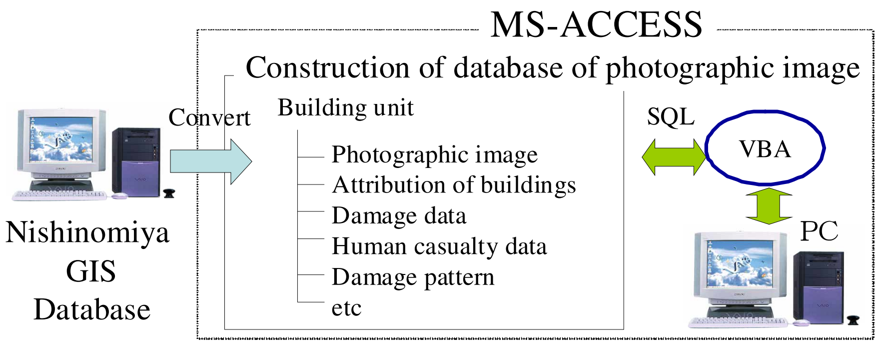
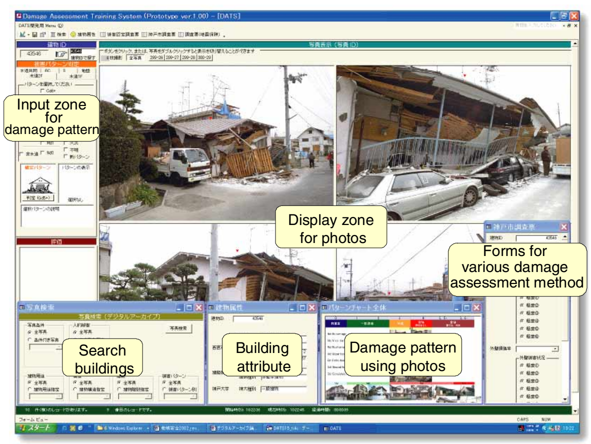


Figure 4: Constitution of simulation system for building damage assessment



FUNCTIONS

- Display the damage image of individual building
- Display the attribute of individual building
- Display the actual assessment results in the 1995 Kobe earthquake
- Display the information of human casualties (gender, age, cause of death, etc.)
- Simulation of damage assessment for various method
- Search buildings

Figure 5: Example of display for the simulation system and functions

SIMULATION OF DAMAGE ASSESSMENT OF BUILDINGS USING BUILDING DAMAGE PATTERN CHART

Damage Assessment Method using the Simulation System

The number of building photographs taken in the Nishinomiya GIS database reaches 26,075. Among these buildings, the wooden-housings whose photographs were taken under better conditions such as the angle of view and the distance, account for 1,536 buildings. These buildings were selected as the target and the extent of each damage was classified based on the damage pattern chart using the simulation system for building damage assessment. Although liquefaction occurred in Nishinomiya city, the wooden-housings that suffered obvious damages due to liquefaction were not found in the target buildings. Thus, the classification of damage pattern was conducted based on the pattern chart of the wooden building proposed by Okada and Takai. The classification was carried out by two authors separately. When the results were different, the pattern was classified once again at the same time.

Result of Classification using Building Damage Pattern Chart

The result of the classification is shown in **Figure 6**. The using chart categorizes the building damages into seven damage grades (D0-D6). In each damage grade, more detailed damage patterns are categorized. As new damaged pattern, ”Pd5±” were derived from “Ud5±” to take into account the amount of loss inside. The dominant patterns in each damage grade were “Nd0”, “Md1”, “Md2”, “Gd3”, “Gd4”, “Gd5+” and “Cd6+”. Namely, cases where the first floor of a two-story building suffered more severe damages were the majority.

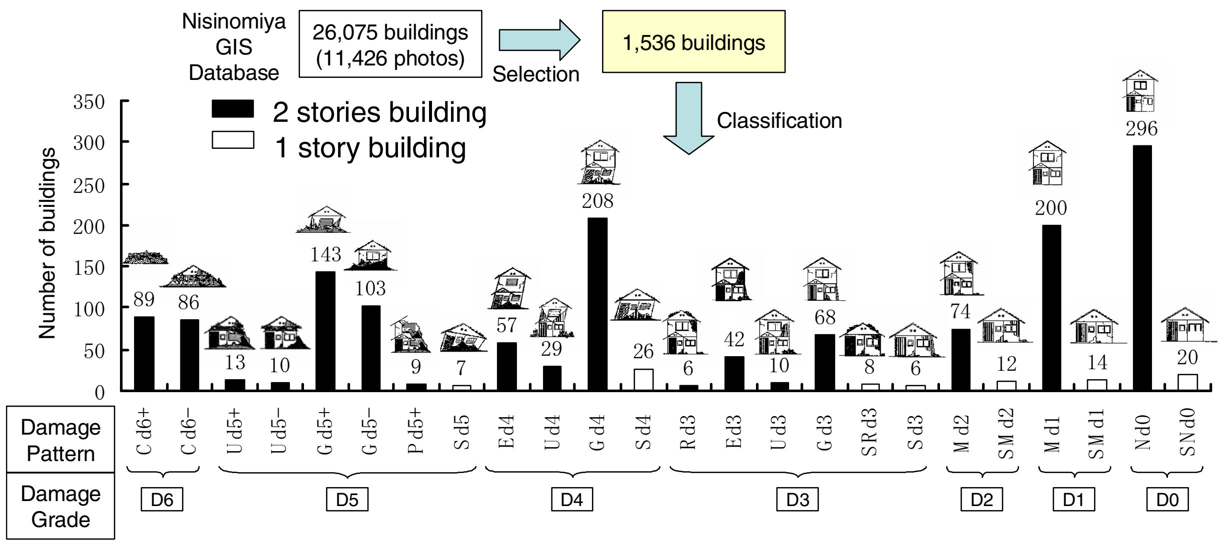


Figure 6: Result of classification based on damage pattern chart

Comparison with the Actual Assessment Result in the Hanshin Awaji Earthquake Disaster Case

The damage pattern chart was developed to provide an objective determination. Thus, the result obtained with the damage pattern chart and the actual results of assessment conducted in the Hanshin-Awaji earthquake disaster were compared. Two actual result data sets were used for comparison: a) the result of *Housing damage assessment* for issuance of victim certification by Nishinomiya city and b) the result of survey for academic interest by the Architectural Institute of Japan and the City Planning Institute of Japan (AIJ&CPIJ) [8].

Comparison with the result of assessment by Nishinomiya city

Although Nishinomiya city carried out the *Housing damage assessment* by visual inspection from outside initially, a considerable number of victims were dissatisfied with the result and applied for resurvey as soon as the victim certificate was issued. The resurvey was conducted taking into account the interior damages. The comparison of the damage grade using the damage pattern chart and the result of assessment by Nishinomiya city is shown in **Figure 7**. "D3" or above are almost equivalent to major damage. In the case of "D2", the proportion of the major damage is 53.8% and moderate damage is 42.8%, indicating that the threshold between major damages and moderate damages is in "D2". It is also conceivable that the threshold between moderate damages and minor damages is in between "D1"and "D0".

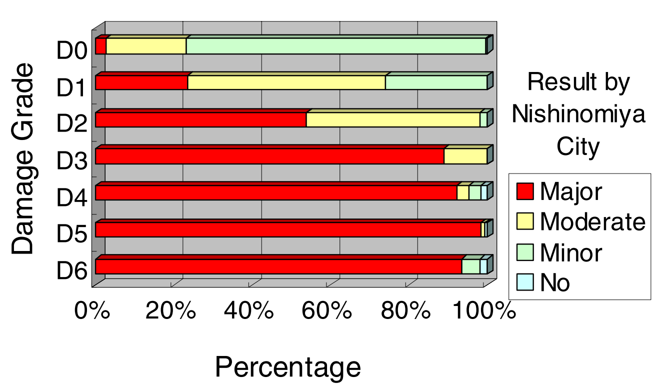


Figure 7: Relationship between the damage grade and actual survey results by Nishinomiya City

Comparison with the result by AIJ&CPIJ

The standard of the survey for academic interest by AIJ&CPIJ was different from that of *Housing damage assessment* for issuance of victim certificates. This survey was conducted by visual inspection from outside. Additionally, there were little social restrictions such as the victim certificate, such that the result of assessment by AIJ&CPIJ can be regarded as being more objective. The comparison between the damage grade and the result by AIJ&CPIJ is shown in **Figure 8**. "D4" or above are almost equivalent to major damages. In the case of "D3", since the proportions of major damages and moderate damages are 31.8% and 42.8% respectively, the threshold between major damages and moderate damages is presumed to be in "D3". The threshold between moderate damage and minor damage is in between "D2" and "D1".

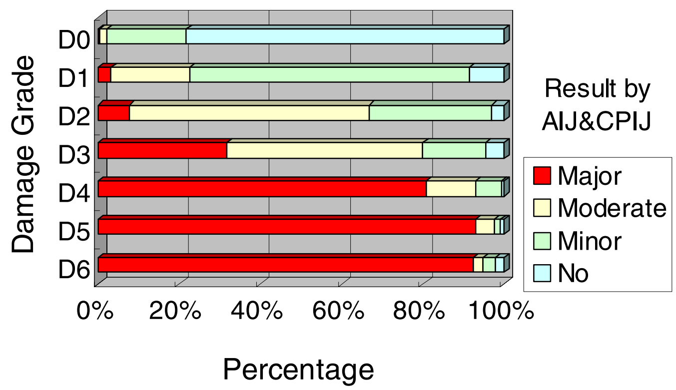


Figure 8: Relationship between the damage grade and actual assessment results by AIJ&CPIJ

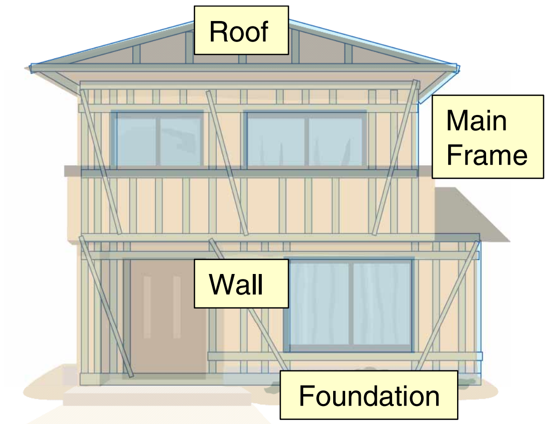
APPLICABILITY OF INSPECTION METHOD USING BUILDING DAMAGE PATTERN CHART

Housing Damage Assessment Method Devised after the Hanshin-Awaji Earthquake Disaster

The improvement of the method for *Housing damage assessment* was carried as mentioned in second chapter. The improved standard and the guideline lack history, such that the trend of the determination must be checked. Therefore, simulations for *Housing damage assessment* were performed using the simulation system for building according to two methods: a) damage assessment by the national government and b) damage assessment by the local government.

Assessment method based on the guidelines developed by the national government

According to the method by the national government, the assessment was conducted using three stages, as shown in Figure 1. The first survey has the objective to estimate damages at an early stage and to distinguish between obvious major damages and the others. In the second survey, in the case of wooden housing and prefabricated housing, the inclination of housing is checked firstly. If the inclination is 1/20 rad or more, the extent of the damage is determined as a major damage immediately. In the case of less than 1/20 rad, The damage ratio of each assessment item which are 1) roof, 2) columns (or shear strength walls), 3) walls (outside walls) and 4) foundation, is evaluated from outside of the housing. Subsequently, the percentage of loss is calculated by multiplying component ratio by the damage ratio on each item. The component ratios are shown in **Figure 9** combined with those by local government described later. If the amount of economic damage is 20% or more, the extent of damage is judged as moderate damage, and major damage if it is 50% or more.

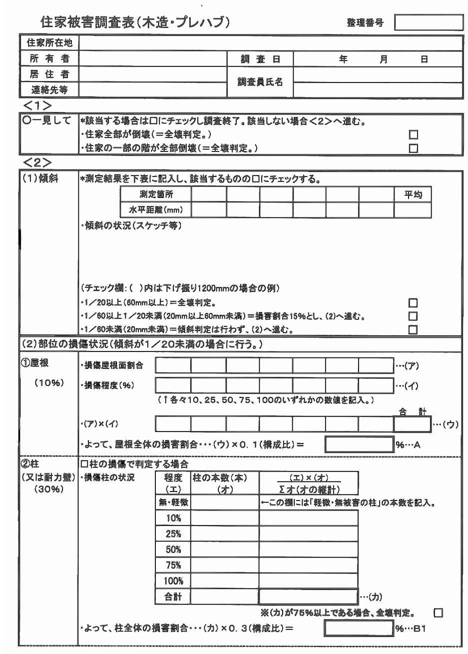


Percentage of loss =

$$\sum_{items} (\text{Component ratio} \times \text{Damage ratio})$$

	Constitution rate in the case of visual inspection [%]			
	Roof	Wall	Main frame	foundation
Method by national government	10	50	30	10
Method by local government	15	45	40	-

Example of Assessment Form (Check Sheet)


住家被害調査表（木造・プレハブ）　整理番号

住家所在地			
所有者		調査日	年　月　日
居住者		調査員氏名	
連絡先等			

<1>

○一見して　*該当する場合は□にチェックし調査終了。該当しない場合<2>へ進む。
・住家全部が倒壊（＝全壊判定。）□
・住家の一部の階が全部倒壊（＝全壊判定。）□

<2>

(1)傾斜　*測定結果を下表に記入し、該当するものの□にチェックする。

測定箇所							平均
水平距離(mm)							

・傾斜の状況（スケッチ等）

（チェック欄：（　）内は下げ振り1200mmの場合の例）
・1／20以上（60mm以上）＝全壊判定。□
・1／60以上1／20未満（20mm以上60mm未満）＝損害割合15%とし、(2)へ進む。□
・1／60未満（20mm未満）＝傾斜判定は行わず、(2)へ進む。□

(2)部位の損傷状況（傾斜が1／20未満の場合に行う。）

①屋根（10%）
・損傷屋根面割合 …(ア)
・損傷程度(%) …(イ)
（↑各々10、25、50、75、100のいずれかの数値を記入。）
・(ア)×(イ)　合計 …(ウ)
・よって、屋根全体の損害割合…(ウ)×0．1（構成比）＝　%…A

②柱（又は耐力壁）（30%）
□柱の損傷で判定する場合
・損傷柱の状況

程度(エ)	柱の本数(本)(オ)	(エ)×(オ) / Σオ(オの縦計)
無・軽微		←この欄には「軽微・無被害の柱」の本数を記入。
10%		
25%		
50%		
75%		
100%		
合計		…(カ)

※(カ)が75%以上である場合、全壊判定。□
・よって、柱全体の損害割合…(カ)×0．3（構成比）＝　%…B1

Figure 9: Housing damage assessment method devised after the Hanshin-Awaji Earthquake Disaster

Assessment method developed by the local government

Kobe city developed an assessment method, which was an improved version of the method that was utilized actually at the time of the Hanshin-Awaji earthquake disaster. The standard of the damage assessment by Kobe city was based on the previous national standard of 1968. Therefore, the method by Kobe city was similar to that of the national government. The assessment consists of two stages: the first stage is conducted by visual inspection from outside; the second stage is carried out by detailed inspection including interior damages. Firstly, the inclination of the housing is checked in the same way as the national government. If the inclination is 1/20 rad or more, the extent of damage is determined as a major damage. In the case it is less than 1/20 rad, each assessment item, i.e., 1) roof, 2) walls and 3) main frame (columns and foundation) are investigated and the damage ratio is evaluated. The percentage of loss is calculated by multiplying a component ratio, which is shown in **Figure 9**, by the damage ratio on each item.

Simulation of Housing Damage Assessment

The photographed building was assessed using the simulation system based on two methods: one was by national government, the other was by local government. The target buildings were selected at random, up to 20 buildings in each damage pattern shown in **Figure 6**. If the number of buildings was less than 20, all the buildings from the damage pattern were selected. The assessment using the simulation system was performed by an expert of building structure.

Applicability of the Building Damage Pattern Chart

The damage grade evaluation by the building damage pattern chart and the two assessments, which were developed by the national or the local government, were compared in order to verify the applicability of the pattern chart to visual inspection from outside in the *Housing damage assessment*. Comparison between the damage grade and the results obtained by the national government method is shown in **Figure 10** and between the damage grade and the results by the local government is also shown in **Figure**

11. The buildings, which were classified into the damage grade “D0” and “D5”or more, were excluded from subsequent analyses. “D0” were buildings for which no damage could be found from outside, and “D5” or above were buildings that could be determined as having suffered major damages at a glance.

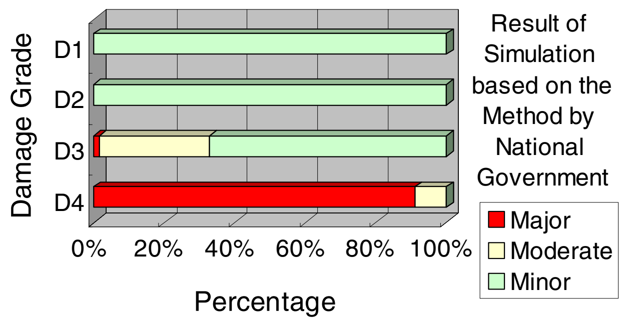


Figure 9: Relationship between the damage grade and result of simulation based on method by national government

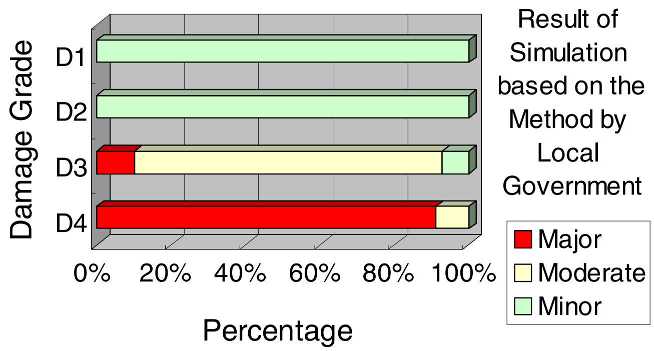


Figure 10: Relationship between the damage grade and result of simulation based on the method by local government

According to **Figure 10**, the threshold between major damages and moderates damage according to the results from the national government method is between “D4” and “D3”. Moreover, the threshold between moderate damages and minor damages is within “D3”. On the other hand, regarding the relationship between the damage grade and the results obtained by the local government, the threshold between major damages and moderate damages is between “D4” and “D3” as in the case of the national government. However, the threshold between moderate damages and minor damages is between “D3” and ”D2”, which is similar to the division by the damage grade.

Next, the relationship between the damage pattern and percentage of loss was analyzed. Four damage patterns, which are defined as “Md1”, “Md2”", “Gd3” and “Ed4”, and the percentage of loss obtained in both simulation results based on the national and local government methods were compared, as shown in **Figure 11** and **Figure 12**. The four damage patterns were major damage patterns of wooden housing, with a sufficient number of buildings as samples for this analysis. It was assumed that the percentage of loss in each damage pattern followed the normal distribution. However, the pattern of "Md1" was excluded from the Figures because it was over-scale. **Figure 11** and **Figure 12** shows that the results based on the guidelines of the national government are generally shifted the leftward, pointing out that evaluation by the national government tends to be on the severe side. In the case of the local government method, “Gd3” and “Ed3”, which are the main patterns in the damage grade “D3”, are distributed almost within the moderate damage zone. On the other hand, regarding the results obtained by the national government method, although the peak values of the normal distributions belong to the moderate damage zone, “Gd3” and “Ed3” are distributed broadly even into the minor damage zone.

From the comparison between the damage grade assessed by the pattern chart and the results of the two damage assessments that were developed for *Housing damage assessment* after the Hanshin-Awaji earthquake disaster, the assessment method based on damage pattern chart appears to be in good correspondence with the method for *Housing damage assessment*.

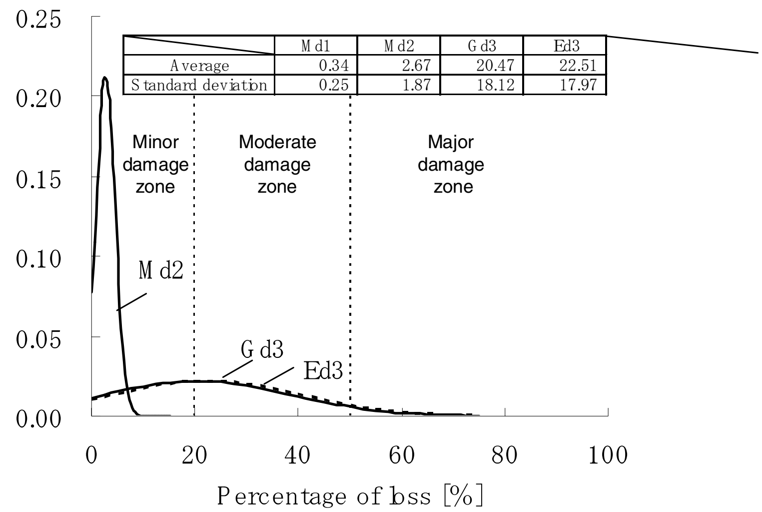


Figure 11: Relationship between the damage pattern and percentage of loss by the method of national government

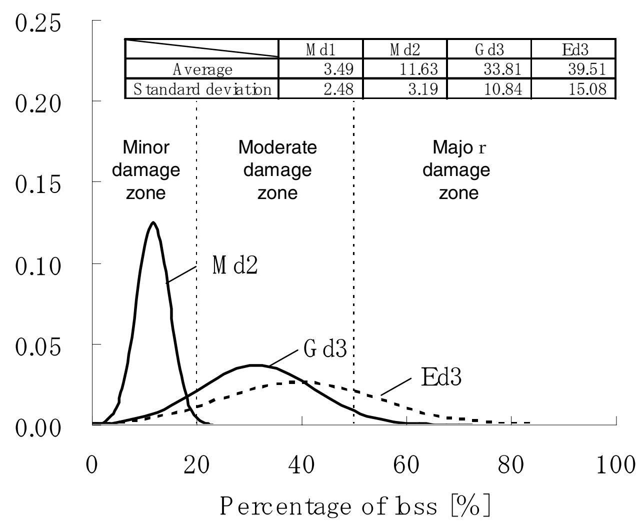


Figure 12: Relationship between the damage pattern and percentage of loss by the method of local government

CONCLUSIONS

The concluding remarks in this paper are as follows.

(1) A simulation system for building damage assessment was developed and the buildings photographed in the 1995 Hanshin-Awaji earthquake disaster were classified using a damage pattern chart.
(2) From the comparison of the results obtained by the pattern chart and results of the damage assessment carried out in the Hanshin-Awaji earthquake disaster, it is clear that the major damages assessed by the Nishinomiya city method was included in the damage grade level “D2”.
(3) The evaluations by the current methods, which were devised after the disaster, tend to be more on the severe side than the previous methods that were applied in the Hanshin-Awaji earthquake disaster.
(4) It was found that the assessment method based on the damage pattern chart was in good correspondence with the method for *Housing damage assessment*.

In the future, an effective damage assessment training system for *Housing damage assessment* will be developed to contribute to expedite the work involved in disaster response based on these analyses.

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