POST-EARTHQUAKE QUICK RISK INSPECTION SYSTEM FOR BUILDINGS

Taiki SAITO[1] and Sunil Kumar THAKUR[2]

1 Chief Research Engineer, International Institute of Seismology and Earthquake Engineering, Building Researcher Institute, Tsukuba, Japan, tsaito@kenken.go.jp
2 Engineer, Department of Urban Development and Building Construction, Ministry of Physical Planning and Works, Government of Nepal, skthakurmanara@yahoo.com

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ABSTRACT

Post earthquake risk inspection of buildings is the first essential step immediately after a major earthquake to mitigate the disaster. The purpose of this inspection is to quickly inspect and judge the risk of collapse of damaged buildings or falling of building components due to aftershocks and to inform the habitants about the safety of their houses as soon as possible to prevent secondary disaster due to aftershocks. The result of quick inspection provides the basic information to estimate the number of temporary houses and refuge centers necessary for the displaced people. It helps the people of the affected area gradually return to their normal way of life and to minimize the loss of economic activity.

This paper introduces a methodology for post earthquake quick risk inspection of buildings, including standard inspection form, damage grade classification criteria of individual element and posting placards, and the formal mechanism for inspection system and a long term plan for capacity building to effectively implement the quick inspection system considering socio-political characteristics, building construction culture and availability of resource.

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1. INTRODUCTION

Earthquake is one of the most devastating forces in the nature. In the last hundred years some of the most significant natural disasters have been caused by earthquakes. Needless to say, earthquake is an unavoidable natural disaster. When a strong earthquake strikes a community, destructive damage occurs to buildings leading to partial or complete collapse as found in many past earthquakes in different countries of the world. After a catastrophic earthquake it has always been found that there is a situation of confusion and chaos in habitants about the safety and reentry of their buildings. From the experience of past earthquake disaster in the world it is found that people scaring building damage are sometimes unnecessarily displaced from the building with just slight damage while heavily damaged buildings are continuously used. Buildings hit by earthquakes can cause further injuries and death to inhabitants if left unchecked and unstable, because the aftershocks may cause the secondary disaster. After a big earthquake normally a large number of aftershocks occur. The intense vibration of these aftershocks further destroys the damaged buildings affected by the main shock and might result in the collapse of the buildings. Damaged buildings not only affect the residents but also can hurt the other persons and adjacent houses. It also affects the nearby roads due to the collapse of buildings, falling hazards of exterior walls and window glasses, overturn of building equipment and others.

The need for the post-earthquake inspection and evaluation of building damage has been highly recognized in most of the countries in the world to prevent the increase of loss of human lives and properties caused by aftershocks. Many countries like Japan, US, Italy, New Zealand, Greece and others have successfully implemented such type of damage assessment work in the past earthquakes. This Emergency Assessment System of Damaged Buildings has been established since the late 1980s. In Italy when the Southern Earthquake struck in 1980, quick inspection work was carried out very systematically. In Japan it has become a matter of significant concern since the 1980 Southern Italy earthquake. A guideline for the post-earthquake quick inspection and evaluation of earthquake damage buildings was developed in 1985 after the five-year National Research Project of Rehabilitation Techniques for Earthquake Damaged Structures which started in 1981. During its development, the guideline was applied to structures damaged by 1985 Mexico Earthquake and its effectiveness was confirmed for the first time for the evaluation of damaged reinforced concrete buildings as an international assistance. "Standard for Evaluation of Damage Level of Earthquake Damaged Buildings and Guideline for Repair Techniques" was developed based on this guideline and published by the Japan Building Disaster Prevention Association in 1991. The Standard was applied to several hundreds of buildings affected by 1993 Kushiro-oki and 1994 Sanriku-haruka-oki earthquakes. It was, however applied to a huge number of buildings for the first time in Great Hanshin - Awaji earthquake in 1995 and the quick inspection of 46,610 damaged buildings were successfully completed with the cooperation of the Ministry of Construction, local governments and private construction organizations. So far this system has shown great results in many earthquakes that have occurred all over the Japan. In Japan, quick inspection of damaged buildings is carried out by local government. Each local government has prepared the post-earthquake safety inspection plan, which determines the risk level and usability posting. The plan consists of field manual and operation system for the inspection work. The post earthquake quick damage inspection of buildings is an action by the Center, which is organized in the Disaster Response Headquarters. Damaged buildings are quickly inspected between three and ten days. The inspection work is carried out by trained and registered volunteer risk inspectors.

In U.S., quick inspection system of building has been used since the Loma Prieta Earthquake in 1989. Quick assessments of buildings are done by volunteer inspectors of engineering community who have already been trained or can be quickly trained. Inspections of damaged buildings are carried out within first few hours or days after the earthquake using the rapid evaluation procedure according to the guidelines provided in ATC - 20- 1, Field Manual: Post -earthquake Safety Evaluation of Buildings. This operation is performed under the direction of the local building department with the assistance of volunteer engineers.

The objective of the post earthquake quick inspection is to quickly inspect and evaluate the safety of buildings in the damaged area. The main purpose of this inspection is to prevent secondary disasters by inspecting the buildings hit by major earthquakes and judging the risks of building collapse, fall of exterior walls, window glass, the overturn of building equipment and others that might be caused by aftershocks and to provide information on the risk of using the buildings before restoration for long term use. The quick inspection system is neither for the evaluation of the property value of the building or house nor for the possible use of the damaged buildings in the future. The purpose of quick damage assessment and its limitation should always be clearly informed to the house owners so that they do not get confused about the result of inspection. Since the quick damage inspection is completed in very short time on the basis of limited inspection items, its result may vary from the detailed evaluation system. The main tasks of the operations are:

- Visual inspection of all the buildings in earthquake stricken areas for the judgment of the risk of collapse and posting them as to their safety.
- Identification of hazards associated with damaged buildings and their surroundings.
- Identification of the vulnerable buildings that require emergency support to avoid collapse and execution of the required work.

The result obtained by such quick inspections assists the nation to accomplish the following goals.

- To judge the risk of collapse of damaged buildings or falling of building components due to aftershocks as soon as possible to prevent secondary disaster.
- To save human life and to prevent injuries caused by the collapse of weakened buildings by earthquake.
- To provide the information on the risk of using the building to the habitants before they restore for long term use.
- To help the people of the affected area gradually return to their normal way of life.
- To assess the need for the temporary work like shoring etc.
- To save property from unnecessary demolition.
- To indicate unsafe area around the hazardous buildings
- To provide the basic information to estimate the number of temporary houses and refuge centers necessary for displaced people.

- To minimize the number of homeless people and the loss of economic activities by identifying the safe houses to be used and occupied as soon as possible.
- To provide the necessary and reliable data for obtaining the cost estimate of damage due to disasters which will be useful for determining the aid and resources to take necessary relief measures and formulate disaster mitigation policies.
- To provide data for future research and study to improve disaster mitigation measure and revaluation of existing building code and construction practices.

2. QUICK RISK INSPECTION SYSTEM

2-1. Quick Risk Inspection System in Japan

As shown in Figure 1, when an earthquake occurred in any region, director of the concern division of local government collects information and forwards the information to the chief of disaster countermeasure office of that prefecture. Then disaster countermeasure office of the prefecture takes decision of the risk evaluation practice and makes declaration of risk evaluation practice. Chief of disaster countermeasure office of the prefecture sets up Risk Evaluation Emergency Headquarters and nominates the chief of risk evaluation emergency headquarters at local governments. Then, Risk Evaluation Emergency Headquarters of local governments make plan for risk evaluation work force, estimate the required number of risk inspectors and make coordination with the support office of related prefectures for the help of required number of risk inspectors and lacking inspection materials. The support office of the prefectures requests extensive area support office of host prefecture of regional council for back up. Extensive area support office requests for back up to the prefectures involved. Then the involved prefectures support the Risk Evaluation Emergency Headquarters and dispatch risk inspectors, risk inspection coordinators and inspection materials.

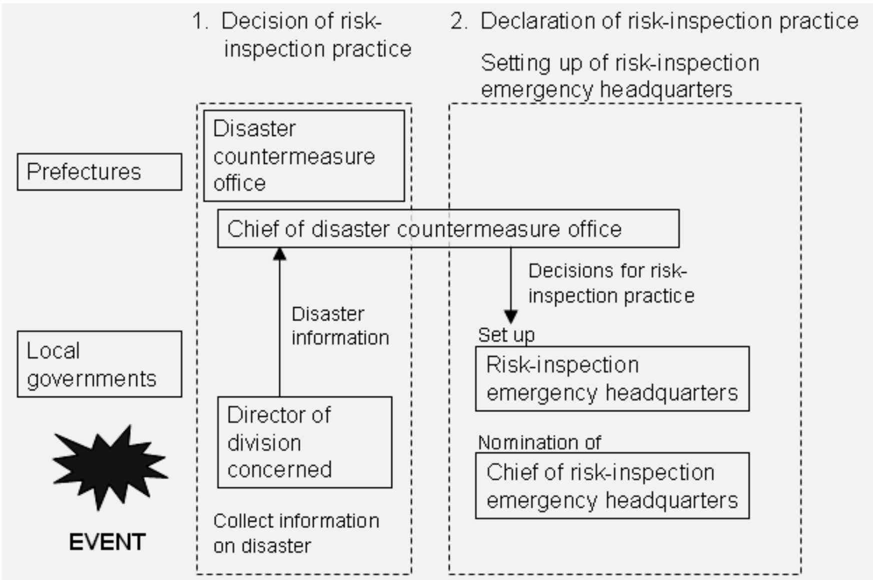


Figure 1: Operation plan of quick risk inspection

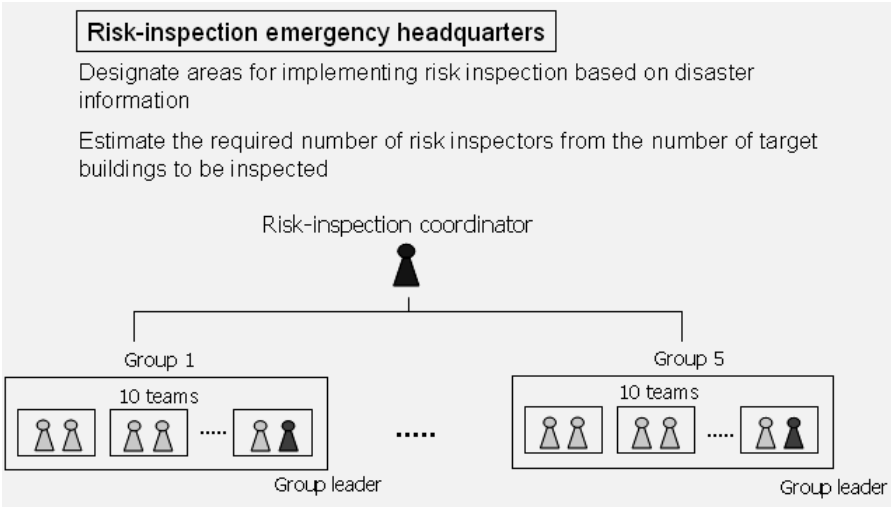


Figure 2: Formulation of risk-inspection work force

Inspection work is carried out by the inspection team consisting of two inspectors. One group leader takes care of the 10 inspection team. Five groups are supervised by one coordinator (see Figure 2).

Inspection is made visually by inspecting building exterior and interior by structural engineers using a damage assessment form as a guide line. Separate quick inspection sheet for reinforced concrete (RC), steel reinforced concrete (SRC), steel, and wooden buildings is used for this purpose. Inspectors inspect all kind of damaged buildings, such as RC, SRC, steel, and wooden structures according to the list of inspection procedures. They start inspection from the exterior part of the damaged buildings, and if necessary and upon the owner's consent, the interior also. They inspect the buildings from the two points of view; the risk of building collapse due to aftershocks and the risk of fall and overturn of building parts. For the risk evaluation of building frames, inspectors inspect building frames to observe whether they will be able to resist aftershocks or not, according to the major point of view based on each structural type. Similarly the risk evaluation of non-structural parts such as fall and overturn of the building parts is also made. They inspect the risk of falling and overturning of roof tiles, window glass, facing materials, outdoor stairs, outdoor signboards, air conditioning facilities, concrete block walls and vending machines, because there is a possibility for these non-structural parts and facilities to fall and to hurt residents and pedestrians in aftershocks. In addition to above mentioned two points of view of damage inspection, they also evaluates the risk of adjacent buildings and surrounding ground conditions such as the possibility of the collapse of the unstable neighboring buildings, surrounding slopes , cliff and ground failure. Then, the entire building is given the evaluation result considering its most dangerous part. The judgment result of this inspection is classified as inspected, limited entry or unsafe depending on damage level and damage rank. Three different post evaluation placards; GREEN for inspected, YELLOW for limited entry and RED for unsafe, are posted on the building near the entrance as shown in Figure 3. The inspectors also write specific details to inform the inhabitants in the remark column on the placards. Post-evaluation placards posted on damaged buildings inform not only inhabitants but also passersby of the risks. It is said that this placard posting system relieves the anxiety of inhabitants, because architects and building engineers actually inspect each building. There are more than 95,000 registered risk inspector volunteers in Japan for this purpose which is equivalent to 0.08% of the total population of Japan.

Figure 3: Post-evaluation placards in Japan

2-2. Quick Risk Inspection System in U.S.

In U.S. quick inspection of buildings is done by volunteer inspectors of engineering community (building inspectors, civil/structural engineers, architects, disaster workers). Inspections of damaged buildings are carried out within first few hours or days after the earthquake using the rapid evaluation procedure according to the guidelines provided in ATC - 20 (Procedures for post earthquake safety evaluation of buildings) and ATC -20-1 (Field Manual: post-earthquake safety evaluation of buildings). These documents provide specific guidance on rapid and detailed inspection methods, posting criteria, selection and size of inspection team, field safety, human behavior following earthquakes and other aspects of post earthquakes safety evaluation. This operation is performed under the direction of the local building department. Buildings are inspected spending approximately 10 to 20 minutes per building by a team of two inspectors. Ideally, two building inspectors or a building inspector and an engineer make up a team. At least 5 years of experience in general building design, construction or inspection is required for the qualification of damage inspectors. The inspection team first identifies both the apparently safe and the obviously unsafe structures and then continues to evaluate more difficult damage condition that may require the restricted use posting. The rapid evaluation procedure consists of

- Examining the structure from the outside by thoroughly looking at each wall of the building from the ground to the roof.
- Examining the ground around the building and over the full site, looking for evidence of surface rupture, liquefaction, subsidence, or potential landslide.
- Evaluating the structure using the rapid evaluation form.

Each building is evaluated using the six basic rapid evaluation criteria given in Table 1 (ATC - 20-2). These are used to rate the building's condition with respect to safety of occupants and the public.

Table 1: Basic rapid evaluation criteria in ATC -20

Basic rapid evaluation criteria	
Condition	Action[a]
1. Building has collapsed, partially collapsed or moved off its foundation	Post unsafe
2. Building or any story is significantly out of plumb(i.e., leaning)	Post unsafe
3. Obvious severe damage to primary structural members, severe racking of walls or	Post unsafe

other signs of severs damage and distress present.	
4. Obvious parapet, chimney, or others falling hazard present	Post restricted use and barricade the unsafe area
5. Large fissures in ground, massive ground movement, or slope displacement is present	Post unsafe
6. Other hazard present (e.g., toxic spill, asbestos contamination, broken gas line, fallen power line).	Post unsafe and/or barricade unsafe area[b]
a. In completing the rapid evaluation assessment form, the evaluating team will be asked to determine the degree of damage (minor/none, moderate, or severe) and to determine the posting. The posting or action recommended above is for the severe situation. b. restricted use posting may be applicable in certain situations.	

If the building is found to have none of the condition listed in basic safety evaluation criteria, and if there are no other hazards or unsafe conditions present, it is apparently safe and can be posted Inspected. Buildings with moderate damage can be difficult to evaluate, especially during a rapid evaluation. When there is uncertainty about posting a structure Unsafe, Restricted Use (with appropriate restrictions indicated) posting is considered and a request for detailed evaluation is made.

After undergoing safety evaluation, based on the information included on the form and discussion with the rest of the team, buildings are posted with one of the three colored placards: INSPECTED, RESTRICTED USE, OR UNSAFE. The colored placards are used to denote at a distance condition. This posting lets owners, occupants and the public know whether inspected buildings are safe for use. The green placard is used to denote a relatively safe structure. This placard is entitled INSPECTED - LAWFUL OCCUPANCY PERMITTED. The criteria for a structure to be posted GREEN are - No apparent hazard is found although repairs may be required. The original lateral load capacity and/or vertical load capacity has not been significantly decreased. No restriction on use or occupancy is required.

The YELLOW placard is used to denote those structures which have been damaged yet access to the building is possible with caution and is titled RESTRICTED USE. This placard identifies those structures which can not be fully occupied without repairs as well as those that can not be occupied but are relatively safe enough to allow access for possession retrieval. The criteria for a structure to be posted YELLOW is: l) the building is damaged but may or may not be habitable, 2) there is a falling hazard present in part structure, 3) there is damage to the lateral force and/or vertical load resisting systems, however, they are still able to resist loads. When these conditions exist, occupancy is permitted in accordance with noted restrictions.

The RED placard is used to denote a building, which represents a significant threat to the safety of occupants and this placard is titled UNSAFE. However, it is recognized that sufficient evaluation has not been performed in order to determine if repair is economically feasible. Most UNSAFE buildings can be repaired. The decisions are often made considering economics for the repair or replacement of buildings. This is a decision that must be made by the owner. Therefore, to make it clear to everyone, it has been added THIS IS NOT A DEMOLITION ORDER so the owner knows they must make decisions regarding what will happen to the building. The criteria for a structure to be posted RED are: 1) there is an extreme hazard and potential collapse of the building, 2) there is imminent danger of collapse from an aftershock, 3) there is a significant decrease in lateral and/or vertical load capacity. When these conditions exist, the building is unsafe for occupancy or entry except by authorities. These three different kinds of placards are shown in Figure 4.

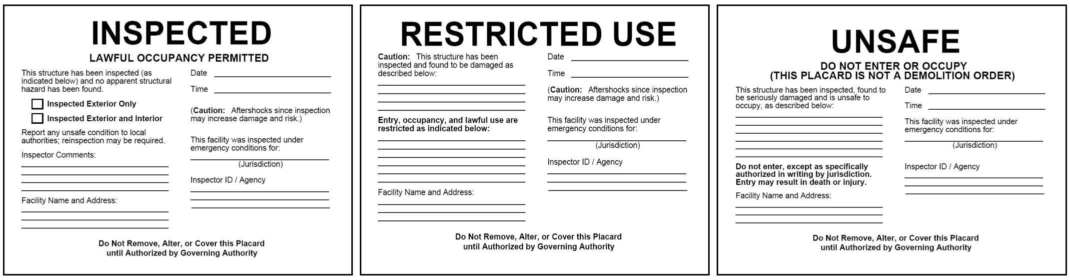


Figure 4: Post-evaluation placards in US (Source: ATC - guideline)

2-3. Quick Risk Inspection System in Greece

The emergency inspection is carried out by a team of two structural engineers, who are assisted, if resources permit, by a driver - technician. These engineers could be public employees or volunteer professionals and should, ideally, have some previous training for this type of work. For an efficient operation, a rapid assessment is first carried out to screen obviously safe and unsafe buildings, followed by a detailed evaluation of those buildings that fall in neither of these two categories. A rapid assessment is performed taking not more than about 30 minutes per building.

The inspected buildings are classified and posted in one of the three categories SAFE (Green), LIMITED ENTRY (Yellow) or UNSAFE (Red) as listed in Table 2, in which the corresponding criteria, indicative damage and restrictions on usability are also summarized. In accordance with the inspection objectives, the safety of people inside and outside the building is the basic criterion for its classification, for which reference is made to its original seismic capacity. A second criterion is the presence or not of any hazardous condition, which could exist even in buildings whose seismic capacity has not decreased (e.g. damaged parapets, chimneys etc.).

According to Table 2, buildings that experienced minor or negligible damage and have no signs indicating a reduction of their original seismic capacity are posted as SAFE (green color), provided that no major hazard is present or in case that some local hazard exists, the dangerous area is barricaded and posted “AREA UNSAFE”. Such buildings are usable immediately except for areas, if any, marked “AREA UNSAFE”. At the other end of the scale are the heavily damaged buildings, those whose original seismic capacity have greatly decreased and thus are subject to sudden collapse even in minor aftershocks. Such buildings are posted UNSAFE (red color) and no entry allowed.

Table 2: Safety, Damage and usability classification of buildings

Posting Classification	Damage State	Usability
SAFE (Green)	**1 = None - Slight**	**Usable - with possible restrictions**
An inspection has shown that the original seismic capacity of the building has not materially decreased and that no major hazard is present. Non observable or slight structural damage. Minor non-structural damage. Use and occupancy allowed, except in areas marked AREA UNSAFE indicating the presence of some local hazard.		
LIMITED ENTRY (Yellow)	**2 = Moderate - Heavy**	**Temporarily unusable**
The original seismic capacity of the building has been decreased and aftershock hazard may be present. Moderate damage or heavy local damage has occurred. Limited entry is permitted at owner's risk but not usage on a continuous basis. Entry by public prohibited. Repair and/or strengthening is required. The need for emergency support of the building should be considered.		
UNSAFE (Red)	**3 = Severe - Total**	**Unusable**
Building is unsafe as subject to sudden collapse. Severe structural damage or partial failure has occurred. Entry prohibited (except by authorities) and building surroundings should be protected. Decision on possible repair or demolition should be made after an engineering evaluation of technical possibilities and their economic consequences.		

(Source: Post earthquake emergency assessment of building safety, Greece)

The posting "LIMITED ENTRY" is used for all the damaged buildings which fall between the SAFE and UNSAFE categories for which there is uncertainty about the extent to which they have been weakened by the earthquake. Such buildings with reduced seismic capacity, though not to the extent of being in danger of sudden collapse, require repair and strengthening before they could be occupied on a continuous basis. Such buildings are subjected to a second, more detailed inspection taking 1.0 to 3.0 hours to complete. All critical facilities or other important buildings are inspected with detailed inspection method from the beginning. The inspectors fill out an appropriate posting placard and a Damage Inspection Form, in which their recommendation for further action is marked. The posting placard is placed at or near all entrances of the building to be clearly visible by anyone who wants to enter. The inspections also identify potential hazards in the damaged buildings that may require immediate removal and also those buildings that need emergency support to avoid collapse.

Damage level classification is made based on the guidelines listed in Table 3 for each type of buildings

Table 3: Typical damage level of masonry building and RC building

	Typical damage level description	
DAMAGE LEVEL	Masonry building	Reinforced Concrete buildings
1 = None - Slight	1. No signs of any distress 2. Small cracks in partition walls visible from both sides (d <~2 mm) 3. Small cracks in bearing walls, starting mostly at the corners of a	1. No signs of any distress 2. Slight structural and non-structural damage 3. Fine cracks in wall and ceiling mortar 4. Small cracks in a few infill or partition walls

	few openings (d <~ 2 mm) 4. Patches of mortar falling from ceilings or walls 5. Disturbance, partial sliding and falling down of some roof tiles 6. Large cracks or partial failures of chimneys and parapet	5. Hairline cracks in some structural elements (beams, slabs, joints, columns) and in connections of prefabricated buildings 6. Disturbance, partial sliding or falling down of roof tiles 7. Large cracks or partial failures of chimneys and parapets
2 = Moderate - Heavy	1. Substantial cracking of partition walls (d > ~ 2 mm) 2. Some diagonal cracking in bearing walls (d > ~ 2 mm), but not so extensive as to constitute failure 3. Movement, separation or local failure of roof and floor framing supports 4. Extensive disturbance, sliding and damage of roof tiles in combination with bearing wall damage 5. Collapse of chimneys and parapet walls in combination with bearing wall damage 6. Local heavy damage in some part of the building 7. Minor ground movement	1. Substantial to large diagonal or other cracking in partition or infill walls in one or more stories. Detachment or partial failure of such walls. 2. Small to large cracks (d < 5 mm) in beams and joints and in connections of prefabricated buildings, smaller cracks in columns and shear walls(d < 3 mm) 3. Spalling of concrete from structural members, exposure of reinforcement, crushing of material in certain locations but to an extent that it does not constitute a danger for collapse 4. Extensive disturbance, sliding and damage of roof tiles in combination with other damage listed herein 5. Collapse of chimneys and parapets, in combination with other damage listed herein 6. Local heavy damage in some part of the building 7. Slight dislocation of structural elements 8. Minor ground movement but no signs of foundation failure
3 =Severe – Total	1. Partial or total collapse 2. Partial or total failure of bearing walls, floors and/or roof 3. Walls out of plumb 4. Failure of floor and roof support areas and dislocation of their framing 5. Bearing walls with large diagonal or other cracking 6. Fractured foundation 7. Substantial ground movement, dislocation of the whole building or parts of it 8. Any type of damage indicating considerable danger for collapse	1. Partial or total collapse 2. Widespread infill failure or severe cracking extending to the concrete elements in one or more story 3. Large number of crushed structural elements and connections, exposure and buckling of reinforcement in several locations 4. Considerable dislocation of structural elements, residual drift in any story or dislocation of the whole building 5. Substantial ground movement, uplift of footings or fracture of foundation beams, fracture or bowing of basement perimeter walls etc. 6. Any type of damage indicating considerable danger for collapse

2-4. Quick Risk Inspection System in New Zealand

In New Zealand, rapid evaluation of damaged building is carried out by field inspection team consisting of two technical inspectors. After the declaration of state of emergency after a catastrophic earthquake, territorial authorities are responsible for coordinating the quick damage inspection to provide public safety. Before the event, two or three local persons qualified for the task are identified as Building Evaluation Manager (BEM), listed in the call out order and prepared for the responsibility by appropriate training. Mutual aid agreements with one or more distant territorial authorities are made in advance considering the fact that local territorial authorities may not be available due to their family situations or other reasons like injury due to earthquake. BEM are the main responsible persons for safety evaluation of damaged buildings. A process for rapid evaluations and posting of all buildings in the damaged area is started as soon as possible. Inspectors quickly assess the type and extent of building using a quick damage assessment form as a guide line. The inspected buildings are then classified and posted in one of the four categories INSPECTED (Green), RESTRICTED USE (Yellow), SHORT PERIOD ENTRY (Orange) or UNSAFE (Red). Rapid evaluations are generally undertaken by building inspectors, experienced building contractors and suitably experienced building professionals. Local professional engineering resources are focused on critical facilities. Quick inspection is generally completed in two weeks. The management structure for quick damage assessment is shown below in Figure 5.

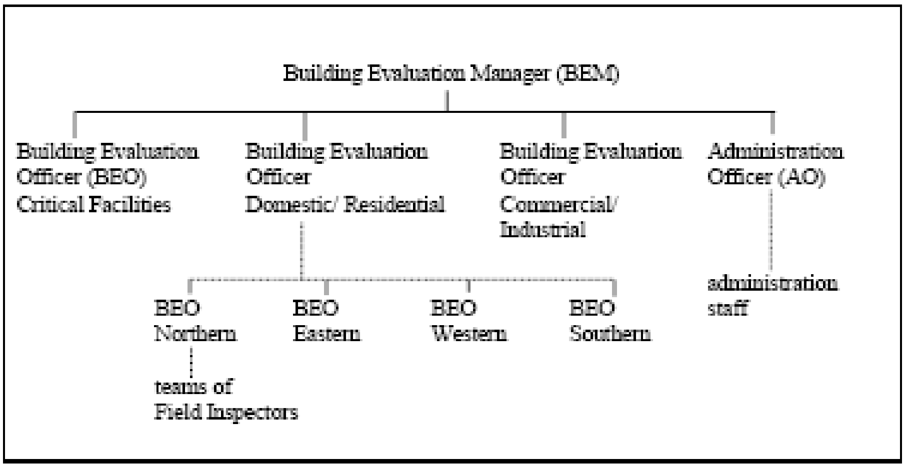


Figure 5: Management structure for quick damage assessment
(Source: Post earthquake building safety evaluation procedures, New Zealand)

2-5. Classification of damage to building in EMS

Although EMS (European Macroseismic Scale) is not used directly for defining the damage grade classification of building but the intensity degrees in the EMS is defined on the one of the basis of damage to buildings. For this, five grades of damage classification to building have been made. A separate illustrated account of damage for masonry buildings as well as reinforced concrete buildings has been addressed in EMS for damage classification of buildings. The EMS scale of damage for masonry building and reinforced concrete building has been shown in Tables 5 and 6 (EMS-98).

Table 4: EMS classification of damage to masonry building

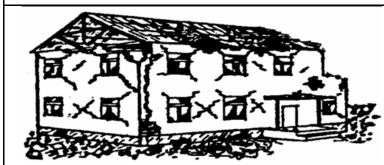
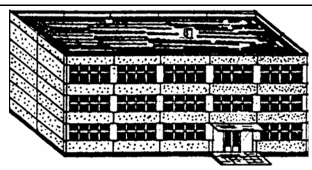
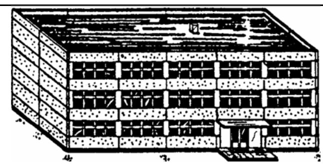
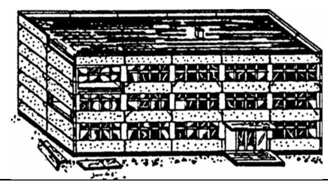
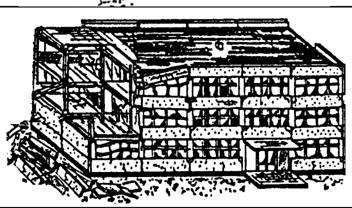
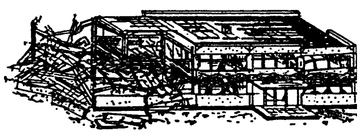
Classification of damage to masonry buildings	
	Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage) Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases
	Grade 2: Moderate damage (slight structural damage, moderate non-structural damage) Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys.
	Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
	Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Serious failure of walls; partial structural failure of roofs and floors.
	Grade 5: Destruction (very heavy structural damage) Total or near total collapse.

Table 5: EMS classification of damage to RC building

Classification of damage to buildings of reinforced concrete	
	Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage) Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infill
	Grade 2: Moderate damage (slight structural damage, moderate non-structural damage) Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels.
	Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage) Cracks in columns and joints of frames at the base and at joints of coupled walls. Spalling of concrete, buckling of reinforced rods. Large cracks in partition and infill walls, failure of infill panels.
	Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage) Large cracks in structural elements with compression failure of concrete and fracture of rebar; bond failure of beam reinforced bars; tilting of columns. Collapse of a few columns or of a single upper floor.
	Grade 5: Destruction (very heavy structural damage) Collapse of ground floor or parts (e. g. wings) of buildings.

3. PROPOSAL OF QUICK INSPECTION PROCEDURE

3-1. Quick inspection sheet for masonry and confined masonry buildings

The quick inspection sheet for typical building typology in developing countries has been developed based on the Japanese quick inspection sheet. This inspection sheet can be used for both the non-engineered light reinforced RC frame with masonry infill buildings and confined masonry buildings. Due to the use of light reinforcement in the frame, these non-engineered RC building has been assumed to perform as similar manner to confined masonry in case of earthquake.

QUICK INSPECTION SHEET FOR DAMAGED MASONRY BUILDINGS AND CONFINED MASONRY BUILDINGS

Inspection 0:

Serial number of Inspection: ....

Time and Date of Inspection: ...., Year.......... / Mon. ..../Day ....

Name of Inspector(s) (Affiliation/ID Number)

.......................(............./..................)

........................(............./..................)

Description of inspected building

1. Name and address of building: ....
2. Contact person: .... Tel: ....
3. Building use:

[ ] Individual house [ ] Residence with commercial Use [ ] Governmental building

[ ] Offices [ ] Hospital [ ] Hotels [ ] Others ……………

4. Type of structure:

[ ] Bricks wall [ ] Hollow concrete block [ ] Stone wall

[ ] Confined masonry [ ] RC with masonry infill [ ] Others ....

5. Number of story:

[ ] One story [ ] Two stories [ ] Three stories [ ] Others ....

6. Size of building:

Dimensions of the first floor ....m X ....m

Inspection method:

[ ] Appearance inspection only. [ ] Appearance and internal visual inspection.

Inspection 1: The degree of danger judged from general inspection of the entire building

If a building is obviously unsafe due to following damage, mark the corresponding reason(s), identify the building "Unsafe" and check as such in SUMMARY in Inspection 5. (Stop the inspection and skip to the Inspection 2 and 3.)

[ ] 1. Total or partial collapse and fallen floors of the building	[ ] 2. Significant damage of the foundation and /or Remarkable offset of superstructure from foundation
[ ] 3. Significant inclination of entire building or individual story	[ ] 4.Others ( )

Inspection 2: The degree of danger judged from the hazard from adjacent buildings, surrounding ground and structural elements

	Rank A	Rank B	Rank C
1. Presence of danger caused by damage from adjacent buildings or surrounding ground Failure	[ ] No	[ ] Uncertain	[ ] Yes
2. Settlement of buildings due to ground failure	[ ] < 0.2 m	[ ] 0.2-1.0 m	[ ] > 1.0m
3a. Inclination of building due to differential settlement (For plain masonry building)	[ ] < 1/400	[ ] 1/400-1/200	[ ] > 1/200
3b. Inclination of building due to differential settlement(For confined masonry building)	[ ] < 1/200	[ ] 1/200-1/65	[ ] > 1/65
4.. Damage to load bearing wall **Inspect the most seriously damaged story, sketch building and measure the length of damaged walls as indicated at the bottom of this page, and then fill up the following 4-a and 4-b**			
4-a. Ratio of damage grade III [(3)/(2)X100] ________%	[ ] < 1 %	[ ] 1%-10%	[ ] > 10%
4-b. Ratio of damage grade II [(4)/(2)X100] ________%	[ ] < 10 %	[ ] 10%-20%	[ ] > 20%

Structural safety judgment from 1 to 4	[ ] Inspected (When all items are given rank A)	[ ] Limited entry (When Rank B >= 1 but C = 0)	[ ] Unsafe (When Rank C >= 1 or Rank B >= 2)

[Sketch]	**Inspected Story/Floor**:
	(1) Total length of walls ________ meters
	(2) Length of inspected wall _______ meters
	(3) Length of walls that suffered damage grade III ___m
	(4) Length of walls that suffered damage grade II ___m
	(5) Inspected ratio of walls [(1)/(2)X 100] _________ %
	1. Sketch building configuration and wall location of the inspected story in the left box. **2. Find out walls with damage grade II and III and indicate them on sketch**.

Inspection 3: The degree of danger caused by falling and/or overturning of objects

	Rank A	Rank B	Rank C
1. Frame and glass of the window	[ ] No damage	[ ] Visible deformation and/or cracks	[ ] Danger of falling
2. Stairways [ ] Interior [ ] Exterior	[ ] No damage	[ ] Slight damage	[ ] Significant damage
3. Elevated water tank, chimney, signboard, machinery etc.	[ ] No inclination	[ ] Slight inclination	[ ] Danger of falling down
4. Others Hazard(s) ( )	[ ] No damage	[ ] Special attention required	[ ] Life threatening

Judgment of the degree of danger of Nonstructural element from 1 to 4.	[ ] INSPECTED (only A and / or B)	[ ] LIMITED ENTRY (C >= 1)

Inspection 4: Sub summary on Inspection 2 and Inspection 3

INSPECTED AREAS	[ ] Exterior only	[ ] Exterior & Interior

1) Check one in Inspection 2 and 3, and then choose the highest rating among them as the OVERALL RATING.

	INSPECTED	LIMITED ENTRY	UNSAFE
Inspection 2 (Structural safety)	[ ]	[ ]	[ ]
Inspection 3 (Non structural safety)	[ ]	[ ]	__________
OVERALL RATING. Check the highest rating among Inspections above.	[ ]	[ ]	[ ]

2) Following the above results, fill up the summary in Inspection 5. If B or C Rank for falling and /or overturning hazards (questions 1. through 4.) exists, describe your recommendations and comments in the summary.

Inspection 5:

Summary (Complete the sheet on the following pages and then summarize results below.)

OVERALL RATING

[ ] INSPECTED (Green) [ ] LIMITED ENTRY (Yellow) [ ] UNSAFE (Red)

Original lateral resistance has not been significantly decreased. No apparent hazard was found. Temporary use or occupancy is allowed.	Temporary use is not allowed unless retrofit to prevent damage progress, repair to remove life threatening hazards and/or barricades around hazard striking area are made. Detailed assessment may be needed.	Emergency retrofit to prevent sudden collapse is needed, but entry or temporary uses are not allowed. Detailed assessment is needed.

RECOMENDATIONS:

[ ] Shoring /bracing needed in the following area: ________________________

[ ] Removal of falling and /or overturning hazard needed in the following area: ____________________________

[ ] Barricade/off-limits needed in the following area: ____________________________

[ ] Others : ____

COMMENTS (state whether danger is from the building structural element or from falling objects)**:**

____

____

Posting Placard

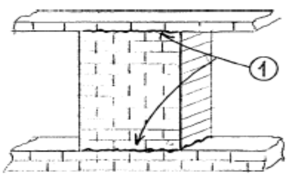
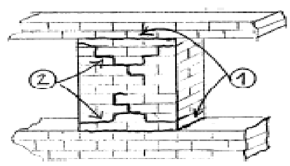
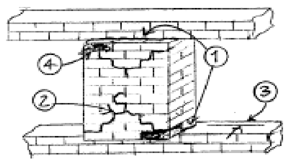
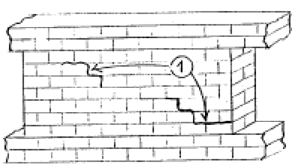
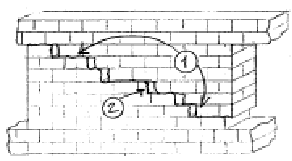
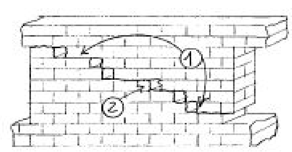
Based on the overall result of quick inspection sheet, the inspected buildings should be posted with colored placard as green, yellow and red for INSPECTED, LIMITED ENTRY and UNSAFE buildings respectively. The three different types of colored placard show the condition of building from distance. These also explain the house owner about the safety of the buildings and some necessary precaution required for continued occupancy. The proposed posting placards have been prepared in local language so that the general people can understand the meaning of posting card.

3-2. Damage grade classification of individual elements

For quick damage inspection system, easy procedure but unified damage grade classification criteria is the most essential to reach the different building inspectors examining the same building at the same conclusion about the structural safety and potential hazard category to aftershocks. Damage grade classification for each type of element for different behavior mode has been taken in account mainly based on FEMA - 306, component damage classification guide for un-reinforced masonry building and confined masonry building. Damaged structural members are divided into three damage levels; Damage Grade I (Slight damage), Damage Grade II (Moderate damage) and Damage Grade III (Heavy or severe Damage).

Example of description of the each damage grade with typical appearance and definition for each type of component for different behavior mode is shown in Table 6 for plain masonry buildings.

Table 6: Damage grade classification of individual elements for masonry buildings

Damage Grade	Damage Grade I (Slight)	Damage Grade II (Moderate)	Damage Grade III (Heavy)
1. Component Type: Weaker Pier	Behavior Mode: Wall-Pier Rocking		
Typical appearance			
Description of damage	1 Hairline cracks/split mortar in bed joints at top and bottom of pier	1. Hairline cracks/split mortar in bed joints at top and bottom of pier. 2. Possible hairline cracking/split mortar in bed joints within piers but no displacement in horizontal unions.	1. Hairline cracks/split mortar in bed joints at top and bottom of pier, plus one or more of: 2. Hairline cracking/split mortar in bed joints within piers, but bed joints typically do not open. 3. Possible out-of-plane or in-plane movement at top and bottom of piers ("walking"). 4. Crushed/split bricks at corners of piers.
2. Component Type: Weaker Pier	Behavior Mode: Bed Joint Sliding		
Typical appearance			
Description of damage	1. Hairline cracks/split mortar in head and bed joints either on a horizontal plane or in a stair stepped fashion have been initiated, but no offset along the crack has occurred and the crack plane or stair-stepping is not continuous across the pier. 2. No cracks in masonry units.	1. Horizontal cracks/split mortar at bed joints indicating that in-plane offset along the crack has occurred and/or opening of the head joints up to approximately 6 mm, creating a stair-stepped crack pattern. 2. 5% of courses or fewer have cracks in masonry units.	1. Horizontal cracks/split mortar on bed joints indicating that in-plane offset along the crack has occurred and/or opening of the head joints up to approximately 12 mm, creating a significant stair-stepped crack pattern. 2. More than 5% of courses have cracks in masonry units.

4. IMPLEMENTATION OF QUICK INSPECTION

4-1. Quick inspection operation plan

It is essential to have a good operational plan in advance for successful implementation of quick damage inspection of damaged buildings in the earthquake stricken areas at the time of earthquake disaster. According to the Japanese operation plan, when catastrophic earthquake strikes a community, the chief of the respective local government office (municipality/village development committee) collect the information about the disaster and inform the chief of district natural disaster relief committee in the district. The chief of the district natural disaster relief committee calls meeting of district natural disaster relief committee and decide for the quick inspection practice, sets up quick inspection emergency office and nominates the related division chief as a chief of the quick inspection emergency office to perform the task.

4-2. Plan for quick inspection work force

At the quick inspection emergency office, the chief of the office decides the areas for implementation of quick inspection. They estimate the number of damage inspectors, coordinators and group leaders required for the quick inspection operation from the number of target buildings to be inspected considering the duration of inspection 10 days. One inspection team constitutes two damage inspectors. 10 to 15 inspection teams are supervised by one group leader and one coordinator supervises 5 groups. At the same time the office also estimates and prepares inspection material required for the operation.

On the basis of estimated work force, the quick inspection emergency office makes liaison and coordination with public offices, private offices and academia of their region for the dispatch of damage inspectors. If the required number of risk inspectors or the required number of inspection materials is beyond their capacity, they contact central support office and the other division office of the zone for the support and help of inspectors and inspection materials. In response to this, the central support office gives necessary instruction to related division office of the zone for the necessary support and help. At the same time the support office also provide necessary shortage materials and work force. In response the related division office of the zone contacts with the public office, private office and academia of their region and dispatches the damage inspectors and damage inspection coordinators and provides inspection materials.

4-3. Coordination and training of damage inspectors

Principally government servants should take the responsibility of post earthquake quick damage inspections. But in case of a catastrophic earthquake it is not possible to handle the situations only by the governmental people, because in such a situation the disaster area becomes large and number of damaged building becomes enormous. Therefore, in this condition it is better to engage the governmental sector in organizing seminars to train the inspectors and managing other related activities necessary for the operation and engineers and architects from the private sector should volunteer to evaluate the damage.

The training for the inspectors should be done in advance so that the process of post earthquake quick damage inspection of buildings could be started as soon as possible in dynamic way after a catastrophic earthquake. But if there is lack of certified inspectors during the evaluation stage, a short term training sessions of few hours could be conducted for those who wish to help.

5. CONCLUSIONS

Post earthquake quick damage inspection of buildings should be the first essential step immediately after a major earthquake to mitigate the disaster so that the affected people could return to their normal life as soon as possible. This operation should be completed in a very limited period of time on the basis of visual observation of damaged elements of the buildings.

In the case of big earthquake, a large number of work forces with various levels of knowledge and experience are required for inspection purpose. However, the damage evaluation of buildings must be uniform across the inspection area and should be as objective as possible. For this purpose, it is imperative to make procedure simple and damage inspection criteria uniform so that two different individuals examining the same building should arrive, essentially, at the same conclusion regarding the structural safety and potential hazard category to aftershocks. This study attempted to achieve this objective with due consideration of the quick inspection sheet for typical masonry building, damage grade classification criteria for such buildings and criteria for declaration of safety posting placards.

Another important and critical aspect of post earthquake quick inspection is its successful implementation in a short time. This can be achieved only when the system is well planned in advance. A well prepared post earthquake strategy including quick damage inspection as well as pre-event preparedness is critically important to be in place beforehand so that the inspection system would be all set and ready for the immediate application after a big earthquake disaster. For this purpose, establishment of an appropriately organized scheme before the earthquake is necessary. A quick inspection operation plan with organizational structure and necessary training must be established.

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