



13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1121

**AN EFFICIENT SYSTEM FOR ACQUIRING EARTHQUAKE DAMAGE
INFORMATION IN DAMAGE AREA**

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SUMMARY

An efficient system for collecting earthquake damage information in damage area is proposed using digital maps on a PC and various IT tools (GPS, cellular phones, digital camera, *etc.*; The system software, which is a simple GIS and written in Microsoft Visual Basic to run any Windows PC, is license free, and its source code is open to public use (Shibayama, *et. al.*, 2002 [1]). Therefore, it is possible to download and use this system by many people when an earthquake happens. Several field experiments are carried out assuming various situations, in order to check the effectiveness of the proposed system by comparing with the conventional investigation method, which is based on paper maps. The proposed system was comparable with the conventional method as for the time to input data. However, the proposed system is much more efficient when the data are analyzed on a GIS software, because the data are already digital. Although some problems of the system are found during the experiments, such as the maximum period of PC batteries and the difficulty to see characters on a PC display under strong sunlight, the results of the proposed system are more satisfactory than those of the conventional method.

INTRODUCTION

After the 1995 Kobe (Hogoken-Nanbu) earthquake, the national and local governments of Japan have installed a lot of accelerometers to calculate seismic intensities, and developed various real-time information systems for estimating strong ground motions and building damage, such as DIS (Disaster Information System) of the cabinet office of the government of Japan, READY of City of Yokohama, and ROSE of the National Research Institute for Earth Science and Disaster Prevention [2]. However, it should be careful that the actual earthquake damage could be very different from the estimated damage. If we rely on only estimated information, appropriate emergency response may not be accomplished. On the other hand, the estimated information can be useful to locate the actual damage areas at the beginning of damage investigations. Therefore, on the basis of those ideas, we have proposed a real-time system for collecting earthquake damage information (Shibayama, *et. al.*, 2002 [1]). In this paper, we will introduce the details of the newest system, and explain results of field experiments to check the effectiveness of the proposed system.

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INFORMATION SYSTEM FOR EFFICIENTLY COLLECTING EARTHQUAKE DAMAGE

1) Main Features of the System

As shown in photo 1, we have developed an information system to collect efficiently actual damage data in damaged areas utilizing IT equipments (PC, GPS, cellular phone, etc.). As shown in Figure 1 (left), we can readily locate the investigating building using a digital map on a PC and GPS, and easily input the information of the building and damage. We can change the items of investigations according to purpose and time, from quick inspections of the safety of buildings to detailed investigations for academic purposes. As shown in Figure 1 (right), we can quickly obtain a list of the digitized damage information, and send it to a GIS server, using various means, such as a cellular and/or public phone, when they are available.

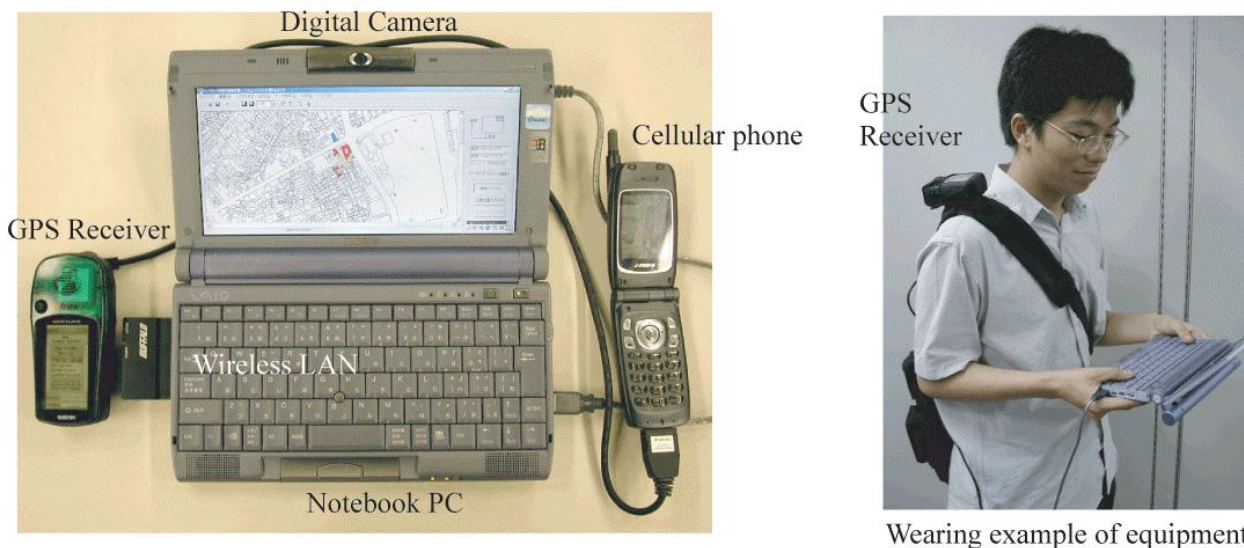


Photo1. An example of the configuration of the proposed system

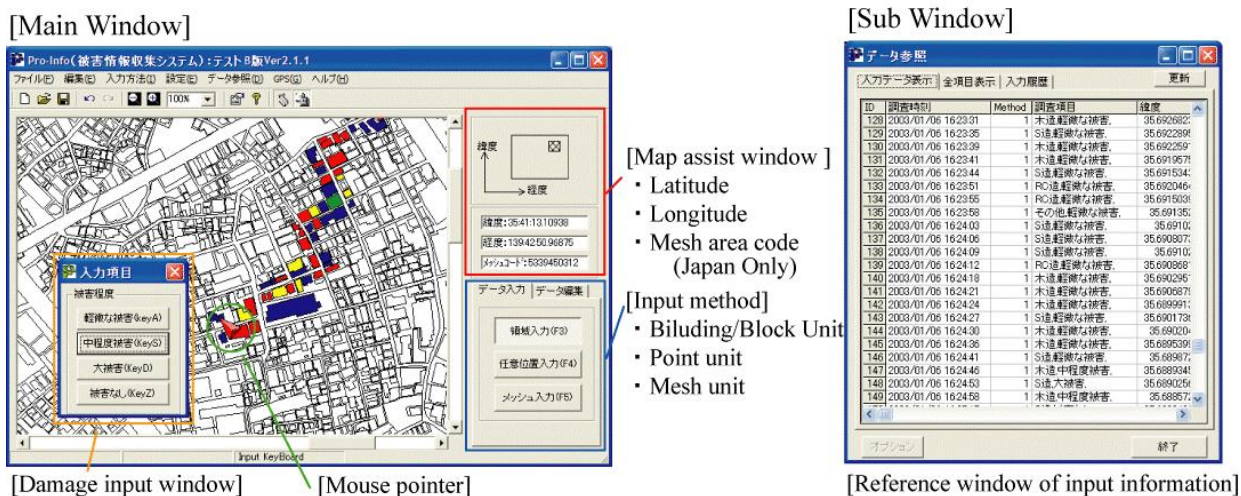


Figure 1. A main window and a sub-window of the system

The main features of the proposed system as follows:

- 1) It is a simple and user-friendly GIS (Geographic Information System) specialized for collecting damage information (see Figure 1). Therefore, anyone can use the system.
- 2) It can be installed in any Windows PCs without special equipments.
- 3) Input items can be changed according to various situations and purposes.
- 4) Its source code is license free and open to the public use. The programming language is Microsoft Visual Basic 6.0 SP5. Therefore, it can be modified for various purposes.
- 5) System configuration can be flexible from PC to PC + various IT tools, such as HMD (Head Mounted Display), GPS (Global Positioning System), a cellular phone, and a digital camera (see Photo 2).



Photo 2. Example of extended system (Notebook PC, Tablet PC, HMD)

2) Basic System Configuration and Peripheral Equipments

The basic system consists of the application software, a personal computer, and digital maps. Its programming language is Microsoft Visual Basic 6.0 SP5, which can be installed any Windows PCs. Its software license is free and open to public use. In addition, common personal computers can be used without any special equipment. Therefore, it is possible to collect damage information by assembling many volunteers after an earthquake. The PC can be a desktop, a notebook and a tablet (see Photo 2). It depends on the purposes and situations. For example, a notebook PC is appropriate in the field, whereas a desktop PC is more appropriate in an office, which collects the damage information.

The minimum specifications of the current system is to be compatible with a Pentium or higher CPU, a 256 color display adapter of the 640x480 resolution or higher, and a keyboard or other input device (mouse, tablet, *etc.*). This system can be run on Microsoft Windows 98, Windows ME, Windows 2000, or Windows XP. The minimum RAM size is 16MB for Windows 98/ME, 64MB RAM for Windows 2000, and 128MB for Windows XP. At least, a 20MB hard-disk space is required to run the system, depending on the size of the digital maps. Both vector-type and raster-type of digital map can be utilized, such as the vector data of the 1/2,500 scale numerical map of Geographical Survey Institute of Japan, the vector data of the MapInfo output format of MapInfo Corporation Company, and the raster data of the BMP format of Windows, JPEG format, and GIF format.

The system configuration can be extended utilizing various peripheral IT equipments, such as HMD (Head Mounted Display), GPS (Global Positioning System), digital communications terminals, a digital camera, and so on. For example, a HMD makes a hand free to be more efficient for inputting data (see Photo 2). The combination of GPS and the digital map can navigate the target area, which is an extremely powerful tool for a person who is unfamiliar with the area. Currently, the system is compatible with the

handheld GPS terminals of GARMIN Company. On the other hand, digital communications terminals, such as a cellular phone, PHS (Personal Handy phone System), or wireless LAN can be used to send the data to a GIS server.

3) Basic Input Data (Location, Properties, and Damage Grade)

The basic input data of this system are as follows:

- Locations of the damaged objects (*e.g.*, building or area), whose unit can be a mesh, a city block, a building block, or a point
- The properties of the damaged objects, such as building, bridge, lifeline and so on
- Damage grades, such as minor to complete collapse

When we find a damaged building, an area or an other object, we first click its location on the digital map. As shown in Figure 2, the system provides three location units: a mesh unit, a building or a city block unit, and a point unit. The mesh unit (*e.g.*, $50 \times 50 \text{ m}^2$, $100 \times 100 \text{ m}^2$, $250 \times 250 \text{ m}^2$) or the city block unit is useful to locate the area where the damage grades of the objects (such as buildings) are almost uniform within the unit. The building unit can be used, when a digital map with individual buildings (vector or raster) is available, and/or the damaged buildings are scattered in the area (or a detailed investigation is needed). The point unit can be used to locate a building or other object, which are not shown on the map. The location data are stored in the form of the latitude and longitude.

Second, we input the information of object's properties. Figure 3 (left) shows an example of a tree structure of object properties, and Figure 3 (right) shows how to input the properties. After choosing the location, a pop-up window to choose the object type appears; it can be a building, a road, a bridge, or a lifeline facility. When we choose the object type, such as building, another window of building type appears (*e.g.*, wooden, steel, RC, or others). Next, we choose the number of stories of the building.

Third, we choose a damage grade, such as minor, major, or complete collapse. A different damage grade is expressed as a different color, such as minor in blue, major in yellow, and collapse in red, as shown in Figure 2.

Finally, after checking the confirmation window, which shows the all input items, we choose the "yes", "no", or "cancel" bottom. We repeat the above procedure from a) to c), when we find a next object.

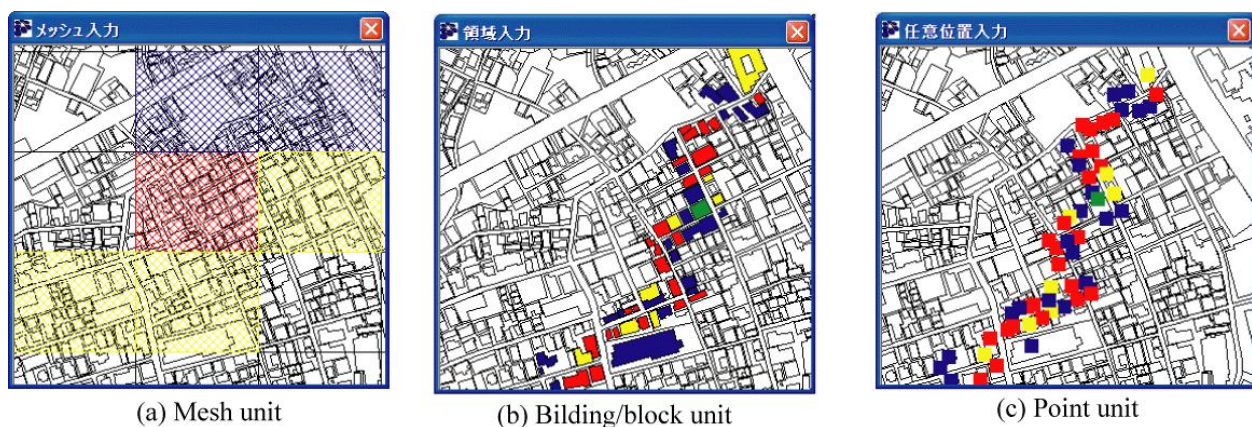


Figure 2. Location units (mesh unit, building/block unit, point unit from left to right) and damage grade.

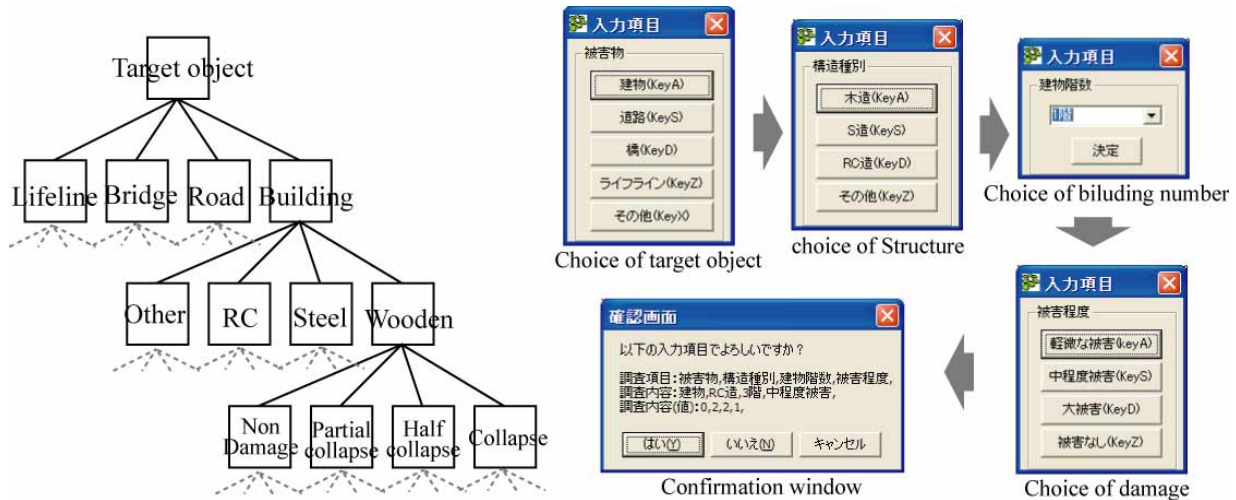


Figure 3. A tree structure of the target object properties (left) and the input menu Windows (right)

4) An Efficient Method for Data Input using Keyboard

In addition to the regular usage of a mouse, this system provides an efficient operation method to move a mouse pointer and to input data using a keyboard. As shown in Photo 3, we can use cursor keys to move the mouse pointer. In addition, we can assign function keys or any other keys to the zoom in/out key, object property keys, and damage grade keys. For example, we may assign the “X” key to the “minor” damage, the “Z” key to the “collapse” damage, and so forth. Once we accustom the assignments and the functions of the keys, this method can become much more efficient than the conventional method using mouse, where we need to move the pointer on a select bottom on a window and push the enter key to enter the data.



The example that has a notebook PC with both hands

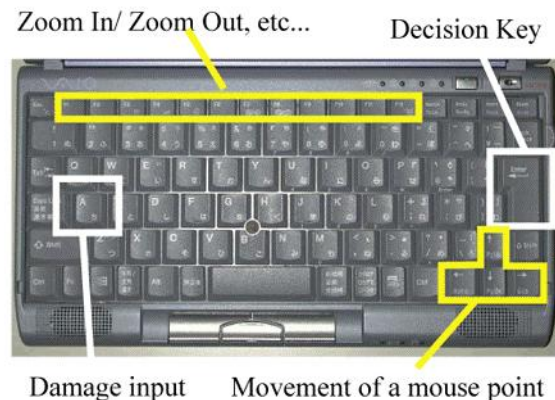


Photo 3. An Efficient Method for Data Input using Keyboard

5) Varieties of Investigation Contents

Using this system, we can change input contents according to the investigation purposes. For example, we may need an overall image of damage in affected areas immediately after a large earthquake. For that case, time is more important than accuracy. On the other hand, in order to inspect the safety of damaged buildings, we need to carry out more detailed investigations. Accordingly, this system can provide various investigation menus from simple to detail one. As shown in Figure 3, the simple menu consists of classification of an object (building, road, lifeline, bridge, *et al.*), sub-classification (wooden, steel, RC, *et al.*), a number of stories, and the damage grade from negligible to collapse. On the other hand, an academic investigation of structural damage can be an example for the detail menus. For this purpose, we use the chart of building damage proposed by Okada *et al* (1999) [3]. As for damage due to subsidence, the damage chart by Kohiyama *et al* (2000) [4] is available.

As for the rapid inspection of the safety of damaged buildings, we can use the manual of the Japan Building Disaster Prevention Association. Figure 4 shows an example of the menu window of the safety assessment. After finishing to input data, it automatically estimates a result, as showing in “Unsafe” (the red tag) in Figure. Moreover, this system has a customized function so that a user can change the investigation menu freely.

木造建築物の応急危険度判定

建築物概要

1. 建物名称 [] 1. 建物番号 [] 2. 建築物所在地 [] 2. 1住宅地図整理番号 []

3. 建築物用途
 戸建専用建物 長屋住宅 共同住宅 併用住宅 店舗 事務所 旅館・ホテル 庁舎等公共施設
 病院・診療所 保育所 工場 倉庫 学校 体育館 劇場・遊戯場等 その他

4. 構造形式
 在来(軸組)構法 枠組壁構法(ツーバイフォー) プレファブ その他

5. 階数 [1階] 6. 建築物規模 [約5m] × [5m]

調査(1. 概観調査のみ実施 2. 内観調査もあわせて実施)

1. 一見して危険と判定される
 建築物全体又は一部の崩壊・落階 基礎の著しい破壊、上部構造との著しいずれ
 建築物全体又は一部の著しい傾斜 その他

2. 隣接建築物・周辺地盤等及び構造躯体に関する危険

①隣接建築物・周辺地盤の破壊による危険
 危険無し 危険あり 不明確

②隣接建築物・周辺地盤等及び構造躯体に関する危険度
 無し又は軽微 著しい床、屋根の落ち込み、浮き上がり 小屋根の崩壊、床全体の沈下

③基礎の被害
 無被害 部分的 著しい(崩壊あり)

④建築物の1階の傾斜
 1/60以下 1/60~1/20 1/20超

⑤壁の被害
 軽微なひび割れ 大きな亀裂、剥離 落下の危険あり

⑥腐食、蟻害の有無
 ほとんど無し 一部の断面欠損 著しい断面欠損

危険度の判定 []

3. 落下危険物・転倒危険物に関する危険度

①瓦
 [ほとんど無被害] 著しいずれ 全面的にずれ、破壊

②窓枠・窓ガラス
 [ほとんど無被害] 歪み、ひび割れ 落下の危険あり

③外装材(湿式の場合)
 [ほとんど無被害] 部分的なひび割れ、隙間 顕著なひび割れ薄利

④外装材(乾式の場合)
 目地の亀裂程度 板に隙間が見られる 目地ずれ顕著なずれ

⑤看板・機器類
 傾斜無し わずかな傾斜 落下の危険あり

⑥屋外階段
 傾斜無し わずかな傾斜 明瞭な傾斜

危険度の判定 []
総合判定 []

終了

Figure 4. Form of questionnaire of the rapid inspection of the safety of damaged building

6) Output Data of Damage Information

As for the output data of the collected damage information, this system produces a map image and a list of damage information. Figures 1 and 2 show examples of map images, which are stored in the BMP format of Windows. The damage information data consist of the investigation time, the location of the object (latitude and longitude), the properties of the object, and the damage grade. They are saved in the CSV format (Comma Separated Value) or the ASCII format. We can easily open and analyze these data using various GIS software. As an example, Figure 5 shows an experimental result, which will be explained below, using SIS 6.0 of Informatix Company.

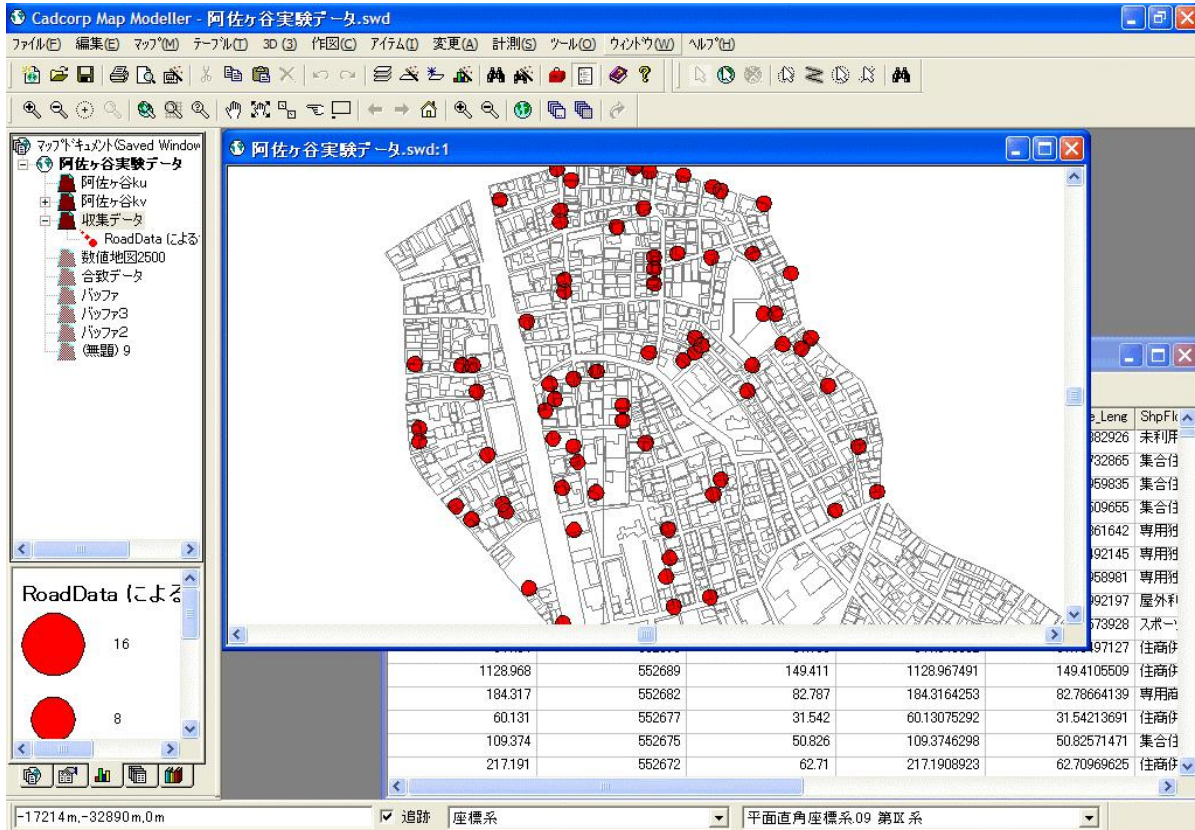


Figure 5. Reading in Informatix Company SIS6.0 by data of TXT format.

EXPERIMENTS

We have carried out several experiments to check efficiencies of this system assuming various situations. In particular, we have checked merits and demerits of this system as compared with the conventional method based on paper maps.

1) About Experiments

Table 1 shows the list of experiments we carried out. Experiments from No.1 to No.4 are the experiments where we investigated all the buildings in certain areas. The investigated contents are the building classification (wooden, steel, RC buildings, and others) and numbers of floors. On the other hand, experiments from No.5 to No.8 are the experiments where we searched specific buildings in certain areas. We searched wooden houses with two floors in the experiments No.5, whereas we searched the buildings, which had cracks in walls, in the experiments No.6 and No.7. As comparisons, we also carried out the same experiments using the conventional paper maps as shown in the bottom of Table 1.

Table 1. All experiment contents

No	Method	Team	Experiment contents	Investigation area	Area	Building number	Investigation contents
1	System	1	All buildings	Nishishinjuku, Shinjuku-ku, Tokyo, Japan	25ha	107	Structure classification(Four kinds),Building number of floors
	Paper	1			25ha	102	
2	System	1	All buildings	Nishishinjuku, Shinjuku-ku, Tokyo, Japan	25ha	130	Structure classification(Four kinds),Building number of floors
	Paper	1					
3	System	1	All buildings	Nishishinjuku, Shinjuku-ku, Tokyo, Japan	25ha	68	Structure classification(Two kinds),Building number of floors
4	System	1	All buildings	Nishishinjuku, Shinjuku-ku, Tokyo, Japan	25ha	65	Structure classification(Two kinds),Building number of floors
5	System	2	Target building	Kamijujo, Kita-ku, Tokyo, Japan	15ha	1103	Structure classification(Two kinds),Building number of floors
	Paper	3					
6	System	1	Target building	Asagayakita, Suginami-ku, Tokyo, Japan	14ha	408	Structure classification(Two kinds),building number of floors,quantity of crazing of a wall
7	Paper	1	Target building	Asagayakita, Suginami-ku, Tokyo, Japan	14ha	759	Structure classification(Two kinds),building number of floors,quantity of crazing of a wall
8	System	1	Target building	Nishihara, Shibuya-ku, Tokyo, Japan	17ha	329	Structure classification(Two kinds),building number of floors

2) Experiment Methods

As for the proposed system, we used notebook PCs of A4 or A5 sizes, and keyboards to input data as explained above. We chose students of Kogakuin University to carry out the experiments, who have never used the system. Before starting the experiments, we explained how to use the system about 15 minutes. The experiments were conducted by making one team of two persons: one for investigating buildings, and the other for inputting data.

As for the conventional method based on papers, we also chose students of Kogakuin University by making one team of two persons: one for investigating buildings, and the other for writing down data on the maps. The map sizes were A4 or A3, depending on the sizes of the areas. Figure 5 shows an example of written-down marks. "R3" stands for the RC building with 3 floors. We draw circles surrounding the marks to find easily the marks on the maps (see Figure 6).

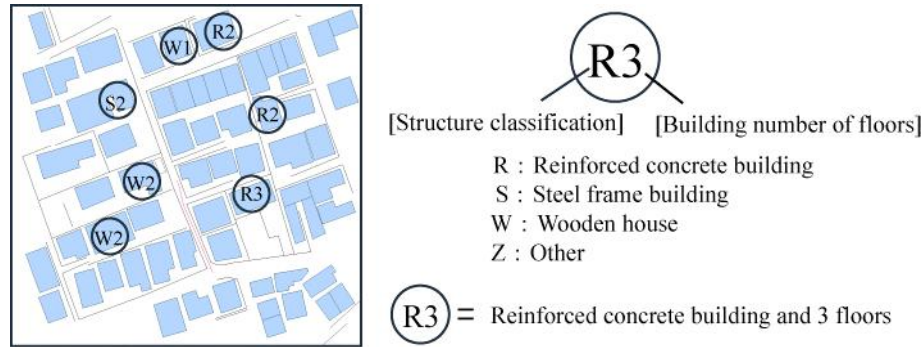


Figure 6. An example of the marks of the object properties for a paper map

3) Experiment Results

Table 2 shows the results of all the experiments. The investigation times between the system and the paper are comparable. For example, the average time per one building for experiment No1 and No2 was 19.4 second using the system, whereas it was 21.8 second using paper. On the other hand, the average time per one building of experiment No 5 was 7.7 second for the system, whereas it was 7.4 second for the paper. In conclusion, the proposed system was comparable with the conventional method regarding the input time. However, when we analyze the data on a GIS software, the proposed system is much more efficient, because the data were already digital.

Table 2. All experiment results

No	Method	Experiment contents	Building number	Investigation time	Investigation time per one building	Average time per one building
1	System	All buildings	107	33 minute	18.50 sec	
	Paper		102	42 minute	24.71 sec	
2	System	All buildings	130	44 minute	20.3 sec	
	Paper		130	41 minute	18.92 sec	
3	System	All buildings	68	26 minute	22.94 sec	
4	System	All buildings	65	25 minute	23.08 sec	
5	System	Target building	1103	143 minute	7.78 sec	7.7 sec
	System		1103	140 minute	7.62 sec	
	Paper		1103	140 minute	7.62 sec	7.36 sec
	Paper		1103	153 minute	8.32 sec	
	Paper		1103	113 minute	6.15 sec	
6	System	Target building	408	109 minute	16.03 sec	
7	Paper	Target building	759	210 minute	16.60 sec	
8	System	Target building	329	71 minute	12.93 sec	

CONCLUDING REMARKS

We have proposed an efficient system for collecting earthquake damage information using digital maps on PCs and various IT tools. In order to check the effectiveness of the system, we carried out several experiments, and found that the proposed system was more effective than the conventional method, which was based on paper maps.

We also found some problems in the system. First, the system needs digital maps (vector or raster) before investigations start. Thus, this may cause serious problems, if the target areas are very wide, rural, or a foreign country. We expect that the satellite image map with high resolutions would become more easily available. Second, the maximum period of PC batteries are around 4 hours. Thus, we have to carry

extra batteries to continue investigation over 4 hours. In addition, PC is much heavier than paper maps. We are expecting lighter PCs with larger battery capacity to solve this problem in the near future. Third, it was very difficult to see maps and characters on a PC display under strong sunlight. However, HMD (Head Mount Display) can solve this problem, although it is not necessarily used widely yet.

ACKNOWLEDGMENT

This research is supported by Special Project for Earthquake Disaster Mitigation in Urban Areas of Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT), and Earthquake and Environmental Research Center of Kogakuin University funded by the Frontier Research Promotion Program of MEXT.

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