DEVELOPMENT OF BUILDING DAMAGE CHART FOR POST DISASTER MANAGEMENT

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SUMMARY

It is found from the questionnaire about the victim’s need for information regarding livability and house repair that the victims needs the information about housing options at the first one week after the Great Hanshin-Awaji Earthquake. However, Building Safety Evaluation, which was the first damage assessment for the individual houses, conducted 6 days after the earthquake from January 23rd to February 9th, 1995. The information needs of the victims cannot be sufficiently fulfilled. The building damage assessment must be conducted both quickly and exactly. It is conceivable that building damage survey using the damage chart is effective. This paper evaluates the effectiveness of the damage chart for damage assessment, and classifies photographic data that are linked to the geographic information systems (GIS) database of Nishinomiya City, based on the damage chart. Inn addition, we develop the damage chart of wooden structures affected by liquefaction from the case of Amagasaki City.

INTRODUCTION

Damage assessment needed for disaster management for housing is as follows, according to time series (1) Initial Damage Estimation, (2) Building Safety Evaluation and (3) Damage Assessment. Initial Damage Estimation is for applying the Disaster Relief Law (Saigai Kyujyo Hou), Building Safety Evaluation is the damage assessment that determines the safety of buildings and Damage Assessment is the assessment for issuing the Victims Certification.

It is found from the questionnaire about the victim’s need for information regarding livability and house repair that the victims needs the information about housing options at the first one week after the Great Hanshin-Awaji Earthquake [Tatsuki and Hayashi, 1999]. However, Building Safety Evaluation, which was the first damage assessment for the individual houses, conducted 6 days after the earthquake from January 23rd to February 9th, 1995. Therefore the information needs of the victims cannot be sufficiently fulfilled. The building damage assessment must be conducted both quickly and exactly. It is conceivable that building damage survey using the damage chart is effective.

The proposals regarding the building damage survey method were based on the comparison and examination of the survey results. Murao and Yamazaki (1999) pointed out that the building damage survey needs the criterion with objectivity and uniformity, and proposed a building damage survey sheet based on the actual construction cost, by comparing 11 surveys. Okada and Takai classified the building collapse patterns and proposed a method of building damage survey based on a building damage chart [Okada and Takai, 1998; Takai and Okada, 1998].

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However, there are no studies to prove the effect of the damage chart.

The damage of the building can be categorized to four types according to the soil condition (no liquefaction - liquefaction) and the structure (engineered and non-engineered). (1) No Liquefaction – Engineered Structure, (2) No Liquefaction – Non-Engineered Structure, (3) Liquefaction – Engineered Structure and (4) Liquefaction – Non-Engineered Structure. The damage chart for (1) and (2) have already exist. The chart by Okada and Takai is for wooden structures, for an unreinforced masonry structure and reinforced concrete structure of no liquefaction soil. There is no damage chart for (3) and (4), Liquefaction – Engineered or Non-Engineered Structure.

This paper evaluates the effectiveness of the damage chart for damage assessment using photographic data linked to the GIS database of Nishinomiya City, and develop the damage chart of wooden structures affected by liquefaction from the case of Amagasaki city.

2. BUILDING DAMAGE SURVEY USING DAMAGE CHART

2.1 Building Damage Chart

Okada and Takai classified building damage pattrens using building damage photographs taken in Hokudan-cho, Awaji Island after the Great Hanshin-Awaji Earthquake Disaster, and proposed the damage chart. This damage chart classifies the damage, and includes figures of the damage patterns. The definition of this damage chart is shown in Table 1. The primary aim of the chart was to identify the damage scale of the building visually from the outside.

2.2 Built Environment Database

We constructed the Built Enviroment Database of Nishinomiya City after The Great Hanshin-Awaji Earthquake Disaster using GIS [Lu, 1999]. This database includes the following data: (1) urbanization area data, (2) real estate tax roll data before the earthquake, (3) data from the investigation of damaged buildings, (4) human casualty data, (5) photographs of the damaged buildings. Total number of photographs in this GIS are about 11,000. We classified these photographs using the damage chart.

Table 1: Definition of damage chart made by Okada and Takai

	Two-Story	One-Story
No Damage	Nd0: No damage	Nd0: No damage
Slight Damage	Md1: Cracking of the wall, peeling and falling off of a small amount of the exterior material	Md1: Cracking of the wall, peeling and falling off of a small amount of the exterior material
	Md2: Peeling and falling off of a much of the tile, mortar of the wall	Md2: Come off and fall a lot of the tile, mortar of the wall
Half Collapse	Ud3: A part of column, beam or wall is damaged, No loss of inside space (only part of 2nd floors) Gd3: A part of column, beam or wall is damaged, No loss of inside space (only part of 1st floor) Ed3: A part of column, beam or wall is damaged, No loss of inside space (part of both 1st and 2nd floors)	Sd3: A part of column, beam or wall is damaged, no loss of inside space
Total Collapse	Ud4: Column, beam are damaged and loss of inside space (only part of 2nd floor) Gd4: Column, beam are damaged and loss of inside space (only part of 1st floor) Ed4: Column, beam are damaged and loss of inside space (part of both 1st and 2nd floors)	Sd4: Column, beam are damaged and loss of inside space
	Ud5-: 2nd floor is collapsed Ud5+: 2nd floor is collapsed and 1st floor is damaged Gd5-: 1st floor is collapsed Gd5+: 1st floor is collapsed and 2nd floor is damaged *	Sd5-,Sd5:Marked loss of inside space (roof falls to the ground, roof may fall to the ground) *
	Cd5-: Almost collapsed (roof falls to the ground, Roof may falls to the ground) Cd5+: Completely collapsed *	

*: Collapse of a story

2.3 Classification Study Using Damage Chart

We classified the photographic data of the Built Environment Database based on the damage chart made by Okada and Takai, in order to inspect the building damage pattern in Nishinomiya City. In this area, the Architectural Institute of Japan (AIJ) and City Planning Institute of Japan (CPIJ) [AIJ&CPIJ, 1995] conducted survey for academic interest mainly. The total collapse rate of all buildings for every community in the southern area of Nishinomiya City, determined in the survey of AIJ&CPIJ, are shown in Figure 1 [BRI, 1996]. The survey by AIJ&CPIJ determined four grades of damage: No Damage, Rank A (Slight Damage), Rank B (Half Collapse) and Rank C (Total Collapse). The target area of the classification study is also shown in Figure 1. This classification study included a total of 24 communities. These communities suffered comparatively heavy damage, the rate of totally collapsed buildings in each community was in the range from 14% to 65%. The numbers of the buildings in the studi area are given in Table 2. Total of 798 buildings and their positions were confirmed from 293 photographs. The damage chart made by Okada and Takai was for wooden structures, therefore, we investigated building damage to 698 wooden structures and classified the damage pattern of these buildings.

2.4 Resuls of the Classification Study

The classification of the damage patterns of buildings in the study area using the damage chart is shown in Figure 2. “Incapable determination” indicates that the degree of damage could not be evaluated because the building taken in the photograph was too small. Consequently, the proportion of total collapse is high at 40.4%. In this area, the proportion of total collapse of non-firm buildings, a non-firm buildings is one or two-story building and indicates to most wooden structure, by the AIJ&CPIJ is survey is 32.4%. The proportion of total collapse determined in this study is a little higher than that determined by AIJ&CPIJ. These photographs do not include all buildings. Therefore, it can be considered that damaged buildings were the main objects of the photographs. In the classification of total collapse, the pattern in which the first floor of a two-story building suffered damage (Gd4, Gd5-, Gd5+) is dominant 45.0%. The pattern in which damage of the second floor is severe (Ud4, Ud5-, Ud5+) is infrequent 6.4%. The proportion of patterns in which a story of a building collapsed, causing considerable casualty occupants is about 53.9%.

On the other hand, regarding individual buildings, the results of the cross-counting analyses is shown in Figure

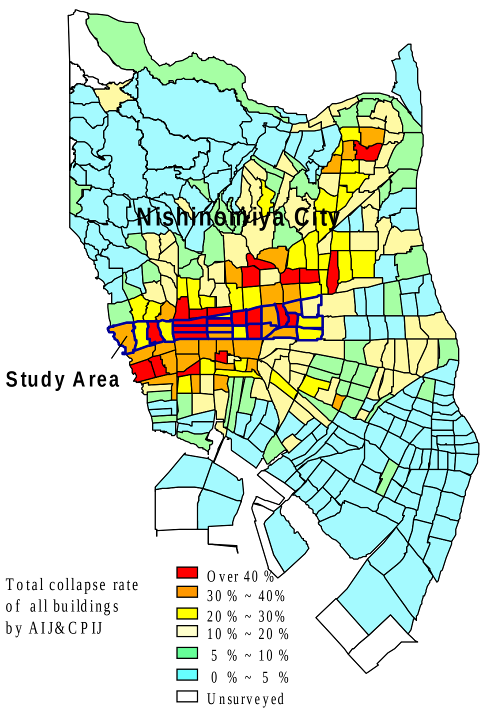

Figure 1: Distribution of total collapse rate in Nishinomiya City and target area of the classification study

Table 2: buildings in the study area

Number of communities		24
Number of photographs		293
Number of the studied buildings	Wooden structures	698
	Nonwooden structures	100
Survey by AIJ&CPIJ	Total number of buildings	5064
	Total Collapse	1526
	Half Collapse	716

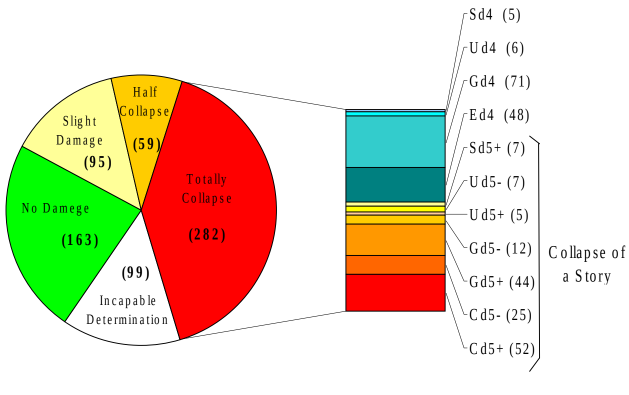

Figure 2: Proportion of damage patterns by the study

3. The 58.0% results determined by both surveys were in agreement. In particular, the buildings which is determined as total collapse by the damage chart corresponded very well at 80.2%. Other cases were unevenness, on the whole, the determination by the damage chart evaluated lower damage than by the AIJ&CPIJ did. The result of totally collapsed buildings with or without collapse of a story is shown in Figure 4. There was little difference from the results of the AIJ&CPIJ survey.

There is difficulty in visual inspection from the outside; when the 1st floor is collapsed completely and damage of the 2nd floor is light, the building may appear to be a one–story building with only slight damage without additional information. In addition, most of the photographs are only taken from one side, therefore, even the building seem to be undamaged from one side, it may seem to be totally collapsed from other sides. These factors may cause the differences in the two survey results. However, the evaluation using the damage chart was easy, we will improve the damage chart based on these results.

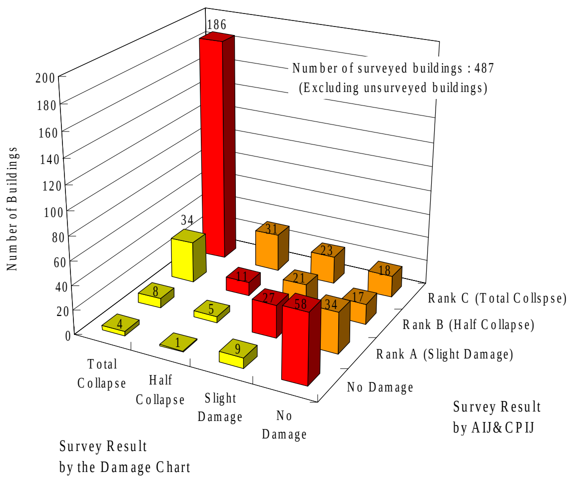

Figure 3: Cross-counting analyses of survey results by the damage chart and AIJ&CPIJ

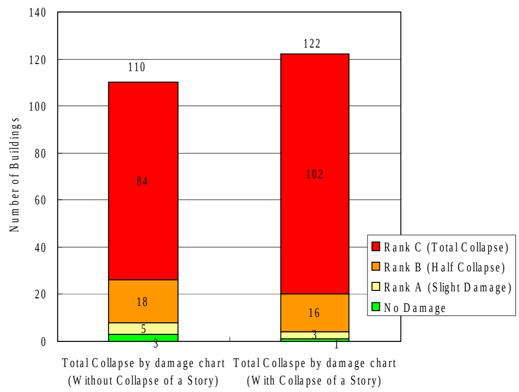

Figure 4: Result divided by collapse of a story

3. DAMAGE CHART FOR BUILDINGS AFFECTED BY LIQUEFACTION

3.1 Purpose of the Survey of Building Damage due to Liquefaction

The damage chart by Okada and Takai is limited to the classification of the superstructure of wooden structures, and only the simplified versions for an unreinforced masonry structure and reinforced concrete structure are shown. Therefore, the damage chart must be supplemented with the collapse patterns of nonwooden structure and those due to liquefaction. Thereupon, for the purpose of clarifying the damage patterns due to liquefaction, we carried out a hearing survey and building damage survey regarding Tukiji area in Amagasaki City, which suffered severe damage due to liquefaction (e.g. Kurazono et al.,1997; Hamada et al.,1997). We carried out the hearing survey at the Tukiji Land Readjustment Office (TLRO) in Amagakaki City, which conducted land readjustment work, and at the Geo-Research Institute, Osaka, which conducted the damage survey consigned by Amagasaki City Goverment.

3.2 Building Damage due to Liquefaction in Tukiji Area

The location of the Tukiji area in Amagasaki City is shown in Figure 5. this area was reclaimed over a sandbar and small islands in the Edo period, and the north, east and south sides of this area face a canal. The ground is an accumulation of loose alluvial deposit from the surface of the ground to a depth of about 8m. The underground water level is very high, with G.L.-0.5m on average. Under these condition, by the 1995 Hyogo-ken Nanbu Earthquake, sand boiling and subsidence of the ground occoured throughout this area. Wooden structures constituted about 90% of all structures. Moreover most of the structures were old wooden structures that were built in the 1800's due to the historic background of this area, which prospered as a castle town in the Edo period. Besides, comparatively new reinforced-concrete structures also existed in this area.

Even though the building damage pattern was mainly subsidence and inclination as shown in Photographs 1 and 2, structural damage such as total collapse or damage to walls and roofs also occurred. As a result of the AIJ&CPIJ survey, the proportions of totally collapsed buildings was 5.8% and that of half collapsed buildings was 5.2% in this area, excluding the unsurveyed buildings. As an example of building subsidence, there was a building have subsiding about 900mm in spite of it being a comparatively light wooden structure.

3.3 Comparision of the Building Damage Survey bys Visual Inspection

We compared the two surveys by visual inspection from the outside: (1) survey conducted by Amagasaki City to determin the actual state of damage in the first step of land readjustment work, (2) the AIJ&CPIJ survey. The Amagasaki City survey was conducted February 3rd to 6th, 1995. Both surveys were conducted by visual inspection. The criterion of structural damage was not defined especially in the TLRO survey. Therefore, this was greatly influenced by the judgment of the investigator. For damage due to liquefaction, this criterion placed great importance on subsidence and inclination. In the criterion, when building subsidence and inclination were observed, the building was classified as half collapse. When they were observed clearly, the building was classified as total collapse. In contrast, the criterion in the AIJ&CPIJ survey more concretely defined structural damage in addition to subsidence and inclination. In the standard of inclination, if building inclination was observed, it was classified as half collapsed. If the building inclination of over five degrees was observed, it was classified as totally collapsed. The criterion of subsidence in the AIJ&CPIJ survey was defined for reinforced concrete structures, which are assumed to be relatively heavy. However, that was not defined for wooden structures and steel structures, which are assumed to be comparatively light. This leads to the conjecture that building damage due to subsidence of wooden structures and steel structures was not been sufficiently investgated in the AIJ&CPIJ survey.

The comparative graph of determined results excluding unsurveyed buildings is shown in Figure 6. Also, the determined result by TLRO is shown Figure 7, and that by AIJ&CPIJ in Figure 8. Furthermore, the

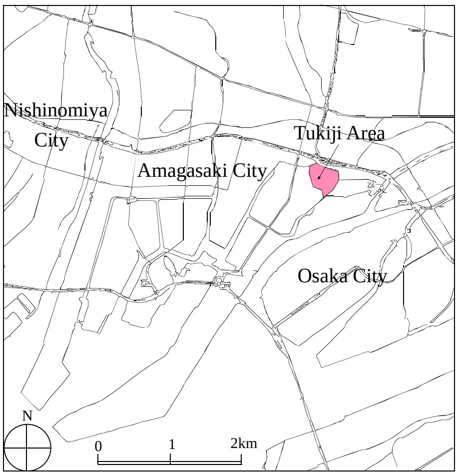

Figure 5: Location of the Tukiji area

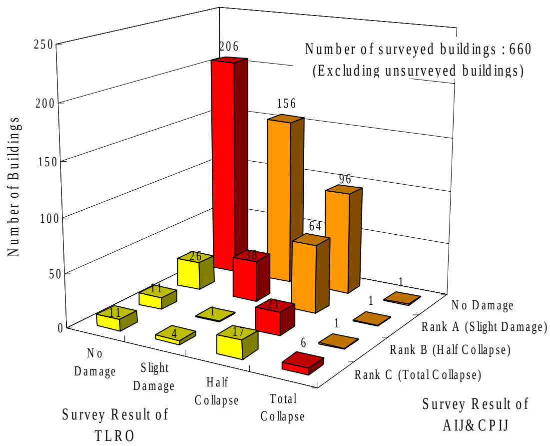

Figure 6: Cross-counting analyses of survey results by TLRO and CPIJ&AIJ

Photograph 1: Inclination damage (inclination angle: 2.0 degree)

Photograph 2: Subsidence Damage (amount of subsidence: 500 mm)

correspondence to the results of the AIJ&CPIJ survey is as follows: Rank C is Totally Collapse, Rank B is Half Collapse, and Rank A is Slight Damage. The AIJ&CPIJ results give a greater number of buildings determined as totally collapsed than the TLRO results. Totally and half collapsed building are fewer in AIJ&CPIJ resuls than in TLRO resuls. The comparative graph indicates that results giving the same rank in both the AIJ&CPIJ survey and the TLRO survey are about 41.1%, and results of the TLRO survey that give a more severe rank than the AIJ&CPIJ survey are about 48.3%. As a result, the trend is that the evaluation by TLRO is more severe than that by AIJ&CPIJ. As common points of both damage criteria, when the inclination of the building was observed, it was classified as more than half collapsed. In this case, the inclination of the building was considered to determined by almost the same procedure in both surveys. We examined the relation between the two survey results and the result of measuring the inclination angle of a building in order to clarify the factors causing the difference in the results.

The locations of inclined buildings are shown in Figure 9, where 63 buildings measured by Geo-Research Institute, Osaka. As a result, the buildings classified as more than half collapsed correspond to about 71% of

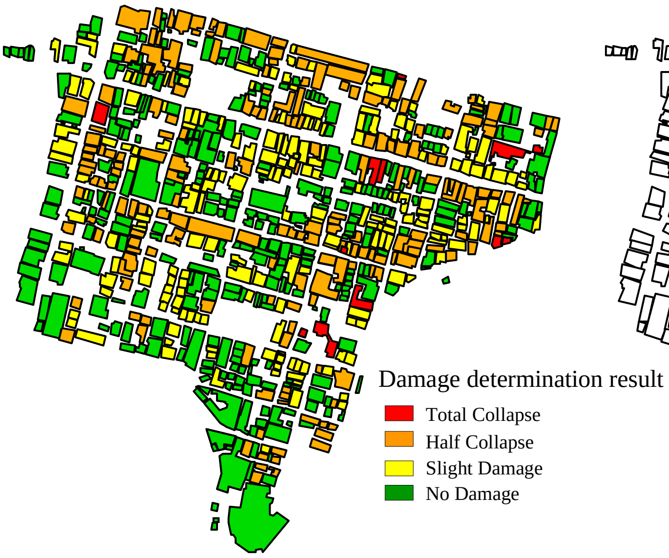

Figure 7: TLRO survey results

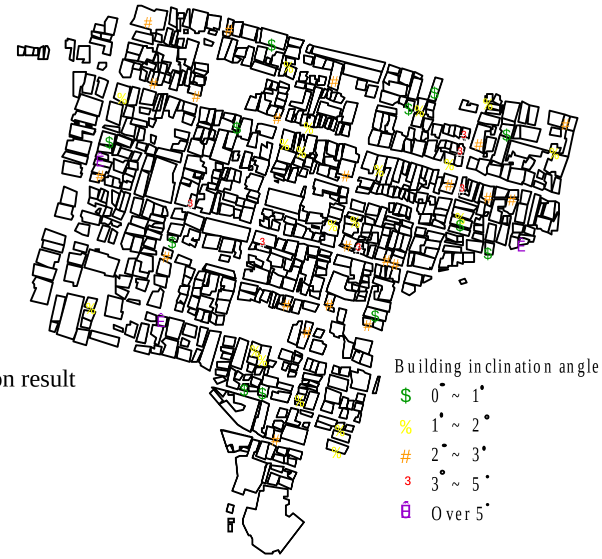

Figure 9: Location and inclination angle of buildings

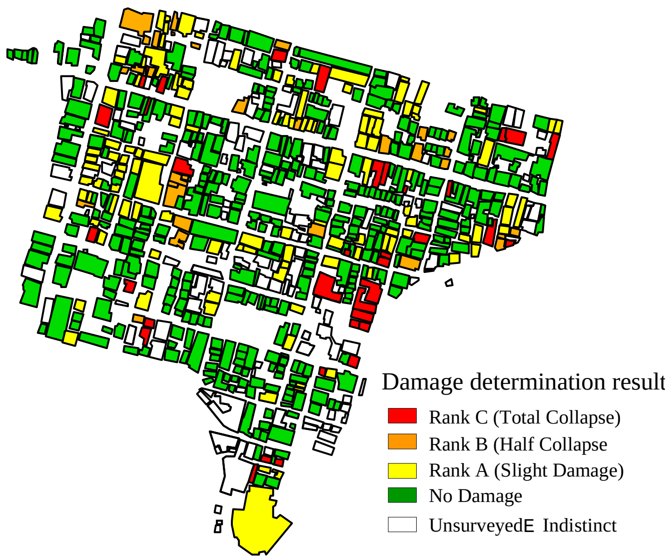

Figure 8: AIJ&CPIJ survey results

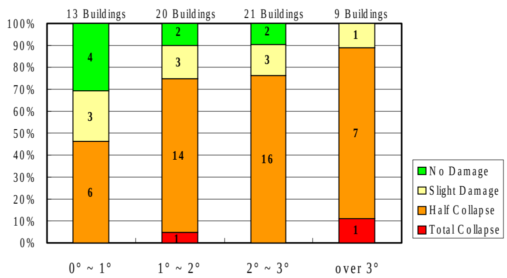

Figure 10: Relation between TLRO survey result and inclination measurements

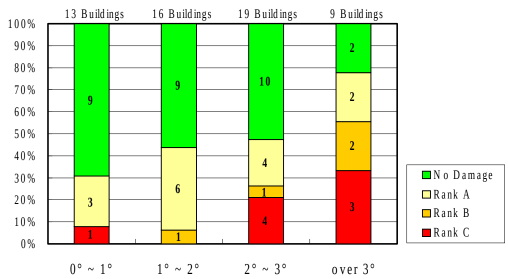

Figure 11: Relation between AIJ&CPIJ survey result and inclination measurements

buildings in the TLRO survey, and about 21% in the AIJ&CPIJ survey for which the angles of inclination were measured. Therefore, the TLRO survey shows a better correspondence to actual measurements than the AIJ&CPIJ survey dose.The angles of inclination are classified into the four classes shown in Figures 10 and 11. When the angle of inclination becomes large, the proportion of totally and half collapsed buildings increases in both surveys. This trend agrees with the determined results. In the TLRO survey, the proportion of totally and half collapsed buildings of which the inclination angles were in the range from 0 degree to 1 degree is about 46%; the inclination angle cannot be confirmed by visual inspection. However, the inclination in greater than 1 degree can be recognized. In the AIJ&CPIJ survey, the proportion of totally and half collapsed buildings is about 56% for inclination greater than 3 degrees. In this case, there were many buildings classfied as no damage or slight damage.

Examples of the determined results for individual buildings are shown. The building shown in Photograph 1 was inclined by about 2 degrees. The TLRO survey gave a half collapse classification, the AIJ&CPIJ survey a slight damage classification. In the AIJ&CPIJ survey, the inclination could not be observed. The building shown in Photograph 2 was a steel structure which subsided about 500mm. The TLRO survey classified it as half collapsed, the AIJ&CPIJ survey, as not damaged. Although uniform subsidence of the building occurred due to liquefaction, the structure is not damaged or inclined. In such a case, the classification must be determined as half collapsed or as totally collapsed according to the amount of subsidence.

There are three factors that give rise to the difference in the results of the two surveys even though the visual inspection was employed similarly. First, there is a difference in the objective. Damage by liquefaction was the concern in the TLRO survey. This placed great importance on subsidence and inclination. On the other hand, the AIJ&CPIJ survey placed less importance on damage by subsidence and inclination as comparied to superstructure. Second, in the AIJ&CPIJ survey, the damage due to subsidence was not considered for wooden structures and steel structures. Therefore, there is the possibility that subsidence damage due to liquefaction was overlooked for these structures. Third, the survey was conducted by AIJ&CPIJ from February 10th to March 13th, 1995, after the TLRO survey. Consequently, there is the possibility that sand boilling was not apparent and that the investigators did not pay any special attention to damage due to liquefaction.

Therefore, if attention is paid to the following points when building damage due to liquefaction is determined, it shoud be possible to more precisely determine damage, even by visual inspection; (1) when building damage due to liquefaction is investigated, it is beneficial to gather information on the liquefaction potential or the actural liqufaction evidence like sand boilling in the survey area, (2) in the case that liquefaction occurred, building damage such as the inclination and subsidence can be brought regardless of the type of structure, (3) It is important to consider subsidence and inclination of the building.

3.4 Proposed Chart for Buildings Affected by Liquefaction

Based on damage survey regarding liquefaction in the Tukiji area, we developed the damage chart for wooden stractures shown in Figure 12. Collapse of a Building damage due to liquefaction can be categorized into the two patterns, inclination and subsidence. The damage is classified into three levels according to the angle of inclination and amount of subsidence. Level 1 corresponds to no damage where neither subsidence nor

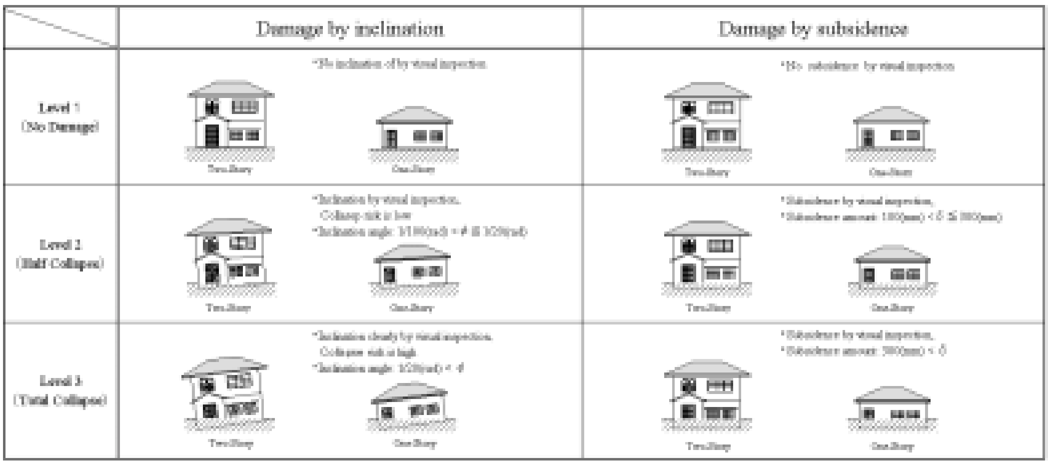

Figure 12: Damage chart for wooden structures affected by liquefaction

inclination of the building can be observed by visual inspection from the outside. In Level 2, some amount of subsidence or inclination can be confirmed. In Level 3, severe subsidence or inclination can be confirmed.

Although subsidence or inclination of the building is considered in this damage chart, the movement of the whole building, damage of the floor and foundation structure must also be taken into account. In the future, they will be included to improve the damage chart for determining damage patterns by visual inspection.

4. CONCLUSIONS

We aim to evaluate the effectiveness of the damage chart for damage assessment, we carried out the damage survey using the damage chart and photographs from the database of Nishinomiya City. As a result, even if there was a little information in the photograph, it was possible to classify the damage pattern and evaluate the building damage based on the damage chart. Also, we conducted the survey of damaged buildings due to liquefaction. The damage patterns in liquefaction area were inclination or subsidence. In liquefaction area, it was important to observe these damage patterns for building damage survey. And we developed a damage chart for wooden structures affected by liquefaction. In the future, we will carry out a classification study in all area of Nishinomiya City, including liquefaction area, and improve the damage chart.

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