17th World Conference on Earthquake Engineering, 17WCEE

Sendai, Japan - September 13th to 18th 2020

DEVELOPMENT OF A SAFETY ASSESSMENT SYSTEM FOR SCHOOL FACILITIES BY TEACHERS

S. Tanaka[(1)], K. Shigekawa[(2)]

[(1)] *Professor, Graduate School of Environment and Disaster Research, Tokoha Univ., tanaka_s@sz.tokoha-u.ac.jp*
[(2)] *Professor, Graduate School of Environment and Disaster Research, Tokoha Univ., shigekawa@sz.tokoha-u.ac.jpds*

Abstract

School facilities, such as school buildings and gymnasium, are designated as emergency shelter in case of disaster. According to the school disaster preparedness plan, the safety assessment of school facilities is to be conducted by the registered inspector immediately after the earthquake. However, due to the shortage of such inspectors in the disaster area, it takes a long time to complete the safety assessment. As a result, many school facilities are used as emergency shelters without safety assessment.

The objective of this study is to construct a new system that speeds the building safety assessment by sharing roles in multiple stakeholders using software technology and to verity the system with school teachers as non-engineer stakeholders. Key concept of this system is to divide the building safety inspection procedure by engineer into two parts: damage observation and damage evaluation. The damage observation, which is identifying and recording the location and level of damage, is carried out by non-engineers on site. The damage evaluation, which assesses safety level, is carried out by engineers on remote area. To realize these functions, (1) Analyze the building damage inspection procedure by engineer; (2) Design and code the components of the system. The damage observation component is a smartphone application that enables non-engineer personnel to observe the building damage with the same quality as engineers do. The damage evaluation component is a cloud server system that enables building engineers who locate outside the disaster area to remote access and assess the safety level of the buildings; (3) Several field tests with school teachers, administrative staffs, and building engineers were conducted to validate the system.

The system developed in this study consists of a smartphone app and a cloud server. On the smartphone screen, the user plots damage markers on it. In addition, take photos of the damaged element, and link them to the damage marker. The result data is uploaded to the cloud server. For the evaluation component, although it could calculate the safety level and residual capacity automatically by counting the number and/or length of plotted damage markers, the engineers then remotely access the data to make a final safety assessment. Field tests were conducted at 4 elementary schools and 1 junior high school. Participants, such as school teachers, staff, and engineers, provided generally positive feedback that was then used to enhance the system.

The feature of this system is that non-engineer people such as school teachers can conduct the damage inspection. And by the demonstration test, it was confirmed that these application function without problems and that building safety could be assessed from a remote location. Although the system developed here is still prototype, it would be useful for speeding up the post-earthquake safety assessment at other facilities.

Keywords: Building Damage Inspection; Safety Assessment; Damage Observation; Smartphone; School Teachers

1. Introduction

School facilities, such as school buildings and gymnasium, are designated as emergency shelter in case of disaster. According to the school disaster preparedness plan, the safety assessment of school facilities is to be conducted by inspector, who is registered architect and/or building engineer in each prefecture, immediately after the earthquake. However, due to the shortage of such inspector in the disaster area, it takes a long time to complete the safety assessment. As a result, many school facilities are used as emergency shelters without safety assessment. For example, at the 2016 Kumamoto earthquake, there were two major quakes at 28 hours interval. After the first quake (M=6.2), many residents whose houses were damaged came to the schools that have been designated as emergency shelter. The school principal opened the school facility, mainly gymnasium, to the evacuees without safety assessment by the inspector. Then, the second quake (M=7.0) occurred at 28 hours later. The second quake damaged some gymnasiums as shown in Fig. 1. Since 28 hours is too short to dispatch inspectors to every school, so it would be quite useful to develop a building safety assessment system that can be used for non-engineers on site.

Fig.1 Damage of a High School Gymnasium after the Second Quake

It is well known that intensive efforts have been done by many researchers to develop the method for safety assessment of public facilities after earthquake, and the standardized assessment methods have been developed. However, these methods are developed for engineers. There is almost no information dissemination to non-engineers such as facility manager and staff since non-engineer is not considered to be able to assess the safety of building.

To address the issues of inspector shortage, the authors have been developed a building damage assessment system, which is carried out by sharing the roles of engineers and non-engineers[1] [2]. This paper presents a development of such building damage assessment system and a demonstration experiment at an elementary school in Shizuoka prefecture for school teachers as non-engineers on site

2. Method

There are several plans and manuals for operating school facilities as emergency shelter. At first, we investigated the plans and manuals and analyzed the roles by organizations such as city office, school, voluntary disaster prevention organization, etc. According to the School Disaster Preparedness Manual, Shizuoka Prefecture (2019) [3], in case of disaster, the role of school facility manager, who is school principal, is to check the facility damage situation and assess the safety in cooperation with city officials. In addition, quick safety inspection by the inspector must be conducted immediately after the disaster. However, in reality, neither city officials nor the inspectors come to the school when they needed.

Figure 2 shows the damage situation report format at the time of disaster in Yokohama City School Disaster Preparedness Plan [4]. Here, the Board of Education asked the school principal to report the damage status, which category is minor, moderate, or major damage. However, it is also impossible to conduct the evaluation in such categories by school teachers.

Disaster Situation Report

Ward	School Name	Filler
year month day	AM/PM Time	

Student Enrolled		Student Absent	
Faculty Enrolled		Faculty Absent	

Damage	YES	NO							
Damage Situation			Faculty	Student	Facility Damage Status		Building	Gymnagium	Yard
	Death					Minor			
	Injury	Serious				Moderate			
		Minor				Major			

Fig. 2 Damage Situation Report Format (Yokohama City School Disaster Preparedness Plan)

Table 1 shows the types of safety checks in School Safety Promotion Guideline, Shizuoka Pref. (2009) [5]. This guideline covers school safety in general, not just during disaster. In Table 1, at extraordinary safety check, the inspection has to be conducted by teachers and staffs, but the inspection items are not set previously.

Table 1 Type of Safety Checks (School Safety Promotion Guideline, Shizuoka Pref. (2009))

Type of Sefety Check	Timing	Target
Regular Safety Check: every semester or every month	At least once per semester by all faculty and staff	Facilities and equipment used by students and fire prevention facilities
	Once a month, by all faculty and staff	School grounds, playgrounds, classrooms, corridors, elevators, verandas, stairs, toilets, hand-washing areas, rooftops, etc.
Daily Safety Check	Check every class	Where students do most activities
Extraordinary safety check: disaster, crime, special event	*Before and after school events such as sports festival, school festival, exhibition etc. *When a disaster occurs, such as storm, earthquake, or fire *When there is a crime in the neighborhood	Set inspection items as required

To summarize the above, the school safety manuals require school teachers to conduct some sort of safety inspection in case of disaster, but the details of the work are not specified. In addition, they don't have any training and exercises for the safety inspection at all.

In general, building damage inspection has two tasks; damage observation and damage evaluation. Damage observation is a task of collecting and recording information about where and what damage has occurred in a building. While, damage evaluation is a task of analyzing and assessing damage information based on the records of the damage observation in a manner specified for each evaluation purpose (safety, livelihood support, repairability, etc.). Since the damage inspection assumes to be conducted by building engineers, current inspection procedure integrates these two tasks for improving the work efficiency. So the engineers could perform these tasks simultaneously on site, but it is difficult to take the same procedure for non-engineers.

In this study, by separating the current inspection procedure into two tasks, damage observation and damage evaluation, a new damage inspection procedure suitable for non-engineers is developed and demonstrated it at elementary schools. That is, non-engineers such as school teachers who are on site conduct only the damage observation, and they upload the result to the cloud saver through internet. The engineers who is on remote area check the result and assess the safety. The engineers then provide feedback to the school teacher on site about the facility safety judgements.

3. Examination of Suitability of School Teachers

For developing a new system, we have to review a capability of school teachers to observe the damage. According to the School Safety Promotion Guideline, Shizuoka Pref. (2009), school faculties have safety checks of school facilities regularly (daily and/or monthly). Therefore, the relationship between this regular safety check and the building damage inspection is examined. Table 2 is an example of the checkpoints of the regular safety check. Among them, the check points for floors, walls, and joinery correspond to the damage inspection points. Further, the method of regular safety check is almost the same as the method of building damage inspection, such as visual inspection, hammering inspection, vibration inspection. Based on the above, it is considered that the similarity between the building damage inspection and the regular safety check is quite high, which implies that school teachers could carry out the damage observation.

Table 2 Example of Regular Safety Checkpoint for Classroom (left) and Its Method (right)

	Checkpoint
Classroom	Are there nails or nicks on the floor or the floor is damaged?
	Are there any floating, worn, or damaged floor vinyl tiles?
	Is the floor slippery and there is no risk of falling?
	Is there any peeling or crack on the inner wall?
	Is the thumbtack tight?
	Are things hanging on the wall, hanging items under the ceiling, etc. easy to fall?
	Is there any danger of the blackboard, display board, picture frame, etc.
	Are there any accessories or nails on the blackboard?
	Are windows and windowpanes easy to come off?
	Is the door of the entrance easy to come off?
	Are the desks and chairs strong and nails free?
	Are shelves and lockers kept from falling?

Visual	(1) Ground irregularities (2) Contorting, cracking, corrosion, scum (3) Wear, rust (4) Weld bead protrusion (5) Damage to outer fence
Hammer	(1) Clear sound (2) Tapping and wobbling, muddy
Vibration, load	(1) Shake (2) Push (3) Twist (4) Hanging (5) Pull
Operation check	(1) Turn on the switch (2) Rotate
Reagent	Water quality inspection

On the other hand, the recording method of the result is different. The regular safety check uses a checklist as shown in Fig. 3. While, the damage inspection uses a floor plan in addition to checklist. To evaluate the building damage, it is necessary to obtain an overview of damage situation such as distribution of damage in the entire building. For this purpose, the inspector enters the damage status of each building elements into the floor plan.

Fig. 3 Checklist for Regular Safety Check

Therefore, the system developed in this study is used the floor plan of the building to record the damage status. So the key factor to exaime is whether school teacher could record the building damage in floor plan accurately.

4. Development of the New Building Safety Assessment System

The new building safety assessment system developed in this study is shown in Fig. 4. The system consists of two parts, a smartphone app and a cloud saver system.

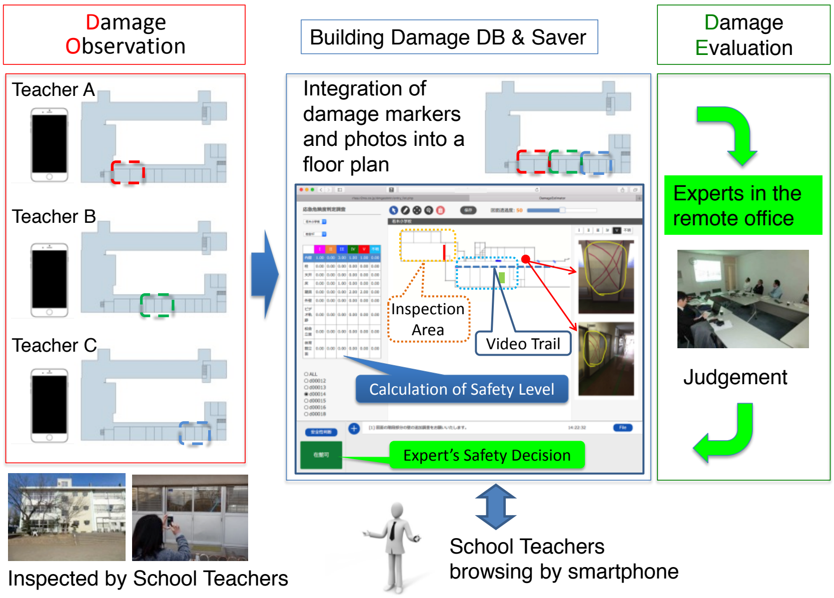

Fig. 4 Building Safety Assessment System

The smartphone app is the damage observation tool designed not only for engineer but also non-engineer use (Fig.5). At first, import a photo of the floor plan into the smartphone. Then plot markers at the damage locations on the floor plan. Finally, take pictures of the damage element and link them to that marker. In other words, the inspector tasks were: 1) finding building damages, 2) identifying the location of the damage on the floor plan, 3) plotting markers at the damaged location on the floor plan, and 4) taking pictures of the damaged element. After the inspection, upload the data to the cloud server.

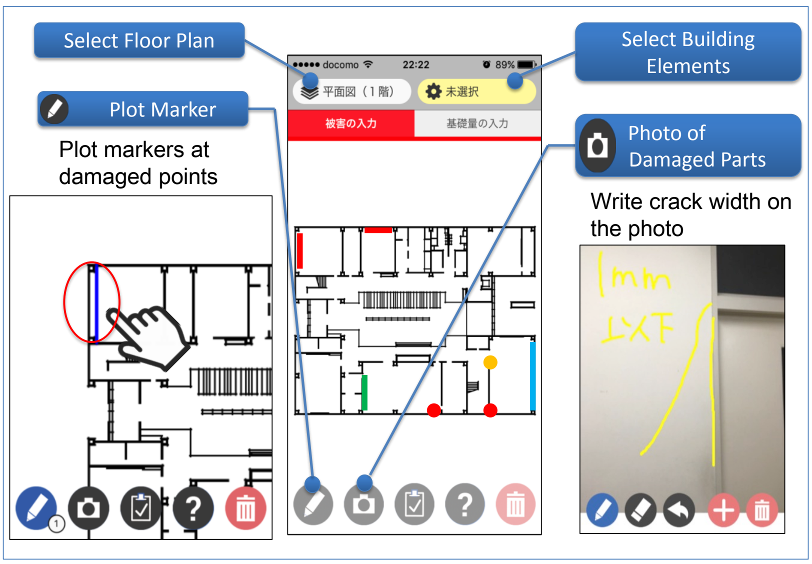

Fig. 5 Smartphone App for Building Damage Observation

Each inspection team is assigned a inspection area, and the inspection activity is carried out in multiple inspection area simultaneously. All the inspection results are integrated in the saver and displayed on a floor plan.

Eengineers on remote area access the saver, check the survey results and assess the building safety. The safety assessment results are stored on the server, and fed back to the school faculties with safety advices using a browser.

5. Demonstration Experiment at Elementary School

Demonstration experiments were conducted at several elementary and junior-high schools. In this paper, a demonstration experiment at Nakajima Elementary School, Shizuoka, is presented. The school faculties and local neighborhood association members participated in the experiment.

The Nakajima Elementary School is 4 stories RC building constructed at 1966. It is retrofitted but still many cracks are observed inside and outside the building. In this experiment, regarding these cracks as damages caused by an earthquake, the damage inspection was conducted.

On the day of the experiment (Fig.6), the participants first learned about outline of the building damage inspection and the observation method using the smartphone app. Then the damage observation started in pairs. When they found a crack, they identified the location on the floor map in the smartphone and ploted a damage marker on it. In addition, taking photos of damaged element from various angles, the observation work on that location ended.

Fig. 6 Demonstration Experiment at Nakajima Elementary School

It took about 1 minute per damage location. After the observation was completed, they uploaded the result to the cloud server. Although the building damage observation was the first experience for all participants, they did almost all of the tasks, such as plotting the damage marker on the floor plan and taking pictures of the damage, without any problems.

An example view of the uploaded result data is shown in Fig. 7. The location of damage element and their photos are displayed in the floor plan. It was determined that the minimum information required for the building safety evaluation was obtained.

After the experiment, we had a discussion on the damage observation by school faculties. There were many opinions regarding the operation of the system. The main opinions are summarized below;

* Building damage observation using this system is technically possible, but who has a responsibility for the result?
* If this system also could use for regular safety inspections, it can be used more efficiently in case of a disaster.

*It will be more efficient if local residents who may use the evacuation shelters also conduct damage investigations.

* Celling of gymnasium is too high to observe the damage from the floor

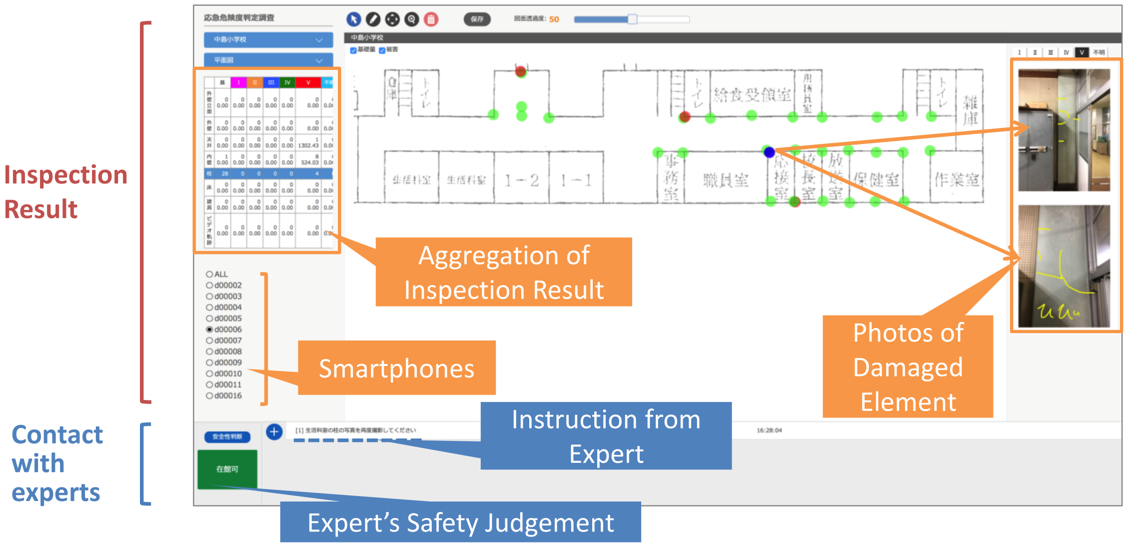

Fig. 7 Example View of Uploaded Inspection Result Data

At a later date, engineers accessed the server and check the results whether it is sufficient information for safety assessment. As a result, with all the damage information, they concluded that, even in remote area, it is possible to make a safety assessment equivalent to the quick safety assessment by engineer on site. Furthermore, if other building information such as building specifications and design documents can be added, the safety level can be more accurately evaluated.

6. Concluding Remarks

This paper presents a new mechanism for speeding up safety assessment of school facilities after earthquakes. The feature of this mechanism is that non-engineer people such as school teachers can conduct the damage inspection. To enable the participation, a smartphone app and cloud server system is developed in this study. And by the demonstration test, it was confirmed that these application function without problems and that building safety could be assessed from a remote location. Although the system developed here is still prototype, it would be useful for speeding up the post-earthquake safety assessment at other facilities.

7. Acknowledgements

This study is partially supported by the research fund of the Consortium of Universities and Local Communities in Shizuoka and the research fund of Tokoha University.

8. References

[1] Tanaka S, Shigekawa K (2014): Development of Training System for Building Damage Assessment Using Actual Buildings, Journal of Disaster Research, Vol.9, No.2, 188-197.

[2] Mizukoshi K, Tanaka S, Nakajima Y (2018): Development of Damage Assessment System of Medical Facilities by Medical Staffs utilizing Smartphones, Summaries of technical papers of annual meeting, AIJ, 395-396.

[3] Shizuoka Prefectural Board of Education (2019): School Disaster Preparedness Manual (Revised).

[4] Yokohama City Board of Education (2019): Yokohama City School Disaster Preparedness Plan

[5] Shizuoka Prefectural Board of Education (2009): School Safety Promotion Guideline.

