

付録 2. QUICK INSPECTION MANUAL OF DAMAGED REINFORCED CONCRETE BUILDINGS DUE TO EARTHQUAKES

**QUICK INSPECTION MANUAL
FOR DAMAGED REINFORCED CONCRETE BUILDINGS
DUE TO EARTHQUAKES**

**Based on the Disaster of
1999 Kocaeli Earthquake in Turkey**

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QUICK INSPECTION OF DAMAGED REINFORCED CONCRETE BUILDINGS DUE TO EARTHQUAKES

FORWARD

An earthquake of a magnitude of 7.4 (Ms, USGS) occurred at 3:01 local time on August 17, 1999, with an epicenter near the City of Izmit in the western part of Turkey (Kocaeli Earthquake). The epicenter was approximately 100 km east from Istanbul, and catastrophic damage was caused in several cities of the western Turkey including cities of Izmit, Adapazari, Istanbul etc. and immense damage of 40,000 fatalities and missings, 45,000 injured and 200,000 damaged buildings was reported.

Immediately following the earthquake, the Japanese Government dispatched an expert team on disaster relief. They surveyed the hardest-hit areas and recognized that damage inspection of buildings, especially of reinforced concrete residential buildings, was most urgently needed to prevent secondary disaster due to aftershocks and to estimate the number of temporary houses needed for displaced people. They also reported the conclusions above to the Turkish Government, and the Government decided to request technical cooperation to perform quick inspection of damaged buildings.

Following a request from the Turkish Government, the Japanese Government dispatched a second expert team to contribute to the prompt recovery from aftermath in the affected areas, focusing on the development of quick inspection procedure under the cooperation with Istanbul Technical University. Principally based on experiences in Japan, a quick inspection procedure applicable to buildings in Turkey was developed mainly by the following members through field surveys, several discussions and exchange of mutual knowledge.

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This report describes the basic concept, inspection sheet and application guidelines including damage definitions and their examples which may facilitate to perform quick inspections in the field.

ACKNOWLEDGEMENT

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1. SCOPE AND OBJECTIVE

When an earthquake strikes a community and destructive damage to buildings occurs, as was found after the 1999 Kocaeli Earthquake, immediate damage inspections are needed to identify which buildings are safe and which are not to aftershocks following the main event. This is mainly because, as have been often experienced commonly in past earthquake disaster in the world, people scaring building collapse are unnecessarily displaced from buildings with just slight structural damage while heavily damaged buildings are continuously occupied. To identify buildings that can be entered and those that should be kept from entering or using to avoid secondary disaster due to aftershocks etc., it is significantly essential to perform quick inspections of damaged buildings at the earliest stage after the disaster. It should be also pointed out that the results of quick inspection can serve as basic information to estimate the number of temporary houses and refuge centers necessary for displaced people because such facilities are usually required, especially in the case of extensive damage to a community.

When earthquake disaster strikes a densely populated urban center, the number of buildings to be quickly inspected is enormous in general unless the damage is localized. Immediately after a damaging earthquake, local building departments are usually swamped and structural engineers within the stricken area may not be able to perform inspections due to damage to their houses, offices or even to themselves. It is therefore needed to seek additional manpower available or to extend the period of time for quick inspections. To complete the inspection within a certain short period, it is therefore inevitable to seek assistance from outside sources including volunteers other than structural engineers. As long as utilizing many individuals and covering many buildings in the inspections, simplified procedure but unified damage criteria is most essential so that two different individuals examining the same building should arrive at essentially the same conclusion regarding the structural safety and potential hazard category to aftershocks.

The main purpose of this report is to describe an example of quick inspection procedure which can be applied mainly to reinforced concrete apartment houses in Turkey, emphasizing on the technical aspects of the procedure. Although the procedure proposed herein was developed after several field surveys of typical building damage due to the 1999 Kocaeli Earthquake carried out in Avcular (Istanbul), Izmit, Adapazari, Duzce, it should be noticed that the procedure may need some revisions after its further field applications. It should be also pointed out that although not discussed in this report, organizing and managing the inspection work is essential for immediate and efficient inspections, and should be discussed and planned considering earthquake preparedness program in each country and/or community.

2. RECONSTRUCTION STRATEGY

To restore a damaged community as early as possible, well-prepared reconstruction strategy, which needs deep and wide discussions among engineers and governmental personnel prior to disaster, is most essential. Figure 2.1 shows an example of reconstruction strategy for earthquake damaged buildings, which is under discussion in Japan. As is shown in the figure, there may be several stages chronologically after the event in general. Although the detailed and practical flow should be determined after further discussions considering wide array of issues related to earthquake disaster planning and social system in each country, local authority and community, a quick inspection can be definitely the first action to be taken immediately after a major earthquake.

1) Stage 1: Emergency Stage

During the emergency stage immediately after a destructive earthquake, quick inspections of damaged buildings are urgently needed, which is the major objective of this report. As discussed earlier, this is aiming quickly to identify the damage level of a building according to the observed damage and to categorize the building into different potential hazard to aftershocks etc. Natural environment that should be taken into account in evaluating potential hazard of a building may include rainfall, snowfall etc. as well as aftershocks. Heavy or continuous rain may cause another landslide or ground failure where the soil condition is unstable due to the main shock, which may result in secondary damage to buildings. Increase in building weight due to snowfall is obviously disadvantageous to vertical- and lateral-load-carrying capacity of damaged buildings.

After quick inspection, each building is categorized into one of the following three classifications.

UNSAFE: Remarkable danger to aftershocks exists. Emergency retrofit to prevent sudden collapse is needed but entry and temporary use are not allowed.

LIMITED ENTRY: Damage to structural and/or nonstructural members is found. Temporary use is not allowed unless temporary retrofit to prevent damage progress, repair to remove life-threatening hazards and/or barricades around hazard striking area(s) are made. Entry only for emergency purpose is allowed at own risk.

INSPECTED: No or few apparent structural damage is found but no hazard is believed to be present, although some repairs may be needed. Original lateral resistance is not significantly degraded and temporary use or occupancy is allowed.

It is also favorable to post the final results on each building, perhaps with colored placards (UNSAFE : RED / LIMITED ENTRY : YELLOW / INSPECTED : GREEN) such that all occupants, users and the general public can be easily aware of the results.

Quick inspections are basically performed through visual examination from outside the building. It is however favorable to inspect inside if possible because interior inspection may lead to newly found damage. As described later, either interior inspection or at least interview to occupants/users is strongly recommended when the building is rated "INSPECTED".

It should be clearly stated that the quick inspection principally does not deal with assessment to determine whether or not the building need to be retrofitted for long-term use or demolished, to estimate the loss of private property, or to estimate the cost needed for the retrofit. For example, an “UNSAFE” building does not necessarily mean “demolish required” except for those obviously impossible to retrofit. After the 1995 Hyogo-ken Nambu Earthquake, misunderstanding of basic concept on quick inspections among inspectors, building owners and even local government officials caused confusion and trouble in some cities. It is therefore strongly desired to disseminate the basic idea for quick inspection activities.

In general, temporary retrofit to prevent damage progress and/or to remove life-threatening hazards for its temporary use (e.g. “LIMITED ENTRY” building), or emergency retrofit to prevent sudden collapse (e.g. “UNSAFE” building) may be needed. “INSPECTED” buildings may need some repairs for occupancy. Note that engineering judgement by well experienced structural engineers may be most practical in this emergency stage to determine the level and appropriate scheme for temporary and emergency retrofit needed, since detailed structural calculations for numerous damaged buildings can not be generally performed within a short period of time.

It should be strongly emphasized that buildings categorized into “INSPECTED (GREEN)” simply means that they are believed to have no hazards to aftershocks, which are generally less affective than the preceded main event, and does not necessarily ensure the structural safety for long-term use. In general cases, buildings designed and constructed according to the dated codes have seismic capacities less than required in the up-to-date engineering knowledge and current seismic design code, and may often need structural retrofit to provide enough seismic resistance against future major earthquakes.

2) Stage 2: Quasi-stable Stage

Since the quick inspections are performed within a restricted short period of time, the results may be inevitably coarse. Furthermore, it is not generally easy to identify the residual seismic capacities quantitatively from quick inspection. In the second quasi-stable stage following the emergency stage above, damage assessment should be more precisely and quantitatively performed, and then technically and economically sound solutions should be applied to damaged buildings, if retrofit is needed. For this end, the procedure proposed by the Ministry of Public Work can be a candidate for damage assessment, although it may need some modification to efficient application.

Necessary retrofit and possible schemes should be determined considering experienced earthquake intensity, residual seismic capacity etc. of damaged buildings. It should be noted that the retrofit level may be case-by-case practically depending on the disaster scale. It is of course favorable if a building can be upgraded to the level required in the current code and for long-term use. However, if the disaster is vastly distributed and hence the number of buildings to be redesigned and retrofitted is enormous, temporary retrofit for mid-term use may have to be applied. In this case, structural retrofit for long-term (or permanent) use is needed later as

discussed below.

3) Stage 3: Stable Stage

In the final stage, buildings should be retrofitted considering the long-term use. In some cases, seismic evaluation may have been already completed in the second stage. In such a case, results obtained above can be utilized to determine the necessary retrofit level. It is essential to point out that this procedure can be also applied to existing old buildings located in an area where a damaging earthquake has not stricken yet as well.

Stages 2 and 3 are significantly important for comprehensive earthquake preparedness measures, but a lot of discussions will be needed to finalize the procedure and criteria which can be shared throughout Turkey.

As can be found in the flow chart, it is recommended to perform stages 1 and 2 within “1 to 2 weeks” and “2 weeks to 3 months”, respectively, but it is highly dependent on the disaster scale. It may be informative that quick inspections could not be completed in Japan even 1 month after the 1995 Hyogo-ken Nambu (Kobe) Earthquake due to the huge scale damage, although quick inspectors system had been already established in several prefectures at the time of the quake. Considering the lessons learned from such evidence, nationwide quick inspectors system was developed to mutually cooperate in case of emergency.

Corrosion, low quality concrete, poorly detailed reinforcement etc. are often found in field surveys. It is, however, essential to point out that the damage evaluation described 1) and 2) above should be performed principally based on the *observed damage due to earthquakes*. For example, if a building with such problem(s) has minor damage, damage evaluation should be made primarily based on the fact that the structure resisted the ground shaking, and such problem(s) should be carefully taken into account while discussing the retrofit design and required seismic capacity for retrofit in subsequent stages. It is again emphasized that what is needed in a damaged community immediately after an earthquake is not seismic capacity evaluation but damage evaluation.

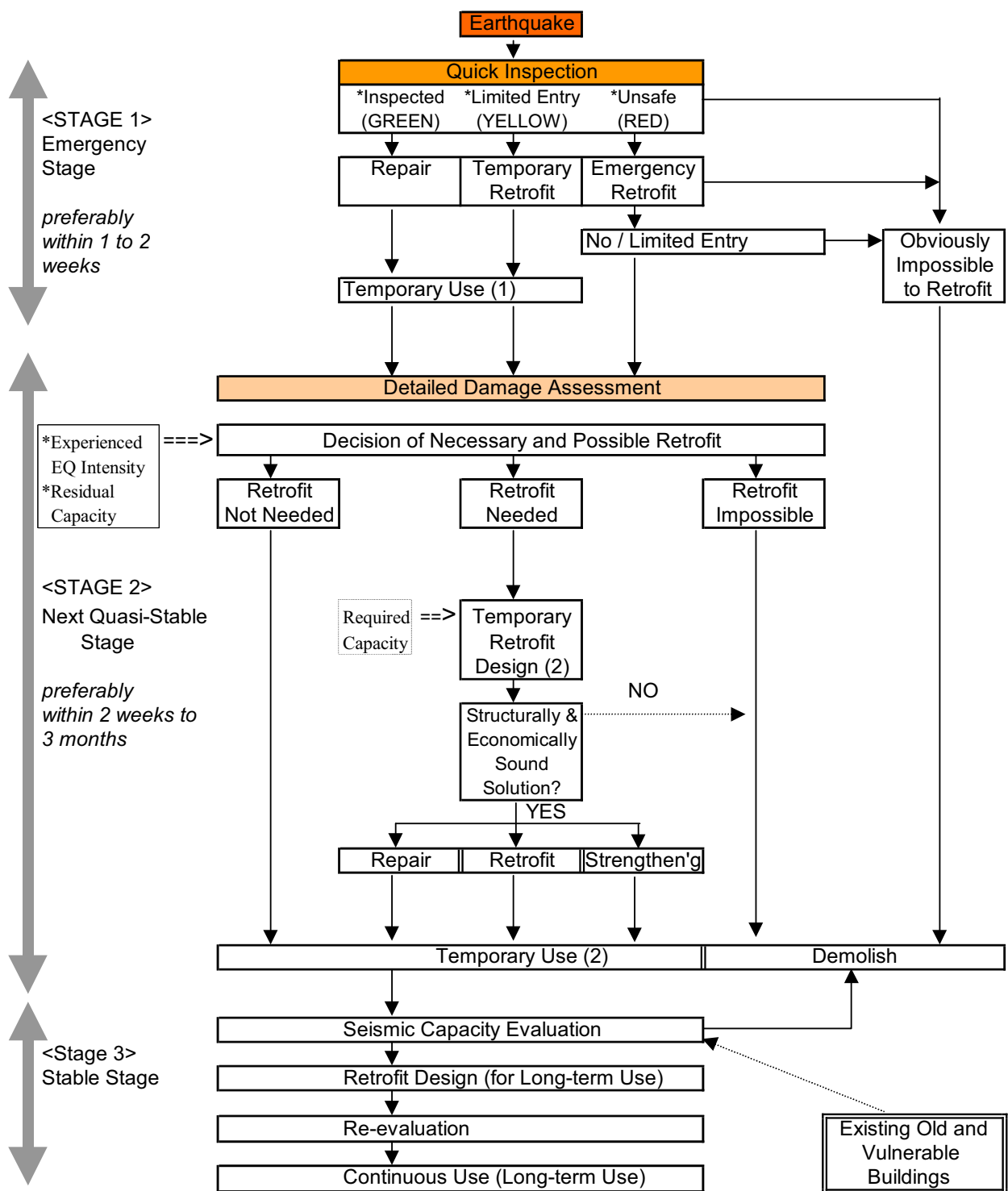


Figure 2.1: General Flow of Reconstruction Strategy

3. INSTRUCTIONS

An example of quick inspection sheet for reinforced concrete buildings appears on the next 3 pages. As described earlier, this inspection sheet mainly concerns the reinforced concrete apartment houses in Turkey. In the following sections, inspection procedures and general guidelines are provided.

3.1 General

1) Inspection Team:

Each inspection team should basically consist of two inspectors. This is mainly because of the following reasons:

- Mutual discussions often help obtaining reasonable damage evaluation, resulting in less variety of damage rating.
- Hazards which may strike an inspector during the building survey may be noticed by the other.

2) Overall Damage to Building:

Inspection should be started by overall damage survey. This is perhaps the best indicator of the damage level experienced by the building. When the building is obviously unsafe, do not enter. It is also of significant importance from inspector's life-safety point of view to ensure exit ways or safe space in the case of aftershocks especially when interior inspections are made.

3) Identification of Structural Members And Their Damage:

Damage to nonstructural members of course may cause hazards to occupants, users and the general public but the structural safety due to aftershocks, which is in general most highly related to life-safety, is significantly dependent on structural damage. Ordinarily people can not distinguish structural members from nonstructural members, and therefore they may not notice a sign of structural damage or may take observed damage more serious than needed. This is one of the major reasons why quick inspections by well-trained inspectors are needed.

4) Falling and/or Overturning Hazards:

Damage to nonstructural members may often give life-threatening hazards to occupants, users, and the general public. It should be noted that the hazard may be given by objects likely to fall down or overturn and not by those already fallen down or overturned. It is therefore appropriate to rate a building "INSPECTED" if nonstructural members are damaged but no hazards present in both structural and nonstructural members. It is also practical to rate the building "INSPECTED" by removing falling hazards by inspectors themselves or asking users to remove hazardous objects when the damage is localized and hazards can be easily removed.

5) Overall Rating:

The inspection procedure is designed to reach the final overall rating following a simple rule. The summarized results should be properly informed to users or occupants, and recommend them necessary actions such as evacuation, removal of falling hazards etc. It is also favorable to post the final results on each building, perhaps with colored placards (UNSAFE : RED / LIMITED ENTRY : YELLOW / INSPECTED : GREEN) such that all occupants, users and the general public can be easily aware of the results.

QUICK INSPECTION OF DAMAGED BUILDINGS (REINFORCED CONCRETE STRUCTURES)

STEP 0 ID Code : _____ Number of Inspections : _____
 Time and Date of Inspection : _____ : _____, 1999 / Mon. _____ / Day _____
 Name of Inspector(s) (Affiliation / ID Number)
 _____ (_____ / _____)
 _____ (_____ / _____)

DESCRIPTION OF INSPECTED BUILDING

1. Address : _____
 2. Contact Person: _____ TEL: _____
 3. Building Use : 1. Apartment House, 2. Individual House, 3. Residence with Commercial Use,
 4. Office, 5. Others (_____)
 4. Type of : [] Hollow Brick [] Solid Brick [] RC wall
 Partitioning Walls [] Other (_____)
 5. Number of Stories: Basement _____ + Ground Story _____ + Upper Stories _____

STEP 5 **SUMMARY** (Complete the sheet on the following pages and then summarize results below.)

OVERALL RATING:

<input type="checkbox"/> INSPECTED	<input type="checkbox"/> LIMITED ENTRY	<input type="checkbox"/> UNSAFE
Original lateral resistance is not significantly degraded, and 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(s) are made. Detailed assessment may be needed.	Emergency retrofit to prevent sudden collapse is needed, but entry and temporary use are not allowed. Detailed assessment needed.

RECOMMENDATIONS:

Shoring / bracing / jacketing needed in the following area(s): _____

 Removal of falling and/or overturning hazard(s) needed in the following area(s): _____

 Barricade / off-limits needed in the following area(s): _____

 Other(s) (area(s): _____): _____

COMMENTS:

INSPECTIONS

STEP 1 Inspection 1. General Inspection of 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 on the first page. (Inspections 2 and 3 can be skipped.)

<input type="checkbox"/> Total or Partial Collapse	<input type="checkbox"/> Extensive Damage to and/or Remarkable Offset of Superstructure from Foundation
<input type="checkbox"/> Remarkable Inclination of Entire Building or Individual Story	<input type="checkbox"/> Other(s) _____

STEP 2 Inspection 2. Hazard from Damage to Adjacent Buildings, Surrounding Ground and Structural Members

	A	B	C
a. Hazard Resulting from Damage to Adjacent Buildings or Surrounding Ground Failure	<input type="checkbox"/> No	<input type="checkbox"/> Uncertain	<input type="checkbox"/> Yes
b. Settlement of Buildings due to Ground Failure	<input type="checkbox"/> <0.2 m	<input type="checkbox"/> 0.2-1.0m	<input type="checkbox"/> >1.0 m
c. Inclination of Buildings due to Differential Settlement	<input type="checkbox"/> < 1/60 rad.	<input type="checkbox"/> 1/60-1/30 rad. (seemingly inclined)	<input type="checkbox"/> > 1/30 rad. (easily noticeable)
d. Damage to Columns 1. Inspect the most seriously damaged story, sketch building and count damaged columns as indicated at the bottom of this page, and then fill up the following d-1 and d-2. 2. If no serious damage to a column but some to beams and/or beam-column joints is found above or below the column, take it into account of damage to the column.			
d-1. Ratio of Damage IV or V [(1)/(3)x100] _____ %	<input type="checkbox"/> < 1/100 (1 %)	<input type="checkbox"/> 1/100 - 1/10 (1 % - 10 %)	<input type="checkbox"/> > 1/10 (10 %)
d-2. Ratio of Damage III [(2)/(3)x100] _____ %	<input type="checkbox"/> < 1/8 (12.5 %)	<input type="checkbox"/> 1/8 - 1/4 (12.5% - 25%)	<input type="checkbox"/> > 1/4 (25 %)

Structural Safety Judgement from a. to d.	<input type="checkbox"/> INSPECTED* (only A)	<input type="checkbox"/> LIMITED ENTRY (B ≥ 1 but C = 0)	<input type="checkbox"/> UNSAFE (C ≥ 1 or B ≥ 2)
---	--	--	--

*** Either Interior Inspection or Interview needed as a general rule**

[SKETCH : If a column shape is rectangular, sketch as such.]	Inspected story : _____
	(1) Number of damage rank IV or V _____
	(2) Number of damage rank III _____
	(3) Number of inspected columns _____
	(4) Number of total columns _____
	(5) Inspected Ratio of columns [(3)/(4) x 100] _____ %
1. Sketch building configuration and column location of the	

STEP 3

**inspected story in the left box.
2. Find out columns with damage rank \geq III and indicate them.**

Inspection 3. Falling and/or Overturning Hazards

	A	B	C
e. Framed Nonstructural Wall [] Hollow Brick [] Solid Brick [] Concrete Block	[] No or slight damage	[] Cracks observed but no out-of-plane deformation	[] Extensive cracks penetrated, offset from boundary members or out-of-plane deformation
f. Unframed Nonstructural Wall [] Hollow Brick [] Solid Brick [] Concrete Block	[] No damage	[] Slight damage	[] Diagonal cracks observed
g. Wooden Roof	[] No damage [] Unknown	[] Some damage observed but no falling hazards present	[] Noticeable inclination, deformation or separation from top story
h. Stairways [] Interior [] Exterior	[] No or slight damage [] Unknown	[] Extensive cracks observed but stair rebars are anchored	[] Noticeable inclination / separation from connected members and rebar anchorage missing or uncertain
i. Window Frame and Windowpane	[] No or slight damage	[] Visible deformation and/or cracks	[] Likely to fall down
j. Finishings [] Plaster [] Mortar	[] No damage	[] Partial crack or separation	[] Remarkable crack and/or separation
k. Elevated Water Tank, Chimney, Signboard, Machinery etc.	[] No inclination [] Unknown	[] Slight inclination	[] Likely to fall down
l. Other Hazard(s) (_____)	[] No damage	[] Damage observed	[] Life-threatening

STEP 4

Nonstructural Safety Judgement from e. to l.	[] INSPECTED* (Only A and/or B)	[] LIMITED ENTRY (C \geq 1)
--	-------------------------------------	-----------------------------------

*** Either Interior Inspection or Interview needed as a general rule**

SUB-SUMMARY on Inspections 2 and 3

Inspected Areas	[] Exterior only	[] Exterior & Interior(or Interview)
-----------------	-------------------	---------------------------------------

1. Check one in Inspections 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 (Nonstructural Safety)	[]	[]	---
OVERALL RATING <i>Check the highest rating among Inspections above.</i>	[]*	[]	[]

*** Either Interior Inspection or Interview is needed as a general rule.**

2. Following the above results, fill up SUMMARY on the first page. If B or C Rank for falling and/or overturning hazards (questions e. through l.) exists, describe your recommendations and comments in SUMMARY on the first page.

3.2 Quick Inspection Procedure

3.2.1 STEP 0: General Information about Inspection and Building Inspected

- 1) Describe inspection date, inspectors' names, address etc. It is anticipated that the quick inspection proposed herein would be performed under the direction of the central or local government. Building ID should be coded or numbered in accordance with the government's direction.
- 2) Include clear information to identify the inspected building since re-inspection due to mistakes to correct, newly found damage, newly caused damage by aftershock, temporary retrofit or repair, or detailed damage assessment of the inspected building may be needed later.

3.2.2 STEP 1: General Inspection of Entire Building (Inspection-1)

- 1) Survey the entire building damage from outside. Walk around the building if possible.
- 2) If the inspected building is obviously unsafe due to damage to the building itself, check corresponding reason(s), and identify the building "UNSAFE". Do not enter the obviously unsafe building.
- 3) If the building is obviously unsafe and rated "UNSAFE", skip the following inspections, return to the SUMMARY on the first page of the sheet, and check "UNSAFE".

3.2.3 STEP 2: Hazard from Damage to Adjacent Buildings, Surrounding Ground and Structural Members (Inspection-2)

- 1) When some damage around or to the building is found, check as such in questions a. through c. Ordinarily noticeable inclination may be larger than 2 degrees (1/30 rad.) and rank C would be appropriate, while unnoticeable inclination may be smaller than 1 degree (1/60 rad.) and rank A would be appropriate. If the building is seemingly inclined but the degree is uncertain, inclination measurement is recommended. Inclination can be easily noticed with a pendant-type measurement as shown below.



note: If the string is adjusted 60 cm long, inclination can be easily measured by the distance from the column surface to the string. (e.g. 1 cm : 1/60 rad. and 2 cm : 1/30 rad.)

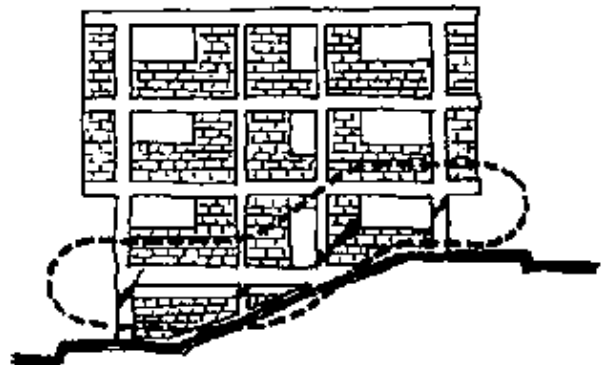
- 2) Identify the most seriously damaged story and inspect column damage in the story. Note that it is essential to identify structural and nonstructural members to assess structural safety. Column surface is often flush with nonstructural (ordinarily brick) walls but vertically or horizontally continuous cracks can be a sign of border between structural and nonstructural members.



Cracks along interface between structural members (column and beam) and nonstructural wall are clearly observed.

- 3) Sketch the building configuration and column location of the inspected story, find out columns with damage rank \geq III and then identify them on the sketch. If no serious damage to a column but some to beams and/or beam-column joints is found above or below the column, take it into account assuming them as damage to the column. Definitions of damage rank and examples will appear in Chapter 4. Note that this inspection sheet is designed to rate the building damage based on damage III, IV, and V, it is significantly time-saving only to identify columns with damage rank \geq III.

- 4) It is often found that a building is located on the slope and damage to columns in two adjacent stories is observed. In such a case, it may be a solution to allow for both stories and to take heavier damage into account as shown below.



- 5) Count the number of columns having damage rank III, IV, or V as indicated on the right-hand side of the sketch area and calculate the damage ratio as indicated in questions d-1 and d-2.
- 6) Judge the structural safety as defined in the sheet. It should be noted that interior inspection may lead to newly found damage, and either interior inspections or interview to occupants/users is strongly recommended if the building is rated “INSPECTED”.

3.2.4 STEP 3: Falling and/or Overturning Hazards (Inspection-3)

- 1) Check the falling and/or overturning hazards to occupants, users and the general public. Note that inspections should be made on objects *likely to fall down or overturn*, neither on *fallen down nor overturned* objects.
- 2) Judge the nonstructural safety as defined in the sheet. Hazards to the general public as well as building users and occupants should be carefully considered. It should be noted again that interior inspection may lead to newly found damage, and either interior inspections or interview to occupants/users is strongly recommended if the building is rated “INSPECTED”.

3.2.5 STEP 4: Sub-summary on Inspections 2 and 3

- 1) Indicate the inspected area. As described above, either interior inspection or interview to occupants/users is strongly recommended if the building is rated “INSPECTED”.
- 2) Check one in Inspections 2 and 3, and then choose the highest rating among them as the OVERALL RATING.

3.2.6 STEP 5: Summary of Inspections

- 1) Following the above results, fill up SUMMARY on the first page of the sheet and categorize the building into one of the following three classifications.

UNSAFE: Remarkable danger to aftershocks exists. Emergency retrofit to prevent sudden collapse is needed but entry and temporary use are not allowed.

LIMITED ENTRY: Damage to structural and/or nonstructural members is found. Temporary use is not allowed unless temporary retrofit to prevent damage progress, repair to remove life-threatening hazards and/or barricades around hazard striking area(s) are made. Entry only for emergency purpose is allowed at own risk.

INSPECTED: No or few apparent structural damage is found but no hazard is believed to be present, although some repairs may be needed. Original lateral resistance is not significantly degraded and temporary use or occupancy is allowed.

- 2) If B or C rank for falling and/or overturning hazards exists in questions e. through l., describe the inspector’s recommendations and comments in SUMMARY. It is also informative for future detailed investigations to provide comments on corrosion of re-bars, material deterioration etc. if they are found.
- 3) Inform the final results to building users and/or occupants, preferably to post them on each building with colored placards (UNSAFE : RED / LIMITED ENTRY : YELLOW / INSPECTED : GREEN) such that all occupants, users and the general public can be easily aware of the results. Note that the results above do not mean the safety for long-term use. For example, old buildings may need structural retrofit, even if they are posted “GREEN”, because their seismic capacities are ordinarily less than required in the up-to-date code.

4. DEFINITIONS OF DAMAGE RANK

4.1 Damage Rank of Structural Members

4.1.1 General Definition of Damage Rank and Damage State of Structural Members

Damaged structural members are divided into five damage levels; damage rank 0 to V. Definition of the damage rank is as follows. In the inspection of damaged building procedure, it is important that the damaged structural members should be provided into three categories, such as 1) Rank II and under, 2) Rank III, and 3) Rank IV and over.

Rank 0: No Damage

Rank I: Slight Damage

Visible narrow shear cracks on surface of concrete
(Average crack width is less than 0.2 mm)

Rank II: Light Damage

Visible clear shear cracks on surface of concrete
(Average crack width is around 0.2~1.0 mm)

Rank III: Medium Damage

Wide cracks (Average crack width is around 1.0~2.0 mm)

Local crush of cover concrete and small exposure of reinforcing bars may be observed.

Rank IV: Heavy Damage

Big cracks (Average crack width is more than 2.0 mm)

Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed.

But buckling of the reinforcing bars is not observed.

Rank V: Collapse

Buckling and/or breaking of reinforcing bars

Crush of core concrete

Visible settlement and/or inclination of floor

Order of the width of cracks in this definition is as follows, Visibly narrow crack < Visibly clear crack < Wide crack < Big crack.

The values of crack width in the damage definition are not strict values, the values are reference values.

If flexural cracks (Fig.4.1.1.1) are visibly narrow and visibly clear, the cracks are negligible in the damage rank evaluation.

If the spalling of cover concrete at the corner of structural member cross section is small, the exposure length of reinforcing bars is less than 20cm, the defect is negligible in the damage rank evaluation. (Fig.4.1.1.2)

If the length of longitudinal cracks along the structural member is less than 20cm, the cracks are negligible in the damage rank evaluation. (Fig.4.1.1.2)

The structural members are usually covered by mortar and/or finishings. If the damages of structural members are not visible because of mortar and/or finishings, take away the mortar and/or finishings and observe the damage, or evaluate the damage rank by the damage of the mortar and /or finishings

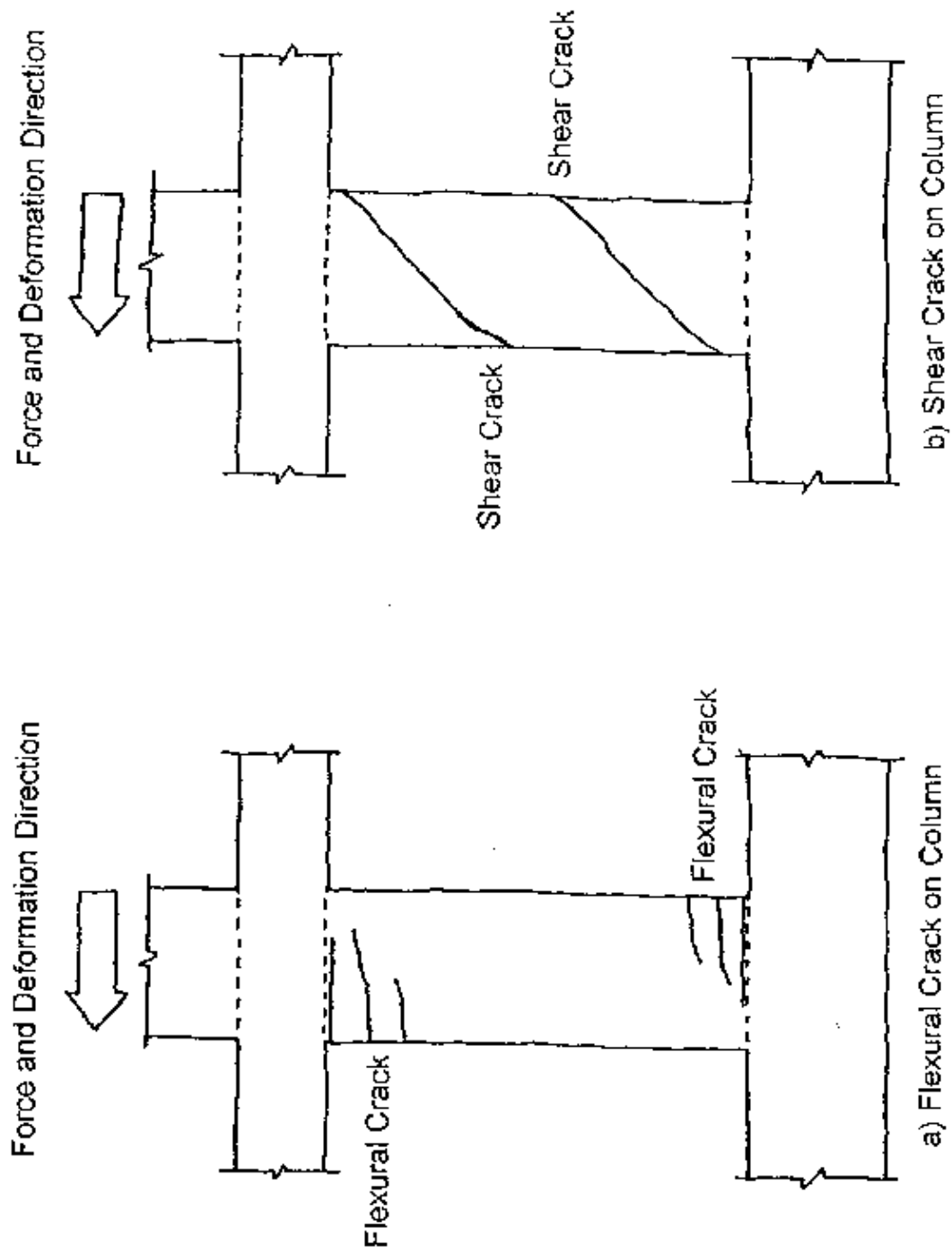


Fig 4 1 1.1 Typical Flexural Crack and Shear Crack observed on Columns

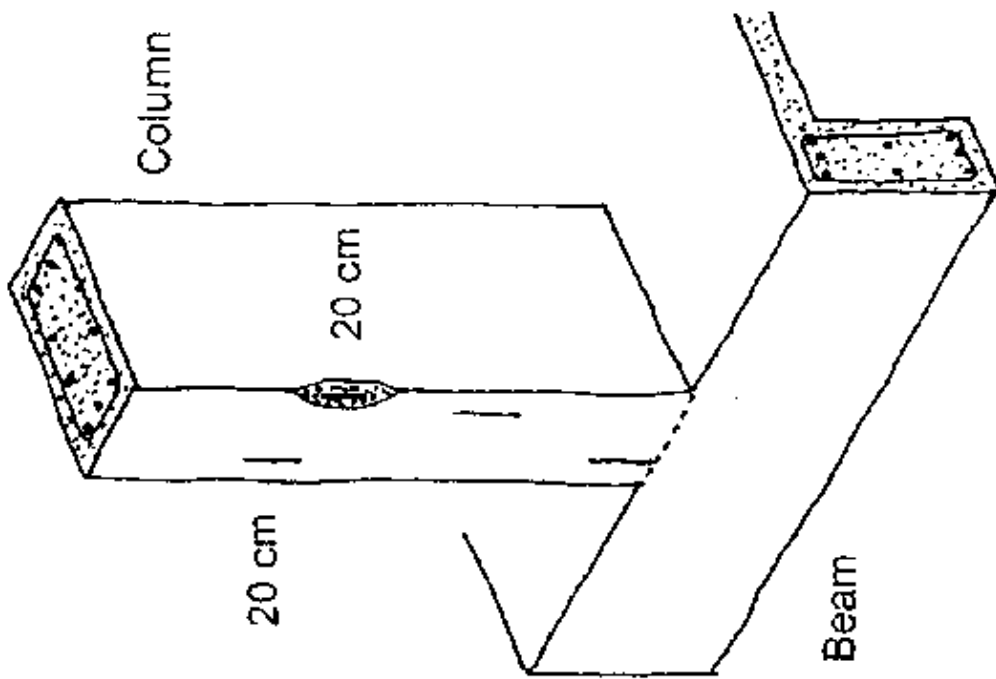


Fig.4.1.1.2 Negligible Cracks and Spalling of Concrete in Damage Rank Evaluation

4.1.2 Detailed Definition of Damage Rank

Damage Rank	Column (Fig.4.1.2.1) Column width > 40cm	Column (Fig.4.1.2.2) Column width < 40cm	Beam-Column Joint (Fig.4.1.2.3)	Beam (Fig.4.1.2.4)
Rank I Slight	Visibly narrow shear cracks (Crack width<0.2mm)	No shear cracks	No shear cracks	Visibly narrow shear cracks (Crack width<0.2mm)
Rank II Light	Visibly clear shear cracks (0.2<Crack width<1mm)	Visibly narrow shear cracks (Crack width<0.2 mm)	No shear cracks Spalling of column corner concrete	Visibly clear shear cracks (0.2<Crack width<1mm)
Rank III Medium	Wide cracks (1<Crack width<2mm) Local crush of cover concrete and small exposure of reinforcing bars may be observed.	Visibly clear and/or Wide shear cracks (0.2<Crack width<2mm)	No shear cracks Spalling of cover concrete of joint	Wide or big shear cracks (1<Crack width<5mm) Local crush of core concrete and small exposure of reinforcing bars may be observed.
Rank IV Heavy	Big cracks (Crack width>2mm) Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed. But buckling of the reinforcing bars is not observed.	Big cracks (Crack width>2mm) Spalling of cover concrete Exposure of reinforcing bars without buckling	Diagonal Shear cracks Spalling of cover concrete of joint	Big shear cracks (Crack width>5mm) Extensive Spalling of cover concrete Extensive exposure of reinforcing bars
Rank V Collapse	Buckling and/or breaking of reinforcing bars Crush of core concrete Visible settlement and/or inclination of floor	the same as left	Buckling of reinforcing bars Crush of core concrete Visible vertical deformation of joint	Buckling and/or breaking of reinforcing bars Crush of core concrete Visible settlement and/or inclination of floor

Order of the width of cracks in this definition is as follows, Visibly narrow crack < Visibly clear crack < Wide crack < Big crack

The values of crack width in the damage definition are not strict values, the values are reference values.

If flexural cracks (Fig.4.1.1.1) are visibly narrow or visibly clear, the cracks are negligible.

If the spalling of cover concrete at the corner of structural member cross section is small, the exposure length of reinforcing bars is less than 20cm, the defect is negligible. (Fig.4.1.1.2)

If the length of longitudinal visibly narrow or visibly clear cracks along the structural member is less than 20cm, the cracks are negligible. (Fig.4.1.1.2)

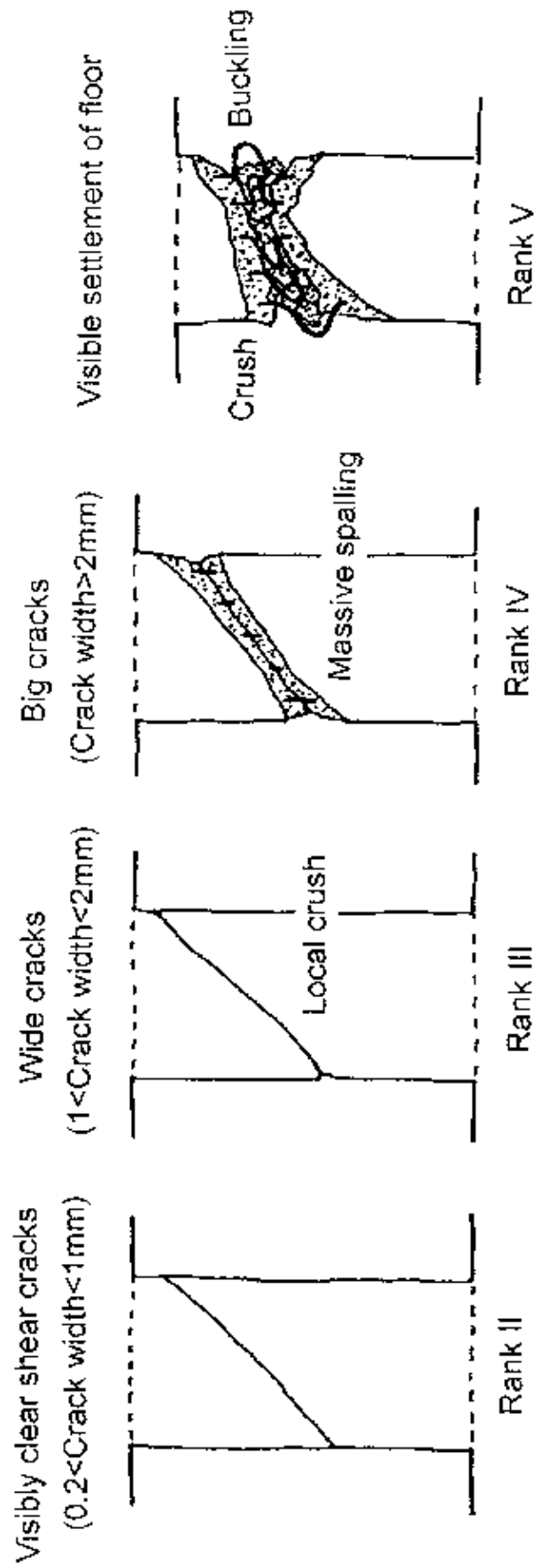


Fig.4.1.2.1 Damage Rank of Columns (Column Width > 40cm)

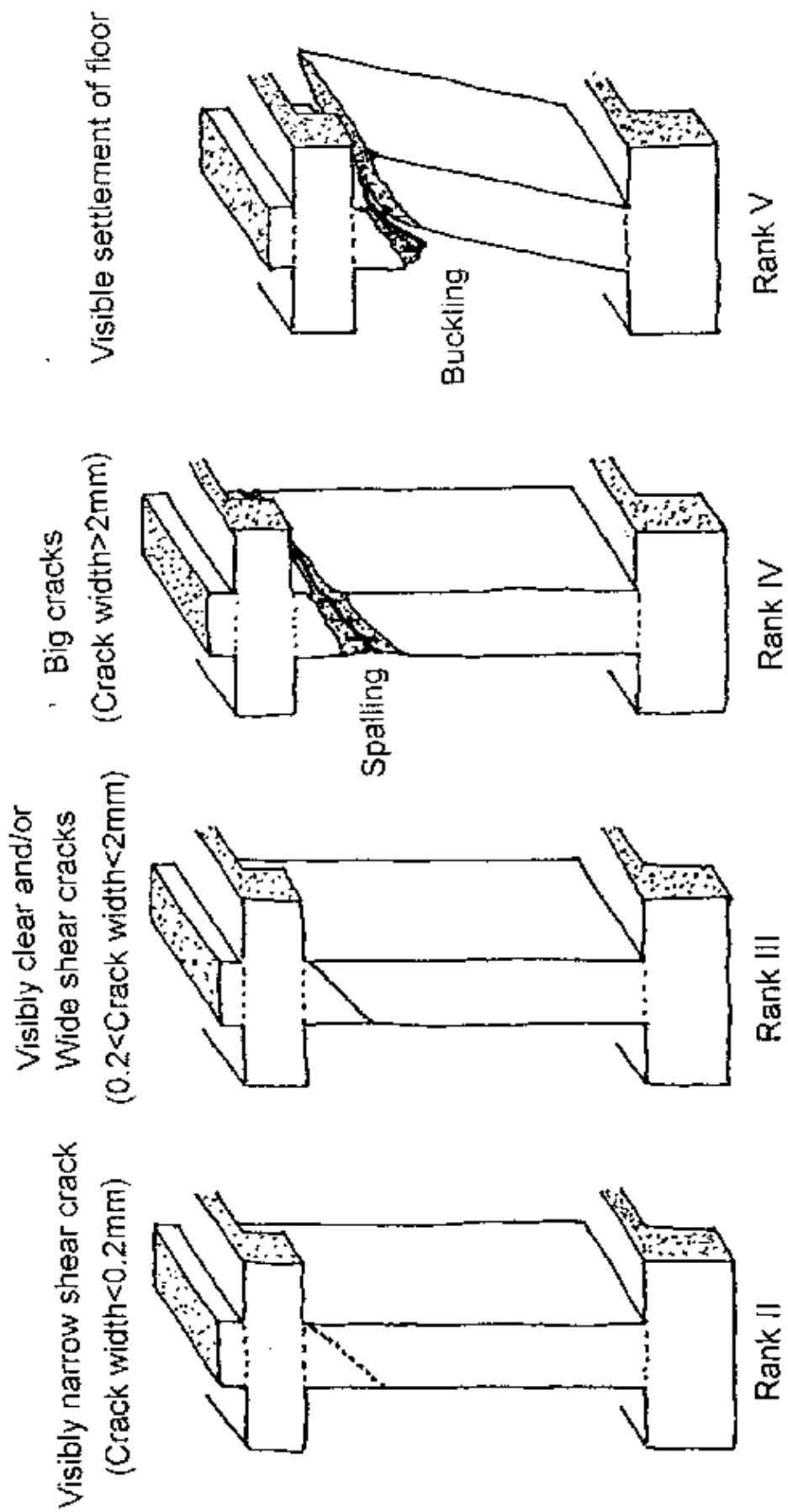


Fig.4.1.2.2 Damage Rank of Columns (Column Width < 40cm)

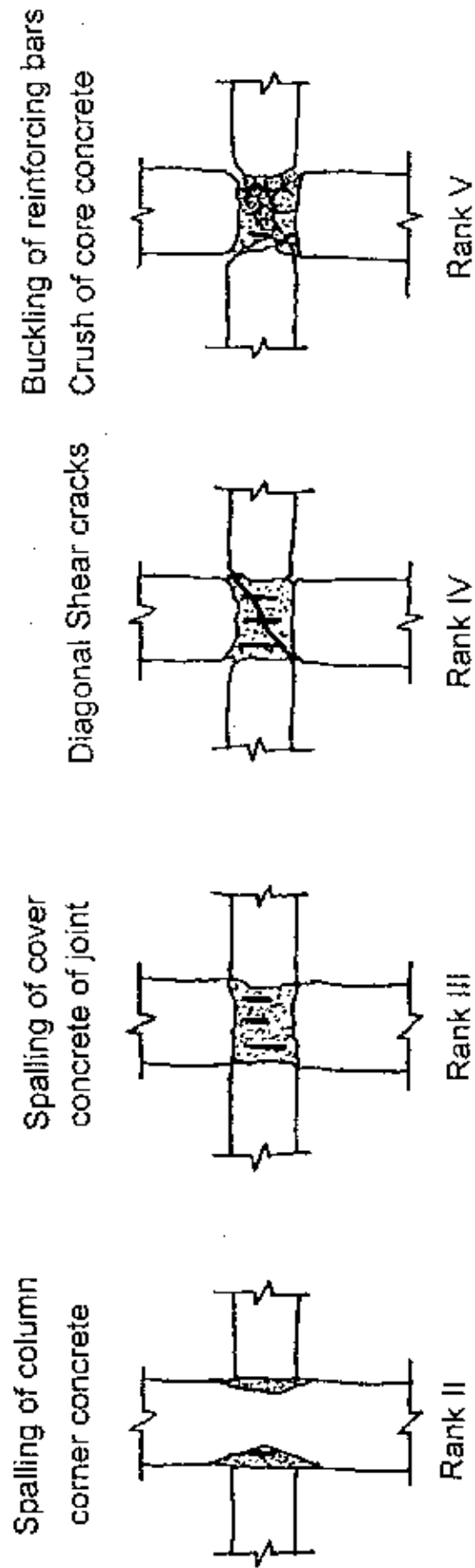


Fig.4.1.2.3 Damage Rank of Beam-Column Joints

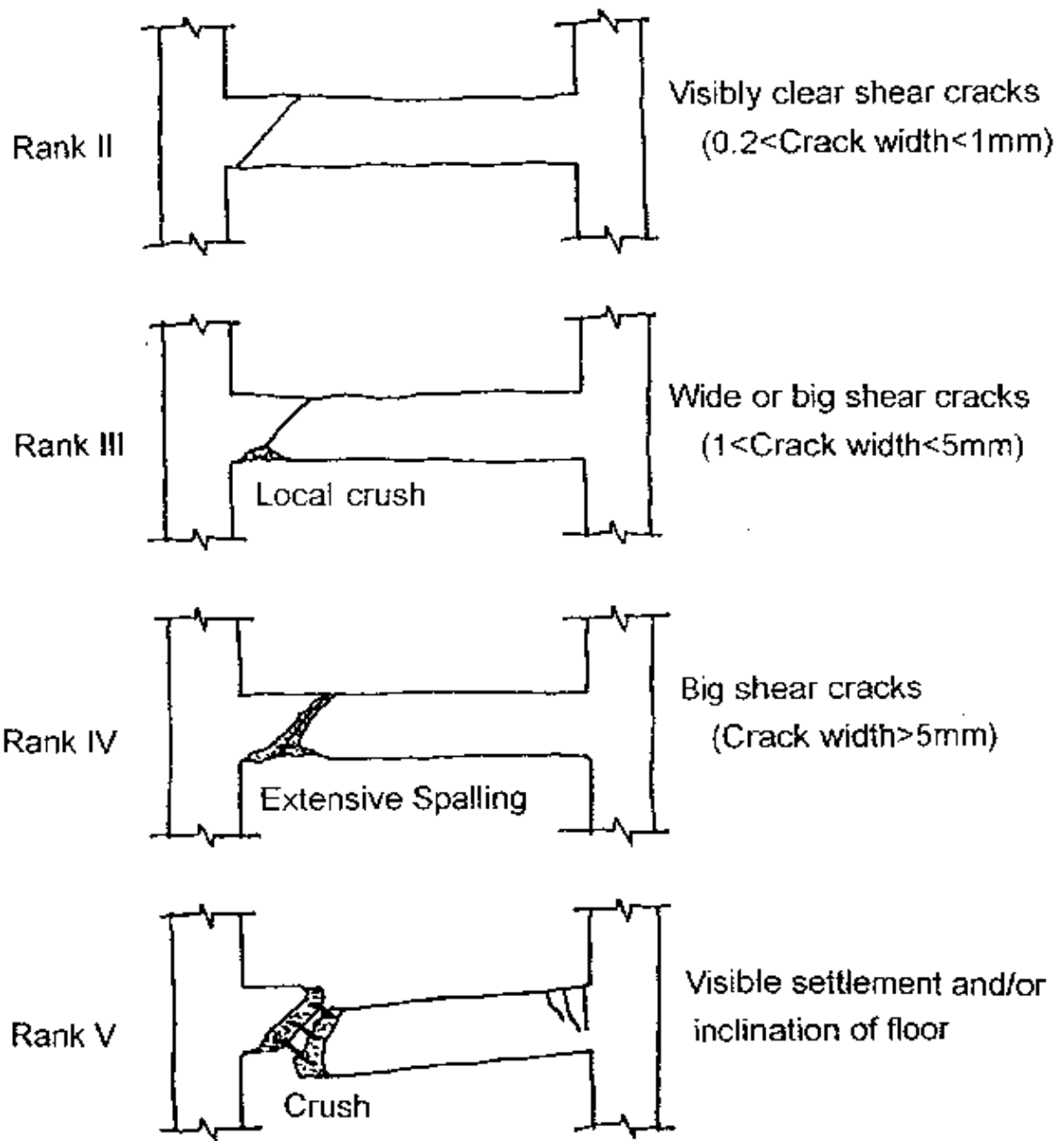


Fig.4.1.2.4 Damage Rank of Beams

4.1.3 Damage Rank Evaluation in Special Cases

Cover concrete at the bottom of columns is easily spalled off, and the damage rank of those columns is sometimes estimated in higher ranks. But there are some cases that the local spalling of the cover concrete should not affect to the structural performance of columns according to the condition of core concrete.

The columns are evaluated in damage rank III in case that the cover concrete of bottom and narrow face of columns is spalled, but there is no crush and no cracks in the core concrete. (Fig.4.1.3.1 a))

But the spalling of cover concrete occurs at the wide face of columns, the damage rank should be IV or V. (Fig.4.1.3.1 b))

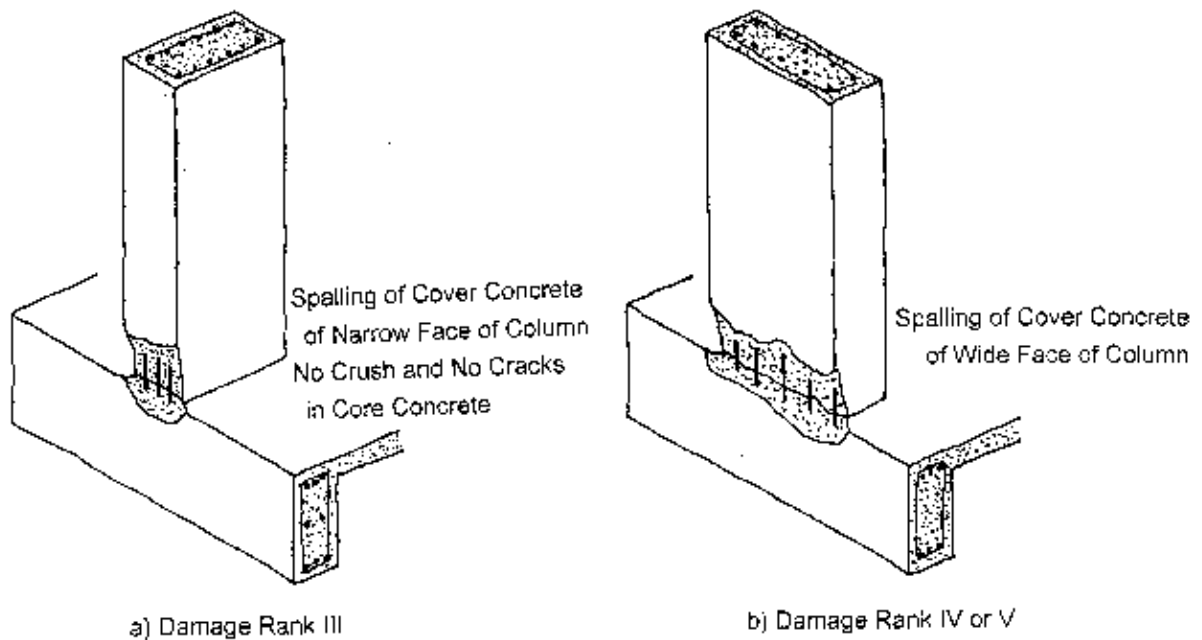


Fig.4.1.3.1 Damage Rank of Columns,
the Cover Concrete is Spalled off Locally at the Bottom of columns