Post-earthquake building damage assessment and new technologies in Japan

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1. Damages from Kumamoto Earthquake

Kumamoto Earthquake

Tokyo

Kumamoto

Base map: Geospatial Information Authority

Kumamoto Earthquake

April 14, 2016: M6.5, Max Seismic Intensity 7

April 16, 2016: M7.3, Max Seismic Intensity 7

Source:

Major Disaster Management Headquarters, Apr 13, 2018, “Damages from 2016 Kumamoto Earthquake” (in Japanese)

NILIM/BRI, May 2016, “Quick Report of the second field survey on building damages from Kumamoto Earthquake” (in Japanese)

Kumamoto Earthquake

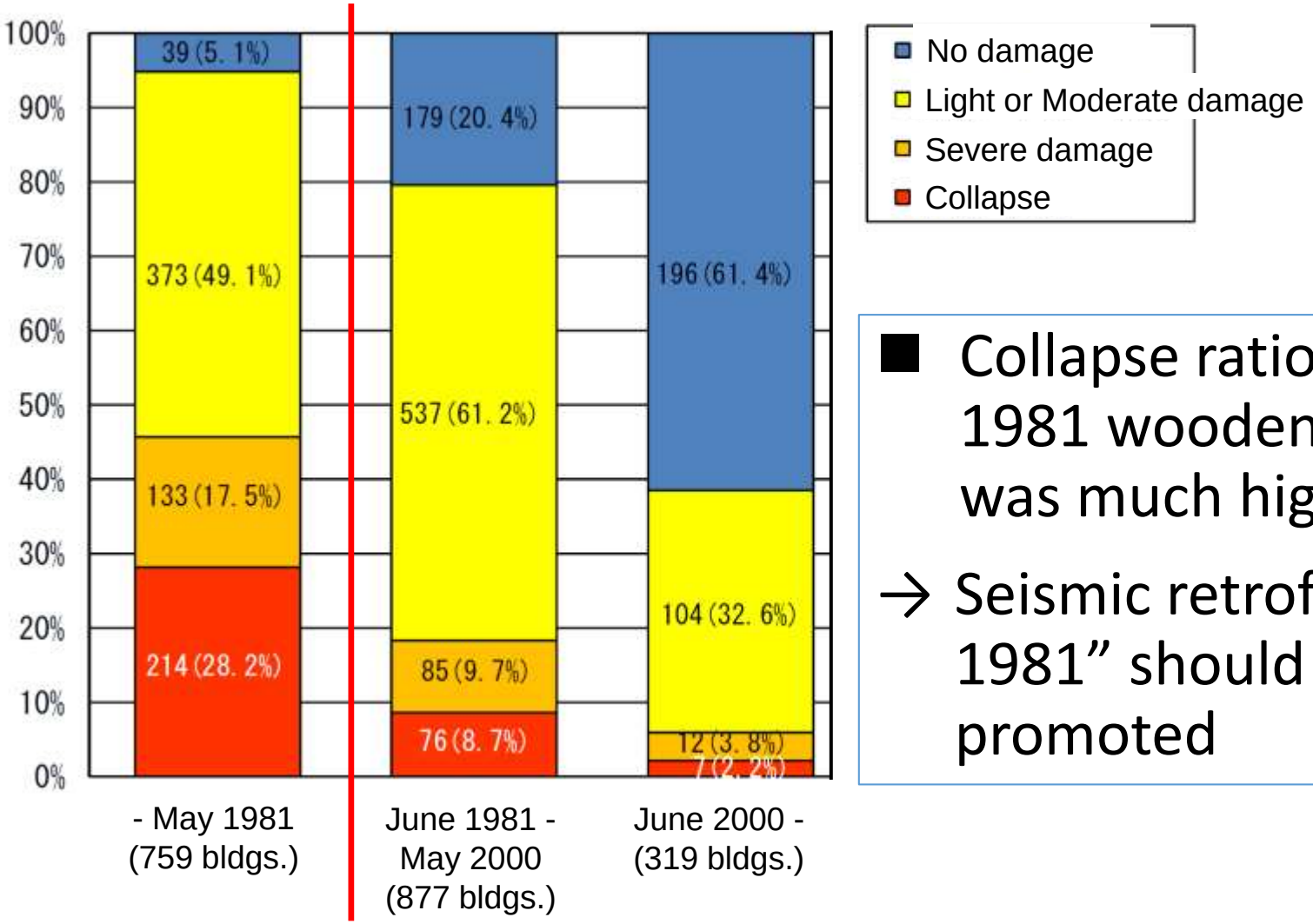
Deaths	50（267 including related deaths）
Damaged houses	205,878
Total collapse	8,673
No. of evacuees (max)	196,325

Source: Major Disaster Management Headquarters, Apr 13, 2018, “Damages from 2016 Kumamoto Earthquake” (in Japanese)

Damage of wooden buildings in Mashiki Town

Source: NILIM/BRI, May 2016, “Quick Report of the second field survey on building damages from Kumamoto Earthquake” (in Japanese)

Damage of wooden buildings by construction year 2016 Kumamoto Earthquake



- Collapse ratio of pre-1981 wooden buildings was much higher

→ Seismic retrofit of "pre-1981" should be further promoted

Source: NILIM & BRI, 2016, "Report of the committee to analyze the building damages in Kumamoto Earthquake" (edited by Sunohara)

2. Post-earthquake building damage assessments

Types of post-earthquake building damage assessments

1. Emergency building safety assessment
   → to prevent secondary disaster

2. Building damage assessment (Disaster victim certification)
   → to be eligible to receive disaster aid

3. Building damage degree assessment
   → to consider how to repair buildings

:

Prepared based on material by Japan Building Disaster Prevention Association

Emergency Building Safety Assessments

- Its purpose is to prevent secondary disaster caused by collapse of damaged buildings in aftershocks and to determine promptly after the earthquake whether occupants can stay at home.
- Conducted by local governments with the help of volunteers.
- Assessments are made by “Emergency building safety assessor”, building engineers who have taken the course and are registered by a prefecture. 108,195 engineers are registered as of March 2017.

Placards are posted to prevent secondary disaster

Prepared based on material by Japan Building Disaster Prevention Association and others

Emergency building safety assessment - placards -

INSPECTED

- Minor damage
- Can be used

LIMITED ENTRY

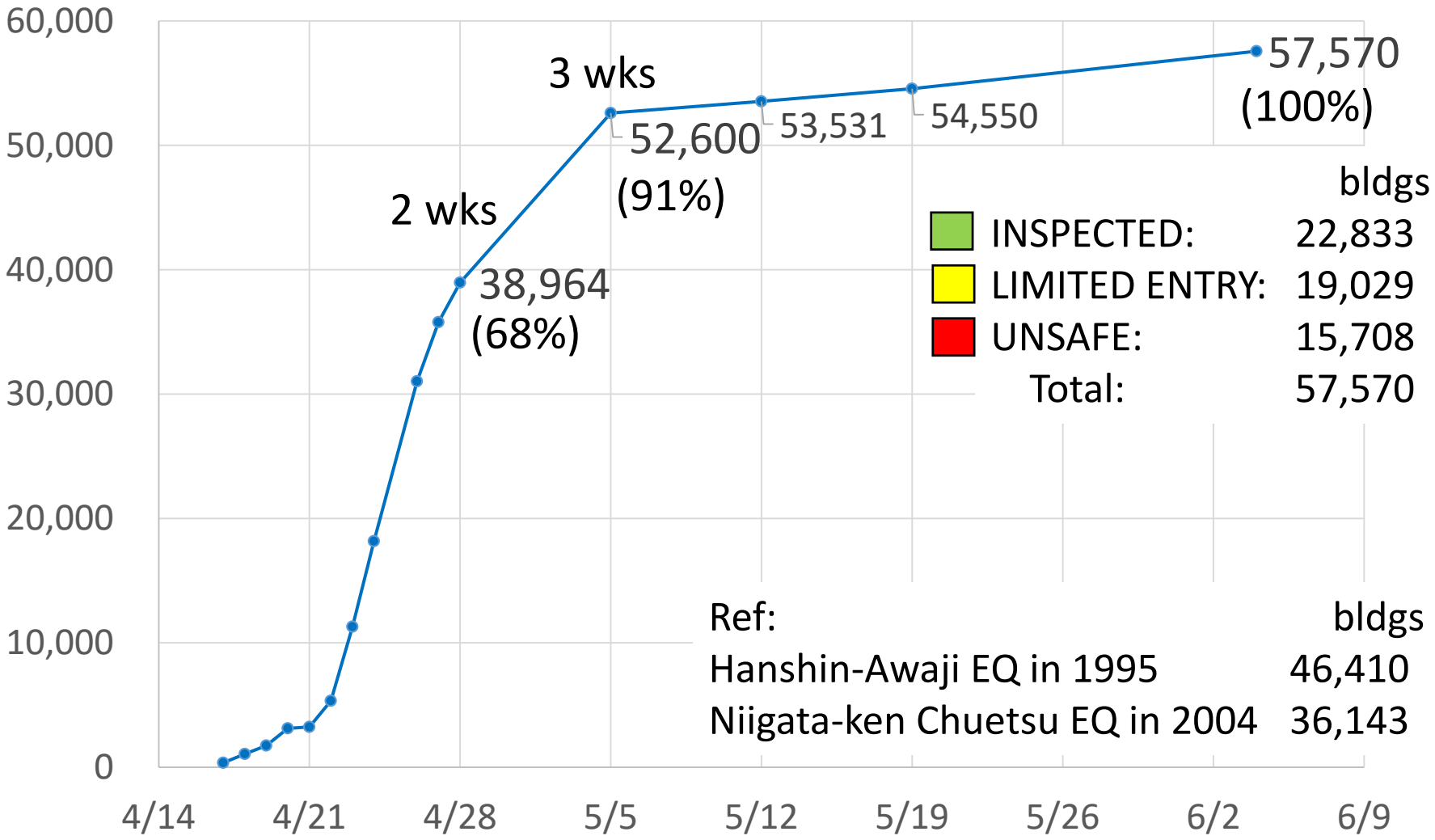
- Use caution when entering
- Consult expert for temporary reinforcement

UNSAFE

- Unsafe to enter
- Enter only after consulting expert and taking temporary measures

Prepared based on material by Japan Building Disaster Prevention Association

Number of Emergency Building Safety Assessments conducted (2016 Kumamoto EQ)



Prepared by Sunohara from reports at Disaster Management Headquarters for "2016 Kumamoto Earthquake" and others

Building damage assessment

- Conducted to certify damage level (total collapse, half collapse, etc.) of houses damaged by earthquake, wind or flood disaster.
- Conducted by municipality.
- “Disaster victim certificate” will be issued based on the result.
- Certified in 4 categories; “total collapse”, “serious damage”, “half collapse”, “less than half collapse”.
- “Disaster victim certificate” is necessary to receive various aids such as disaster victim relief grant and emergency house repair aid.

Application from a victim

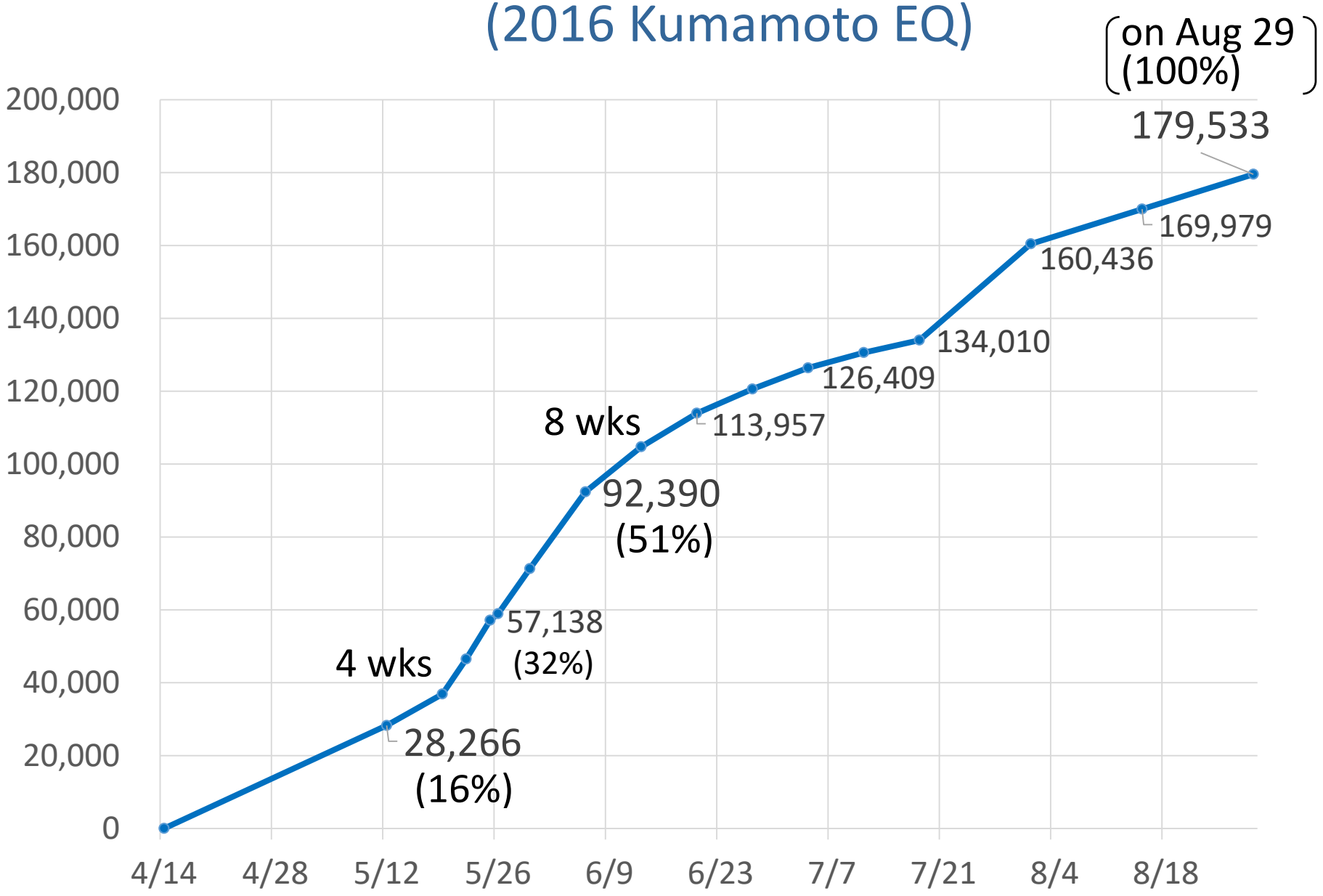
Damage level	Total collapse	Serious damage	Half collapse
Damage ratio	>=50%	40%=< <50%	20%=< <40%

Disaster victim certificate

Various disaster victim aids

Prepared from Cabinet Office, “Damage assessment for houses”

Number of Disaster Victim Certificate issued (2016 Kumamoto EQ)



Prepared by Sunohara from reports at Disaster Management Headquarters for “2016 Kumamoto Earthquake”

3. New technology development related to building damage assessment

Symposium on
"Post earthquake building damage assessment – issues and new technologies –"

Hosted by GRIPS and Building Research Institute (BRI)

Date : Thursday, January 18, 2018
Venue: Sokairo Hall, GRIPS

Part 1: Current status and issues of earthquake damage survey of buildings based on recent earthquake disasters

Part 2: Trend of new technology development related to building damage evaluation

Pages 17-26 are translation of Dr. Norimitsu Ishii's presentation.

Survey of Earthquake Damaged Buildings Using Mobile Devices

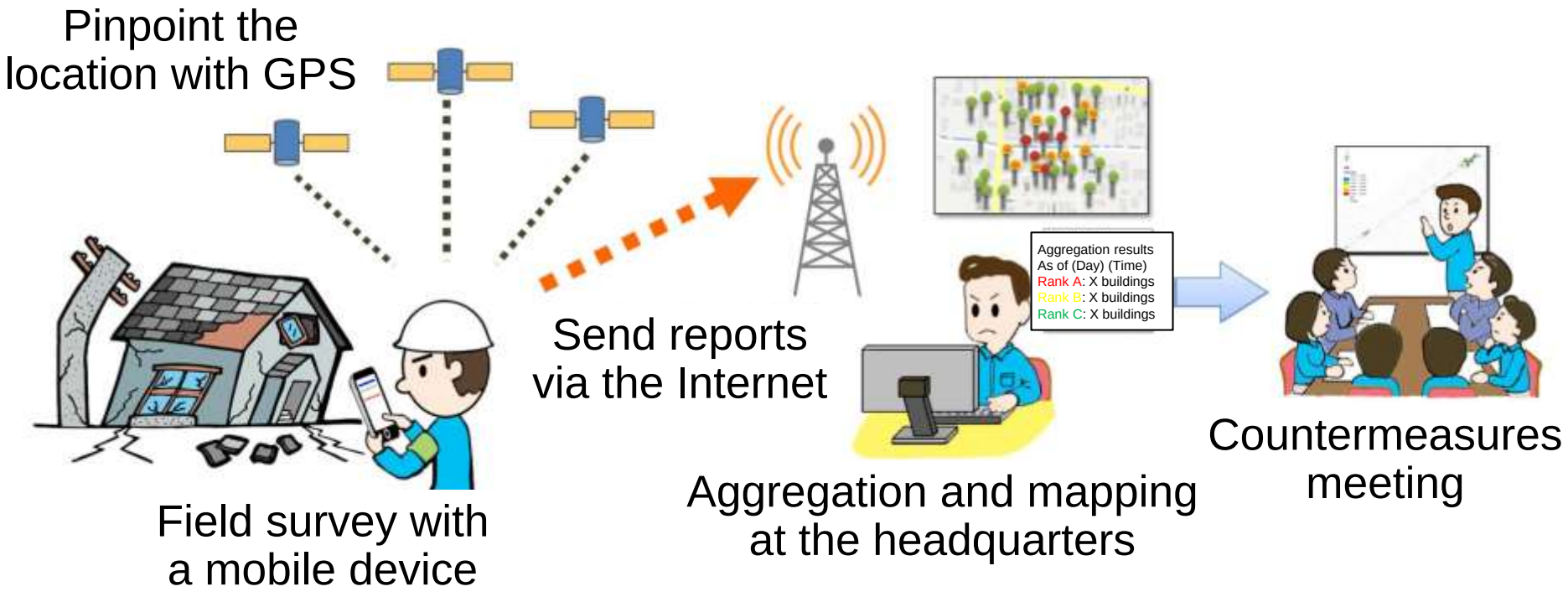
National Research and Development Agency, Building Research Institute,
Department of Housing and Urban Planning
Norimitsu Ishii

Overview

- A support tool for emergency safety assessment developed by the Building Research Institute (BRI)
- Mobile application on the Apple platform
- Facilitates quick post-seismic inspections and data gathering of damaged buildings
- In 2013, its training version debuted and has been available free of charge in the App Store

Application

■ Post-disaster damage survey



- A tool specifically designed for quick “post-earthquake inspection of damaged buildings”
- Developed with Kokusai Kogyo Co., Ltd.

Features - 1

- Operating environment
  - iPad, iPhone, and iPod Touch that run iOS 8.0 and higher (iOS 10.3 and higher recommended)
  - Training version to be used online

Hands-on training using the tool

- Immediately identifies buildings on the map

Conventional	With this support tool
Location search on a paper map	The current location displayed on the screen by GPS* ➢ Assessments conducted efficiently even when not familiar with the area.

Current location display

* iPad (3G and LTE) and iPhone only. Otherwise an external GPS unit or Wi-Fi location info acquisition service needed.

Features - 2

Conventional	With this tool
Manual entries in a paper form	Touch screen operated: ➢ Automatic entries for fixed items such as date and time and investigator name ➢ Multiple-choice sections input with a touch of screen ➢ A keyboard for additional info in the comment field ➢ Assessment result automatically displayed and mandatory fields with no entries flagged ➢ Reduced input errors and workload for investigators

Specify the building location on the map

Fill in the assessment form

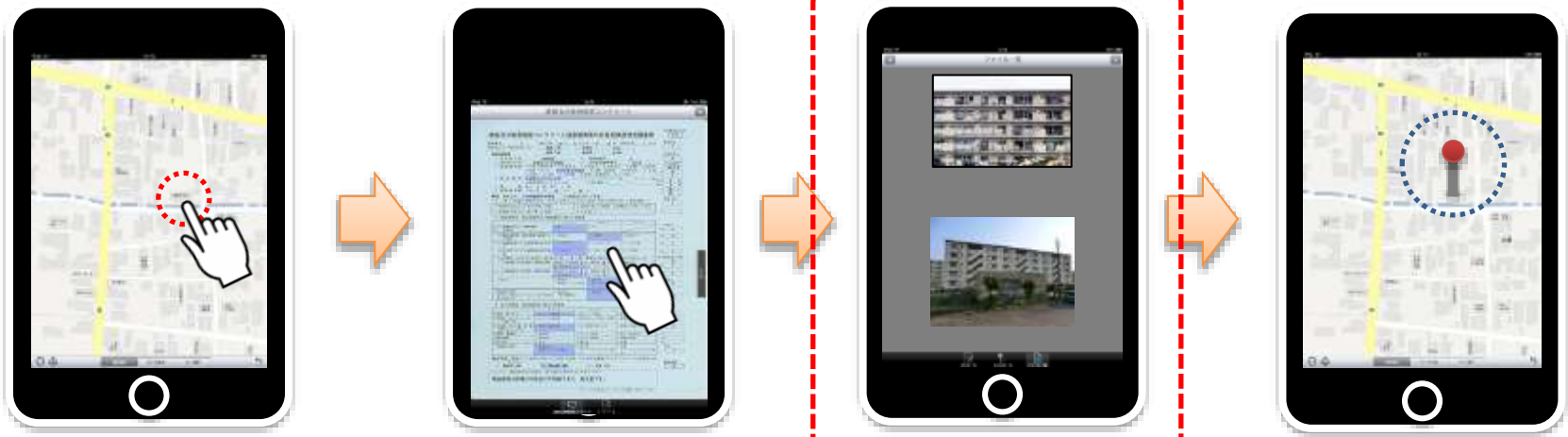
Display the result with a pin

Features – 3 Photographic record

New

Use the built-in camera to take photos and relate them to the assessment form.

- Photographic data are referenced to the assessment form (the number of photos you can take depends on the memory size of the device used).
- The assessment label placed on the building photographed as well.



Specify the building location on the map.

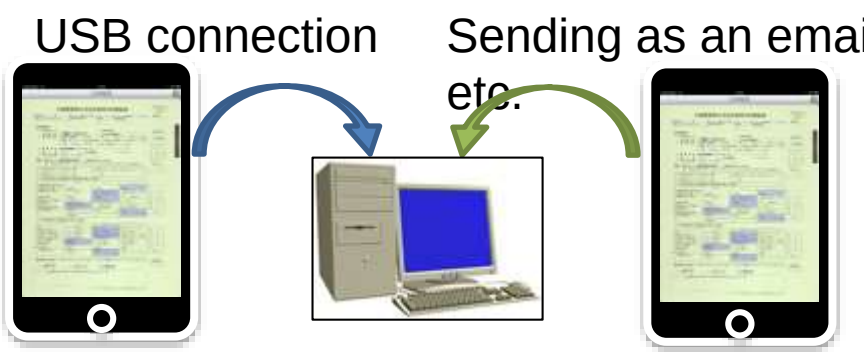
Fill the assessment form.

Take and manage photos.

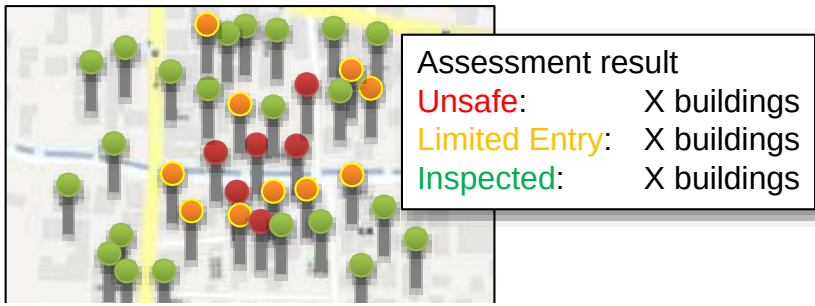
The assessed location is displayed with a pin.

Features - 4 Efficient data management

Conventional	This support tool
Manual transfer of paper data to the computer system.	Connect an iPad or iPhone for data transfer. Import data to Excel, etc. Compile and search immediately. ➢ No data entry is needed, reducing time and labour. ➢ No transcription errors and less verification work.
Manual mapping	Location information (geographic coordinates) is already in the data set transmitted to the computer. ➢ Display a map using GIS, Google Earth, etc. ➢ An assessment form can be called up in the map.



Transferring investigation data



Display the assessment results on the map

Issues identified (1)

- Map availability
  - The training version uses an online map. If the target area is off the Internet, it won't work. .
  - Requirement of offline maps that may not be available and are costly to create.

- Mobile devices
  - Waterproof capabilities, dust resistance, shock resistance, readability under strong sunlight, battery runtime, and weight, given that they are to be used in affected areas.
  - Further advances in device technology are anticipated to address these issues.

Issues identified (2)

- iOS devices
  - Difficult for municipalities to procure a significant number of iOS devices within their own means.
  - Once procured, they must be maintained properly.

- Normalize the use of mobile devices
  - Facilitate the use of mobile devices in everyday operations.
  - Allow and enable the use of personal mobile devices for the assessment.
  - Set up a policy for the use of personal devices in the assessment and data handling (e.g. online investigations only).

- Be creative: combined use of paper-based assessment form
  - A need of an operation model where paper reports and digital data are used at the same time.

Future development

- Incline/tilt measurements
  - An incline angle measuring experiment using iPad's accelerometer failed to produce required accuracy.
  - Size limitation of device affects measurement, which must be addressed.

- Assessment of damage by image recognition
  - Use of photographs to determine the damage level of reinforced concrete columns.
  - Use of machine learning to assess damage based on photo images by training a computer with photos of past damages and their damage indices.

- Off-line data transmission
  - Example: relaying through multiple mobile devices, such as "Relay-by-Smartphone," developed by Tohoku University and Kozo Keikaku Engineering Inc.

Pages 27-34 are translation of Dr. Tomohiko Sakata's presentation.

GRIPS/BRI Symposium "Post-earthquake Building Damage Assessment — Issues and New Technologies"

Development of Rapid Mapping Method for Building Damage using Post-earthquake Aerial Images

Building Research Institute
Department of Housing and Urban Planning
Tomohiko Sakata

20180118

Visualization of damage distribution:

Before

- For reconstruction planning
  - Used as the underlying data

Recent

- For response planning → Pre-disaster reference needed
  - Field survey strategy
  - Clearing roads strategy

Map of building damage distribution at the time of the 1995 Great Hanshin Earthquake

Objectives

- Building damage maps for public agencies to use in their initial response to a large earthquake
  - **Immediacy** is the key

- To use video and photo images to simply and promptly detect changes before and after the disaster

  How about focusing on changes in building heights before and after the disaster?

SfM (Structure from Motion) — Basic Principle

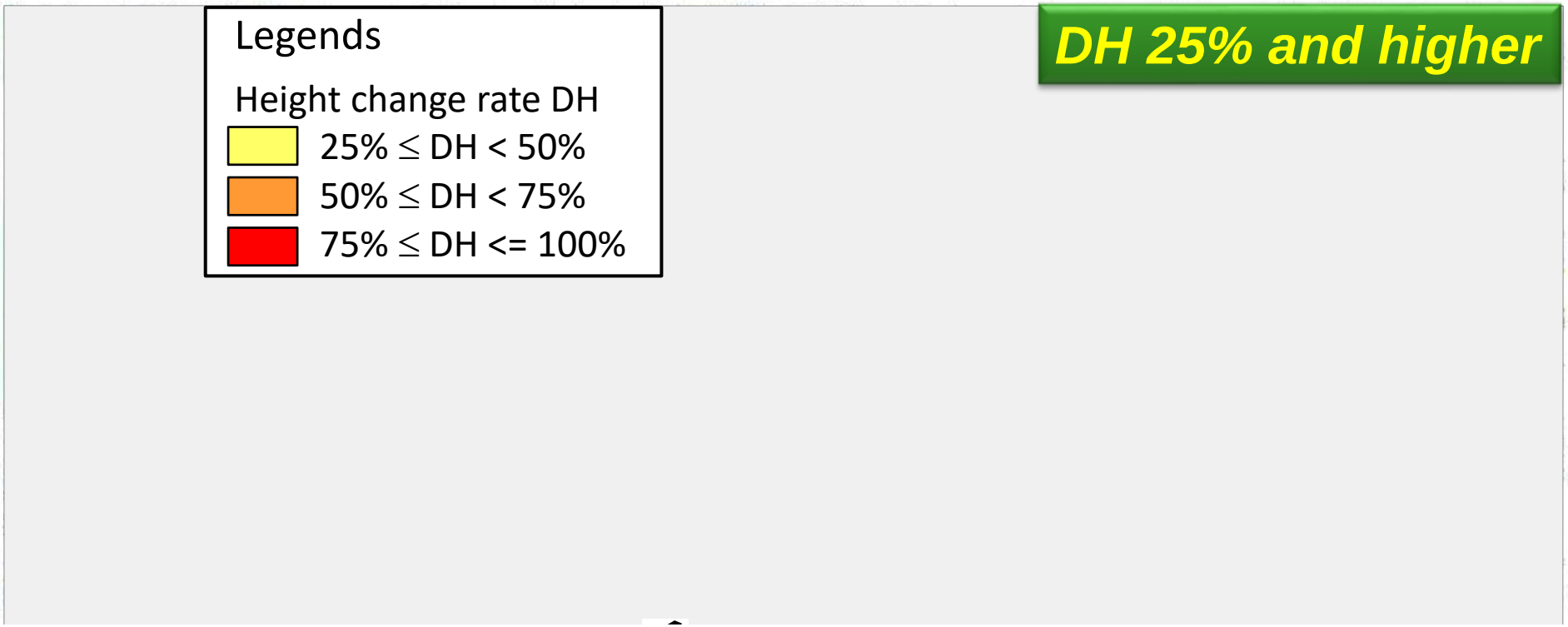
- Aerial view image

✧Location and altitude of the plane taken into account.

Prototype: 2016 Kumamoto EQ

Height change rate DH=(H1-H2)/H1
H1 = No. of stories of pre-disaster building polygon x average floor height
H2 = Median of point cloud height included in building polygon – 5%ile value of point cloud height of ground near building polygons

- Damage in Mashiki-cho urban area (after main shock)



- Based on 36 images taken around 11:00 am, April 16, 2016

Building height before disaster is estimated by the number of floors x the average floor height by use.

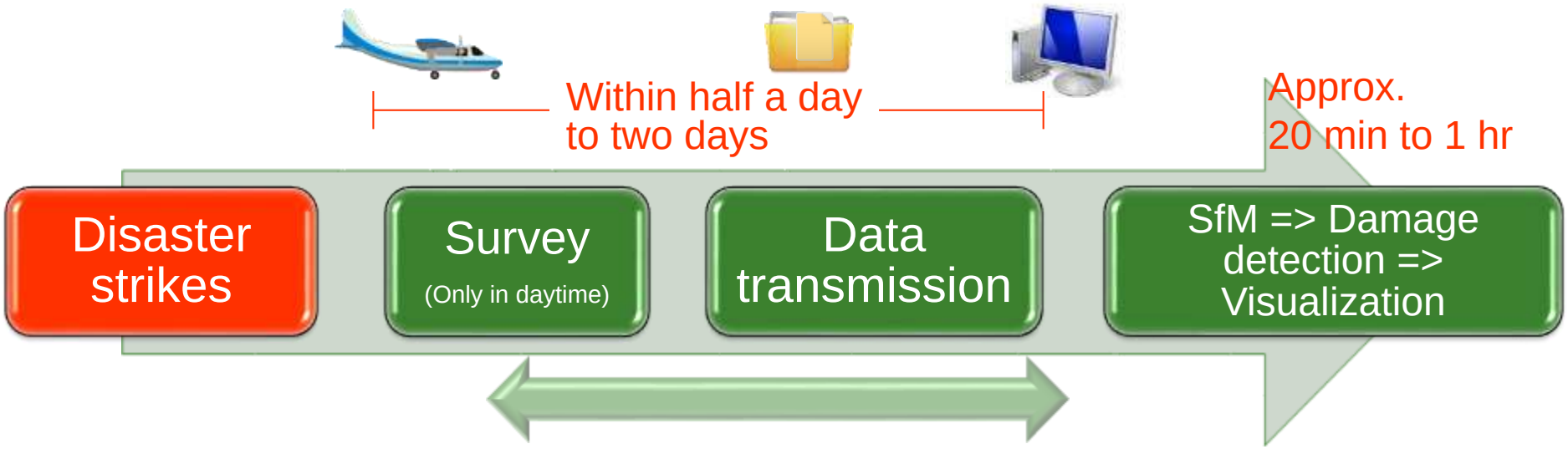
Prototype: 2016 Kumamoto Earthquake

- Comparison with emergency safety check
  - Approximately 70% accurate

(provisional value)		Emergency safety check	
		Not damaged (Inspected: Green)	Damaged (Unsafe: Red, Limited Entry: Yellow)
DH method	Not damaged	6%	16%
	Damaged	14%	64%

- Assessment processing time = Approx. 17 min

Operation



A valuable tool if shorter in time and better in accuracy

Kumamoto Earthquake (Machiki-cho area, Kumamoto City)

- Foreshock (9:26 p.m., April 14, 2016)
  => Aerial survey around 2:00 p.m. the next day
  => GIAJ provided data in the late afternoon.
- Main shock (1:25 a.m., April 16, 2016)
  => Aerial survey around 12:00 p.m. of the same day
  => GIAJ provided data later that day.

Summary

- Building damage maps using SfM on aerial images of urban areas recorded immediately after disasters
  - Gauged ~70% in accuracy at ~17 min of processing time

    => Potential for some cases
  - On-going development

    => Testing against other earthquake events

- Issues
  - Who processes the data? => Build a network
  - Studies of densely populated urban areas
  - Create a system for image acquisition
  - Exploration of other parameters than building height

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Thank you!