ISSN　1346－7328
国総研資料 第40号
平 成 1 4 年　3 月

国土技術政策総合研究所資料

TECHNICAL NOTE of
National Institute for Land and Infrastructure Management

No. 40　　March 2002

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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国土技術政策総合研究所資料
第 40 号　2002 年 3 月

Technical Note of NILIM
No. 40 March 2002

地震被害を受けた鉄筋コンクリート造建築物の応急危険度判定マニュアル
（1999 年トルコ・コジャエリ地震災害を基に）

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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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概要

現地時間 1999 年 8 月 17 日 3 時 1 分にトルコ西部のイズミット付近でコジャエリ地震が発生した。日本での経験と今回のコジャエリ地震による建築物の被害を基に、日本とトルコの知識・経験の交換、地震被害の現地調査及び検討により、トルコの建築物に適用可能な応急危険度判定マニュアルを開発した。

本資料は、この応急危険度判定手法の考え方及び判定シートとその適用方法を示している。また、現場での応急危険度判定を実施するための部材損傷度の定義と例を示している。

キーワード：応急危険度判定、鉄筋コンクリート造建築物、地震被害、トルコ・コジャエリ地震

Synopsis

An earthquake 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). Based on experiences in Japan and the damage of buildings due to the Kocaeli Earthquake, a quick inspection procedure applicable to buildings in Turkey was developed through field surveys, several discussions and exchange of mutual knowledge.

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

Keywords: Quick Inspection of Damage, Reinforced Concrete Building, Damage due to Earthquake. Kocaeli Earthquake, Turkey

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March, 2002

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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

We would deeply appreciate the diligent contribution of Ms. Pinar Teymur and Mr. Cuneyt Vatansever, graduate course students of Istanbul Technical University, for spending their precious time. They kindly joined damage survey and inspection trials of drafted inspection sheet, although on holiday, and provided a lot of valuable and fresh comments and suggestions without which we could not complete this report. We also extend out sincere appreciation to all who contributed to our activities in Turkey.

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.

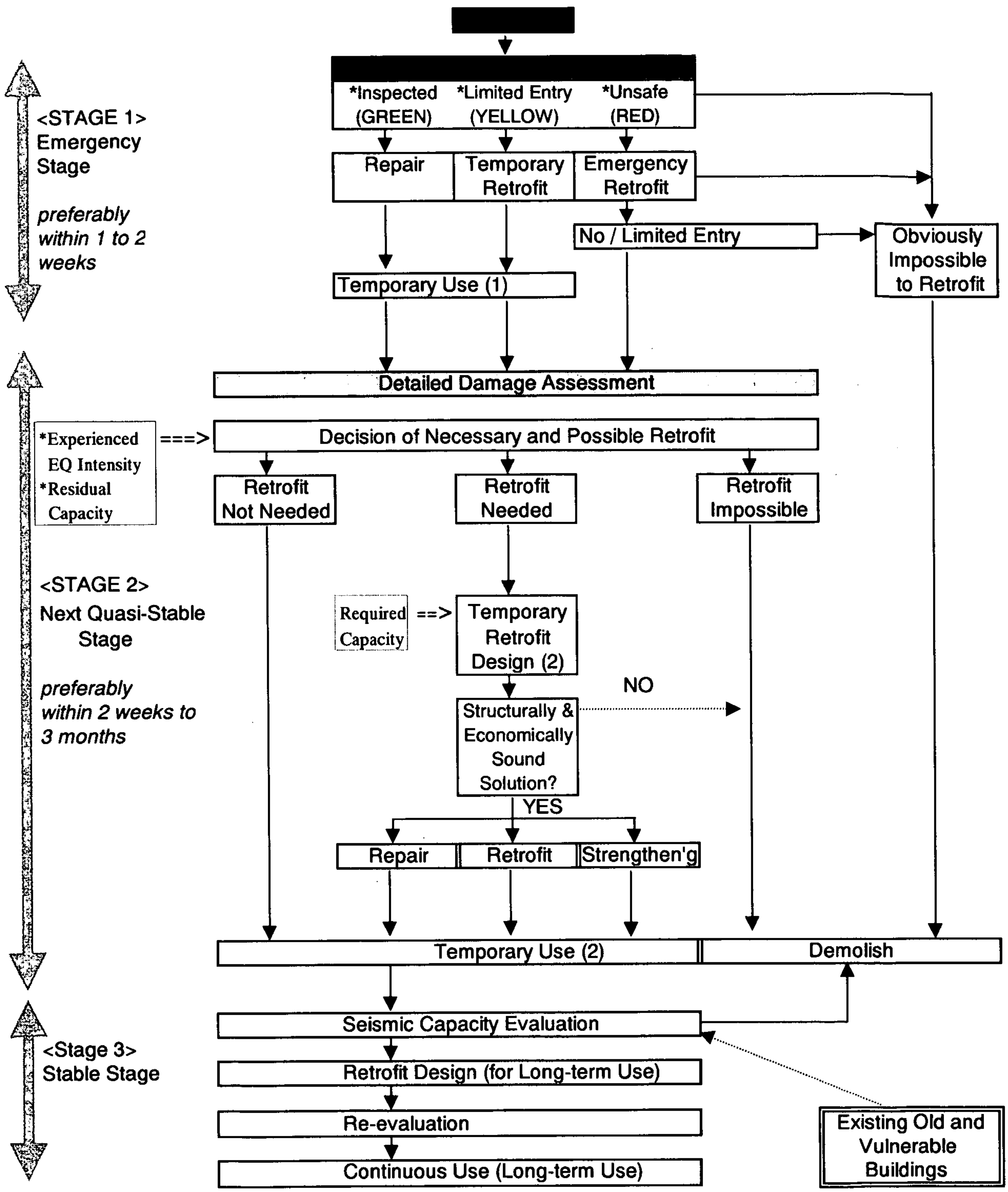


Figure 2.1: General Flow of Reconstruction Strategy

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 Partitioning Walls : [ ] Hollow Brick [ ] Solid Brick [ ] RC wall [ ] 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:

[ ] INSPECTED

Original lateral resistance is not significantly degraded, and temporary use or occupancy is allowed.

[ ] LIMITED ENTRY

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.

[ ] UNSAFE

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.)

[ ] Total or Partial Collapse	[ ] Extensive Damage to and/or Remarkable Offset of Superstructure from Foundation
[ ] Remarkable Inclination of Entire Building or Individual Story	[ ] 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	[ ] No	[ ] Uncertain	[ ] Yes
b. Settlement of Buildings due to Ground Failure	[ ] <0.2 m	[ ] 0.2-1.0m	[ ] >1.0 m
c. Inclination of Buildings due to Differential Settlement	[ ] < 1/60 rad.	[ ] 1/60-1/30 rad. (seemingly inclined)	[ ] > 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] ______ %	[ ] < 1/100 (1 %)	[ ] 1/100 - 1/10 (1 % - 10 %)	[ ] > 1/10 (10 %)
d-2. Ratio of Damage III [(2)/(3)x100] ______ %	[ ] < 1/8 (12.5 %)	[ ] 1/8 - 1/4 (12.5% - 25%)	[ ] > 1/4 (25 %)

Structural Safety Judgement from a. to d.	[ ] INSPECTED* (only A)	[ ] LIMITED ENTRY (B ≥ 1 but C = 0)	[ ] 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 ≥ 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 ≥ 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 *Check the highest rating among Inspections above.*	[ ]*	[ ]	[ ]

**** 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

STEP 0: General Information about Inspection and Building Inspected

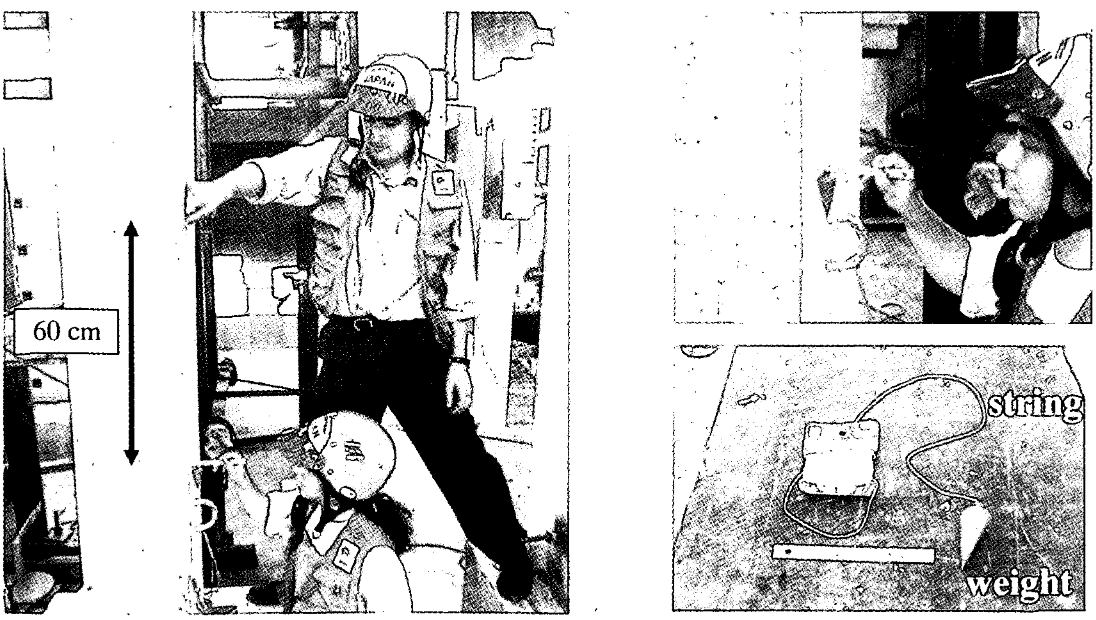
1. Describe inspection date, inspectors' names, address etc. It is anticipated that the quick inspection proposed herein would be performed under the direction of the central or local government. Building ID should be coded or numbered in accordance with the government's direction.
2. Include clear information 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.

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".

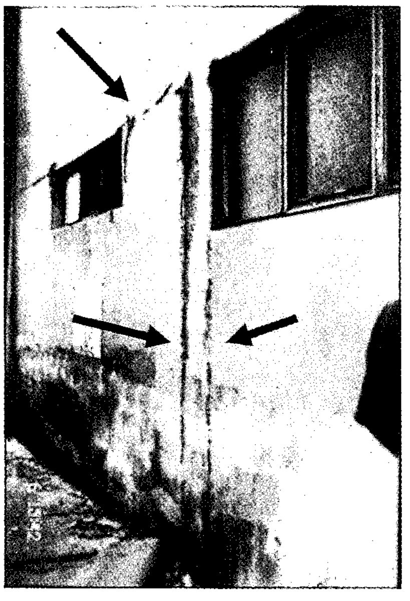
STEP 2: Hazard from Damage to Adjacent Buildings, Surrounding Ground and Structural Members (Inspection-2)

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.



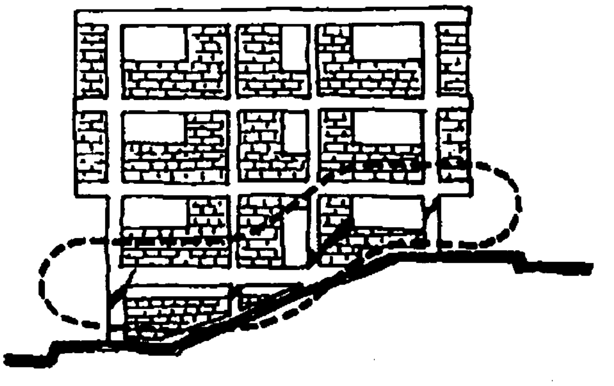
note: If the string is adjusted 60 cm long, inclination can be easily measured by the distance from the column surface to the string. (e.g. 1 cm : 1/60 rad. and 2 cm : 1/30 rad.)

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 ≥ 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 ≥ 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".

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".

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.

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.

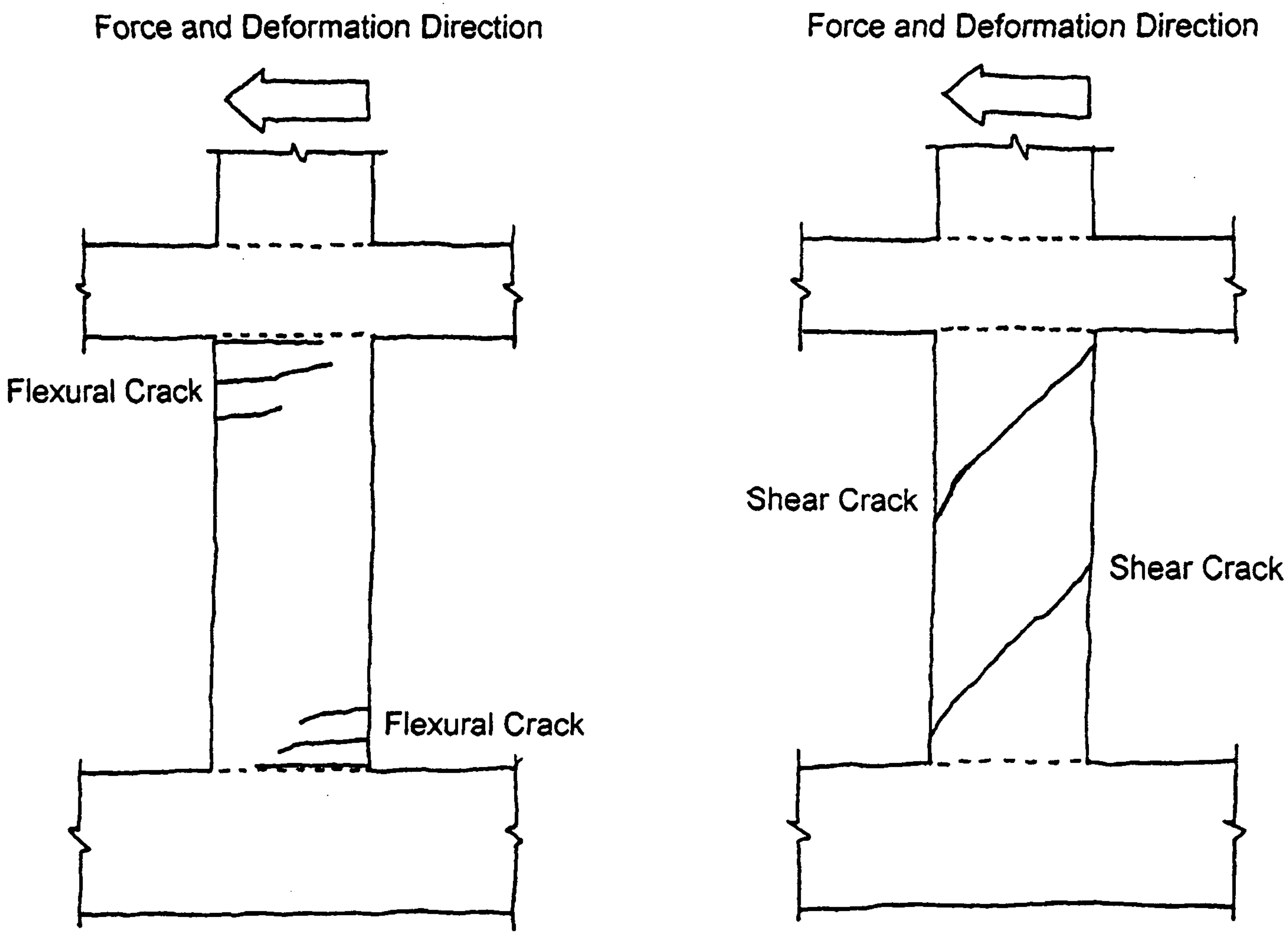
The values of crack width in the damage definition are not strict values, the values are reference values.

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 finisihings and observe the damage, or evaluate the damage rank by the damage of the mortar and /or finishings



a) Flexural Crack on Column

b) Shear Crack on Column

Fig 4.1.1.1 Typical Flexural Crack and Shear Crack observed on Columns

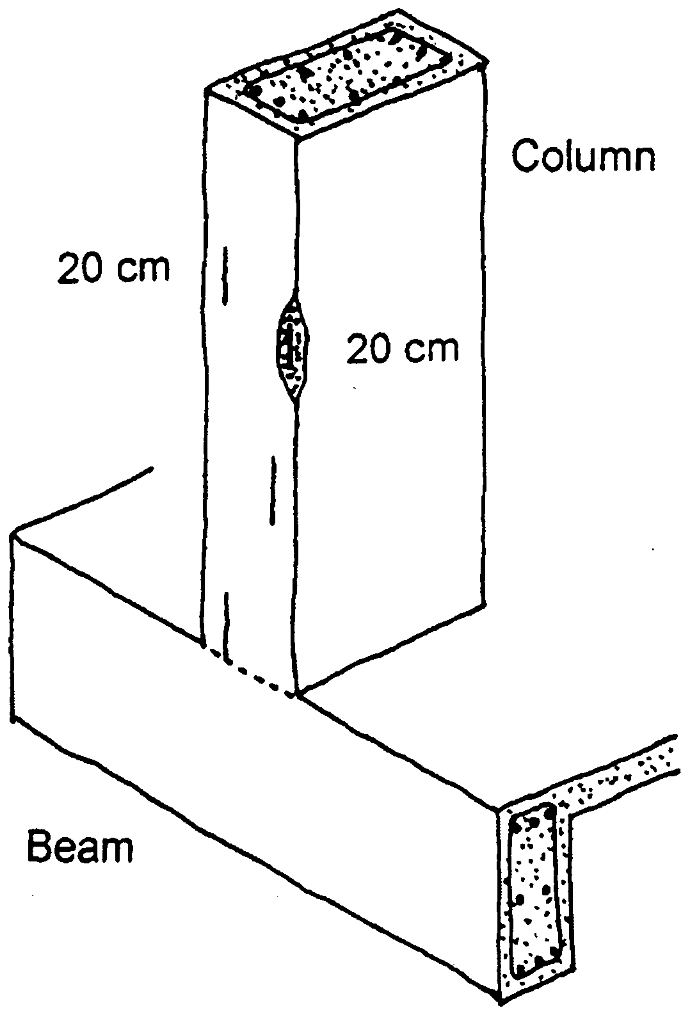


Fig.4.1.1.2 Negligible Cracks and Spalling of Concrete in Damage Rank Evaluation

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)

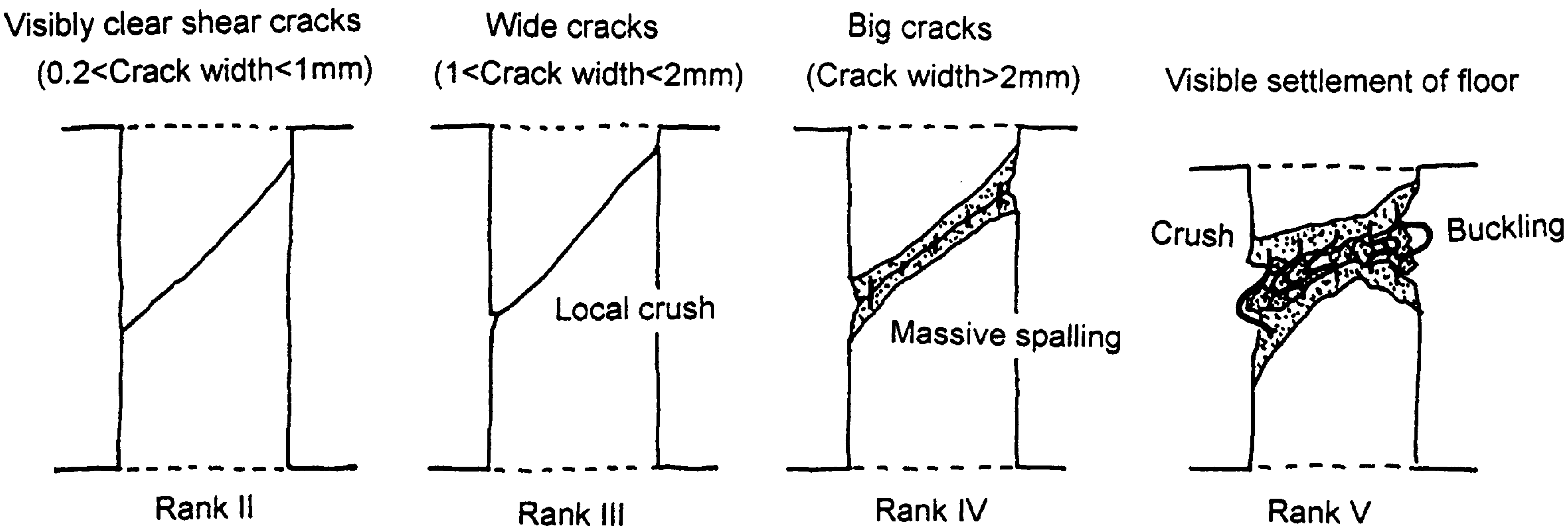


Fig.4.1.2.1 Damage Rank of Columns (Column Width > 40cm)

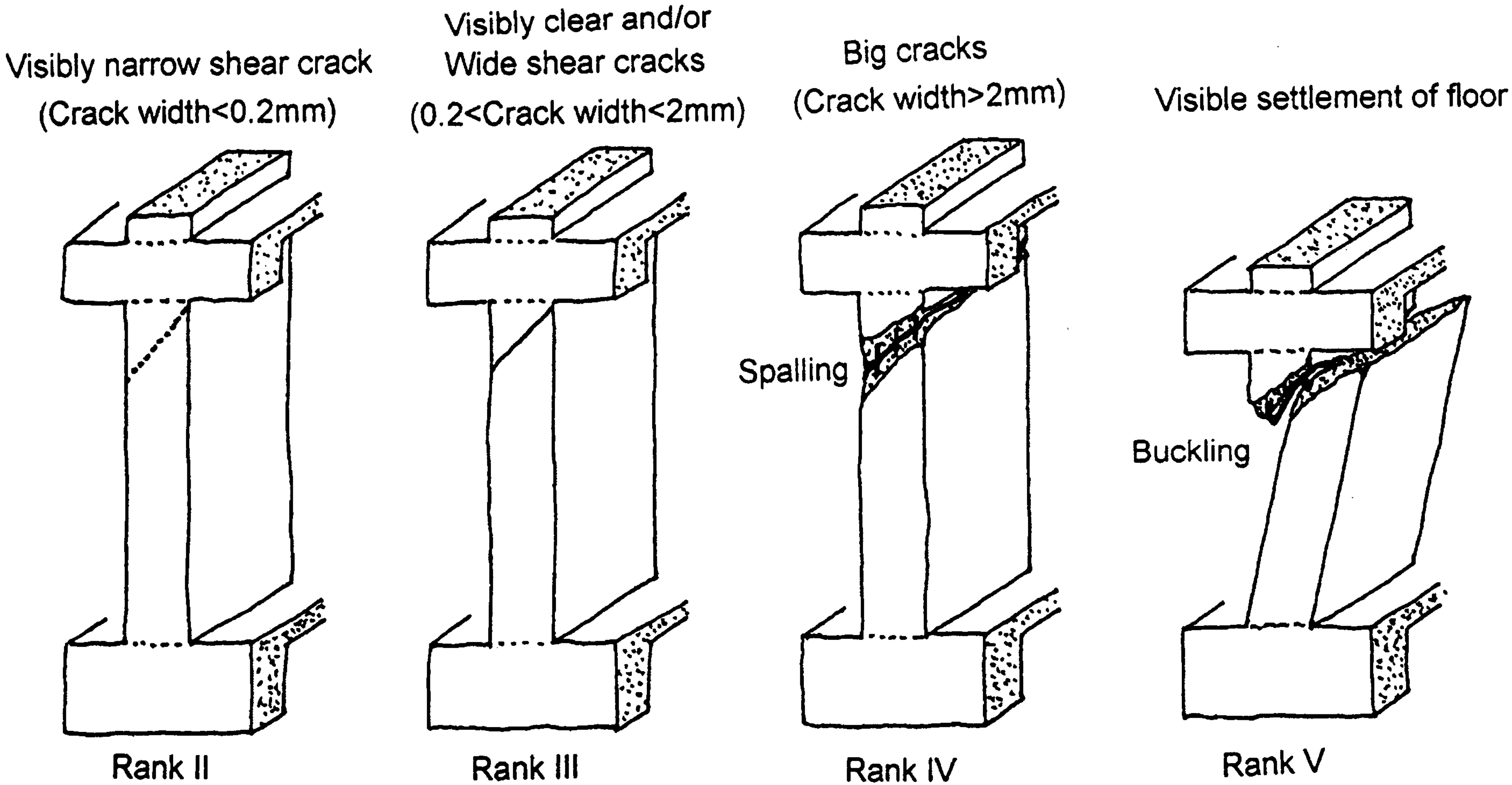


Fig.4.1.2.2 Damage Rank of Columns (Column Width < 40cm)

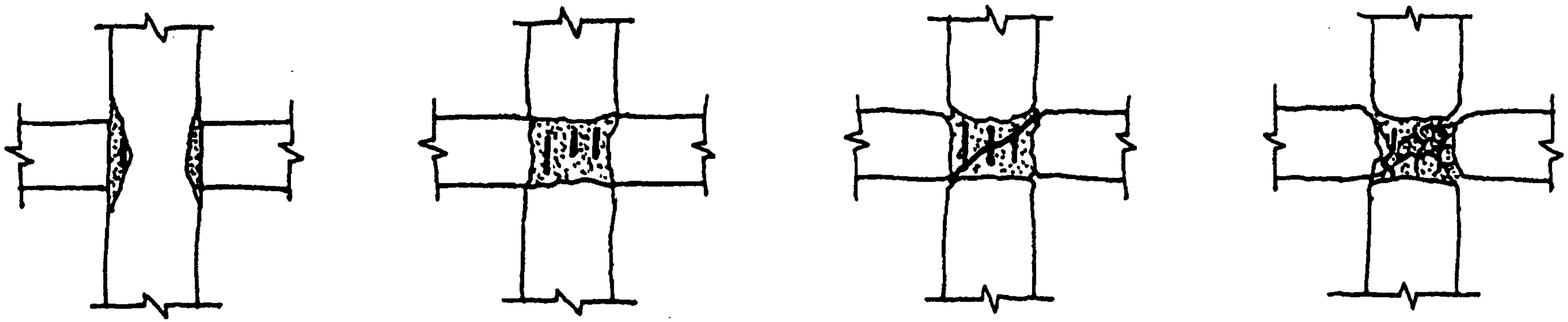


Fig.4.1.2.3 Damage Rank of Beam-Column Joints

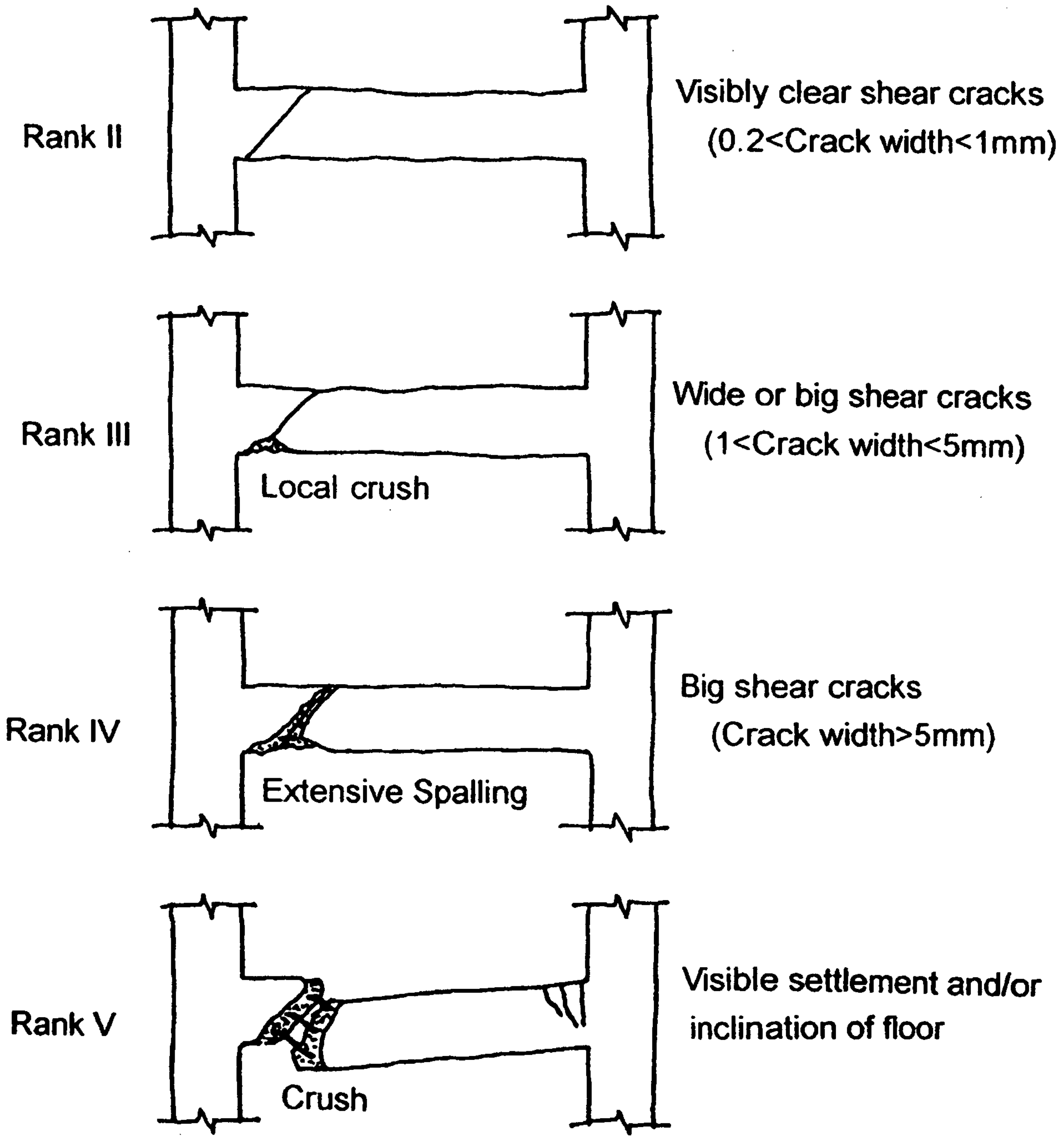


Fig.4.1.2.4 Damage Rank of Beams

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))

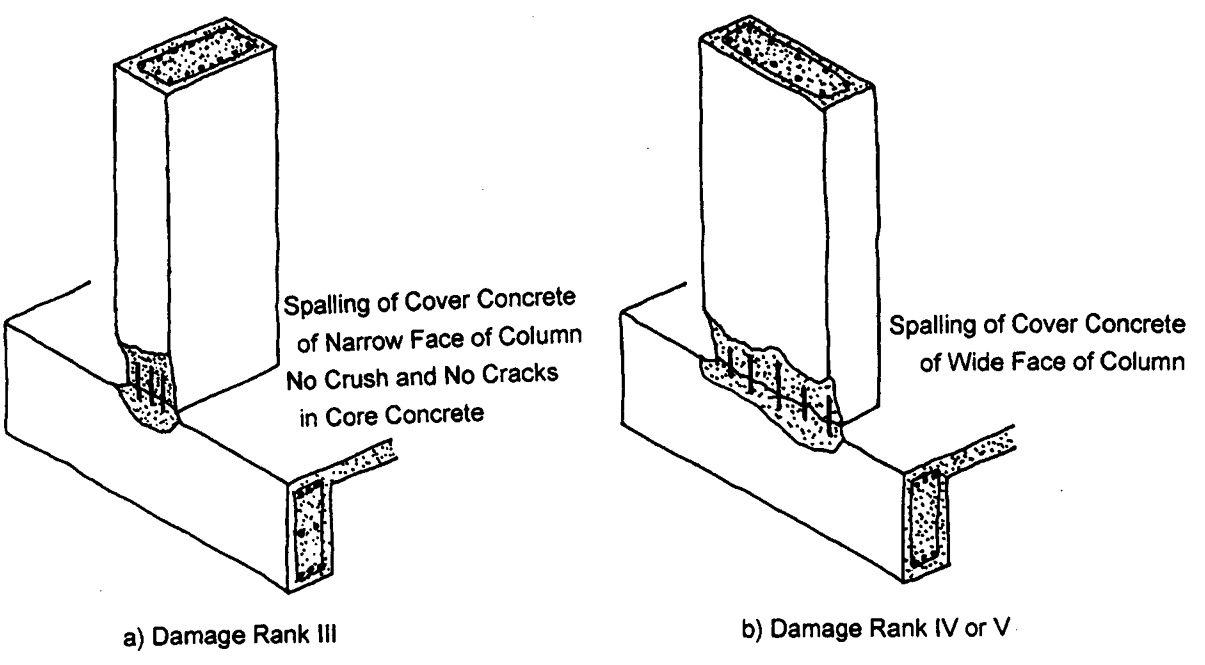


Fig.4.1.3.1 Damage Rank of Columns,
the Cover Concrete is Spalled off Locally at the Bottom of columns

4.1.4 Strength-deflection relationship and damage rank of structural members

Following figures, Fig.4.1.4.1 and 4.1.4.2, show the concept of damage rank and structural performance of structural members.

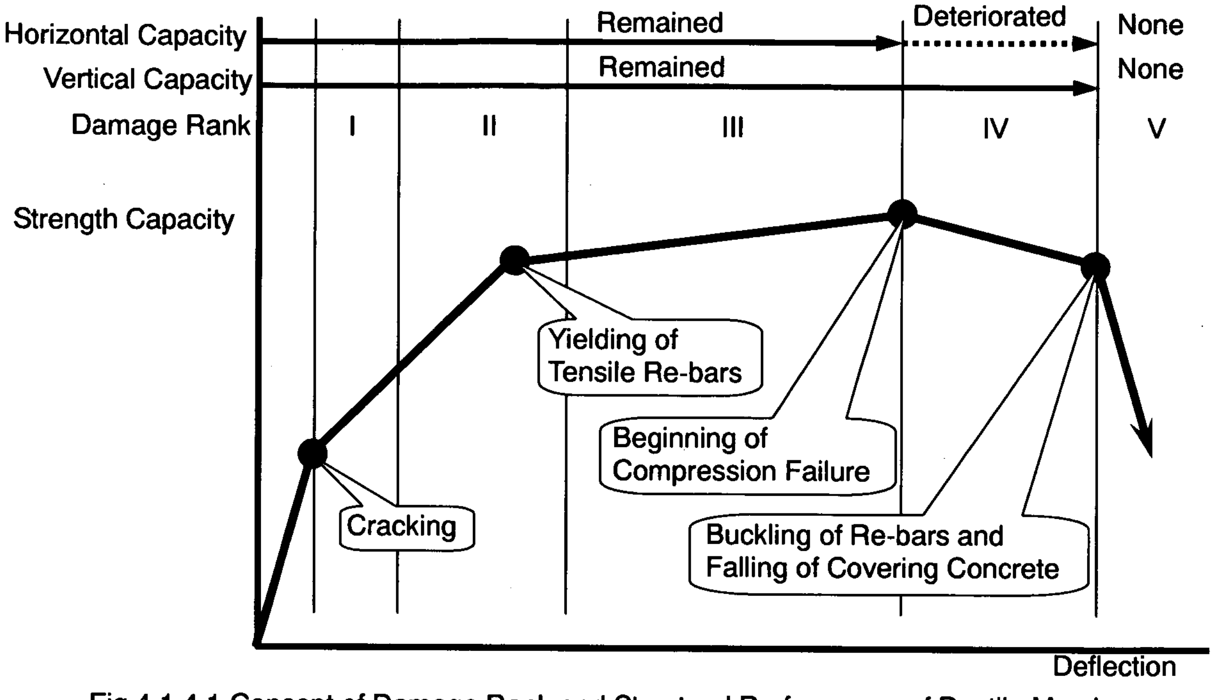


Fig.4.1.4.1 Concept of Damage Rank and Structural Performance of Ductile Members

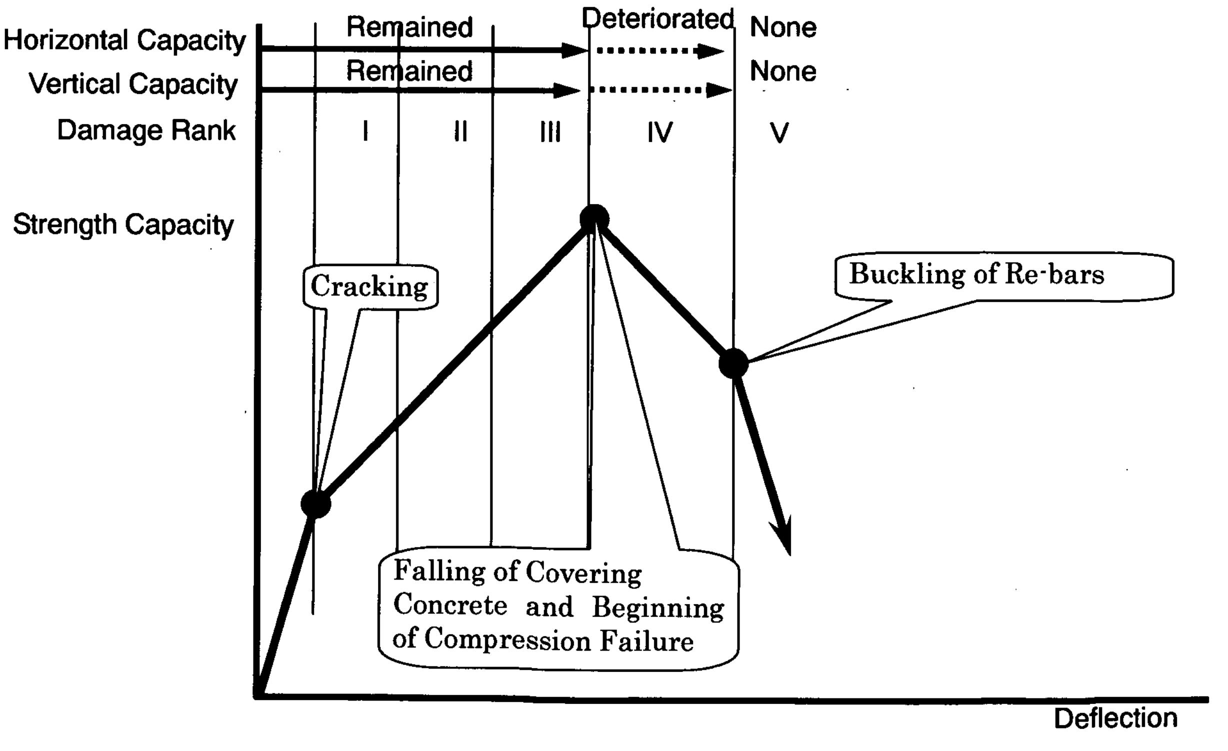


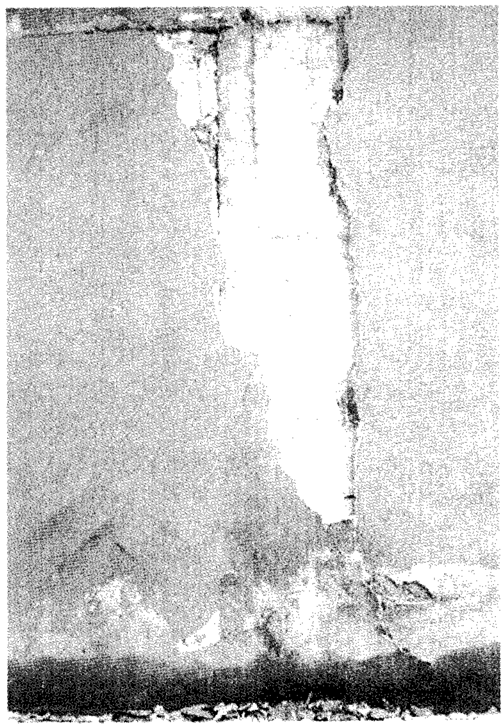
Fig.4.1.4.2 Concept of Damage Rank and Structural Performance of Brittle Members.

4.1.5 Examples of Structural Damage

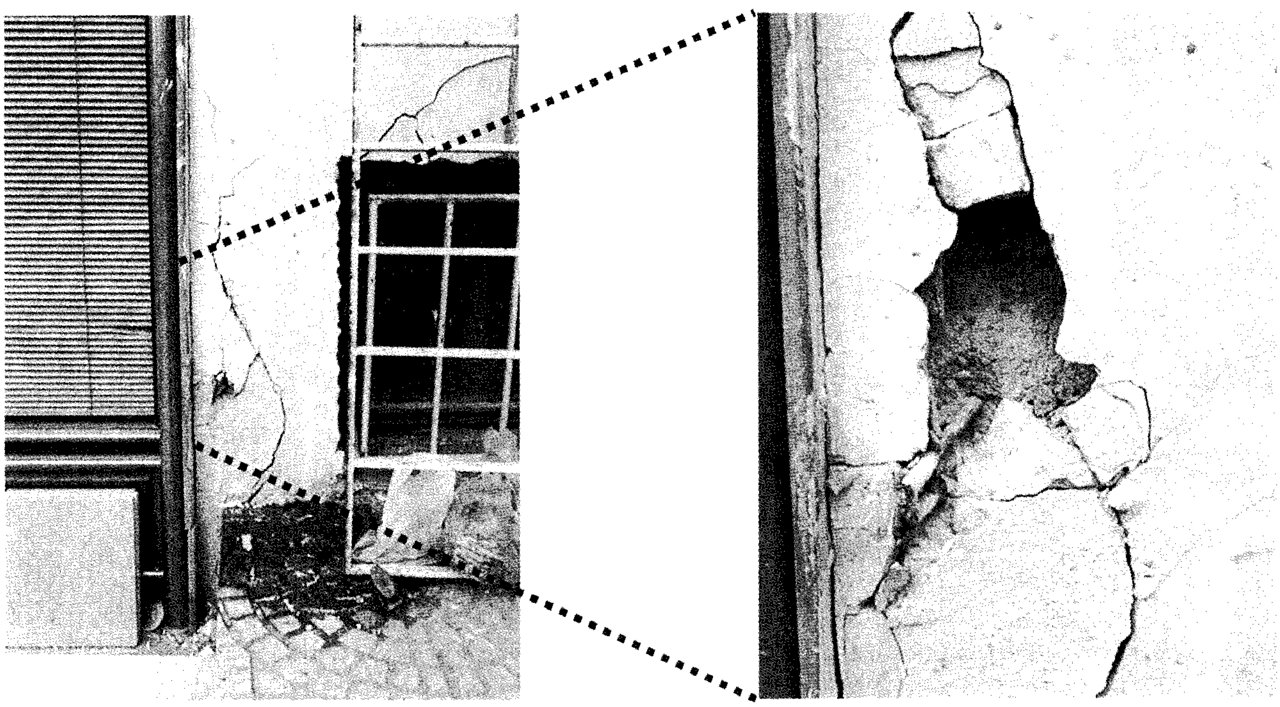
(a) Damage Rank I

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

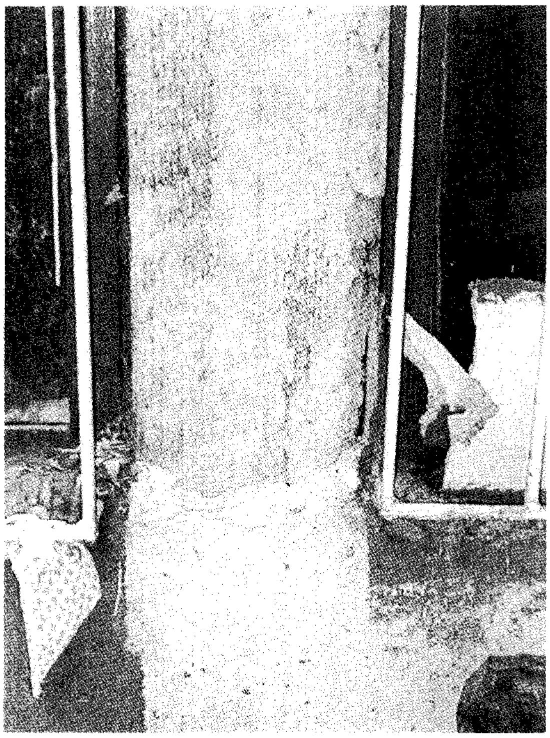
1) Mortar is separated and fallen down, and No shear cracks are observed.



2) Mortar is separated and fallen down, and No shear cracks are observed.



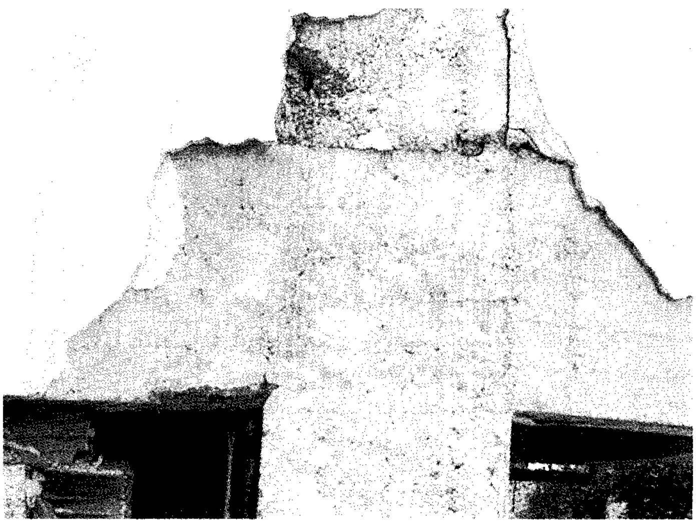
3) Big crack is observed on mortar. But take the mortar away, no crack is observed on the face of concrete. (Right Photo)



4) Corner cover concrete is spalled off.
But shear cracks are not observed.

5) Only flexural cracks occur in beam

6) Corner cover concrete is spalled off.
But shear cracks are not observed.

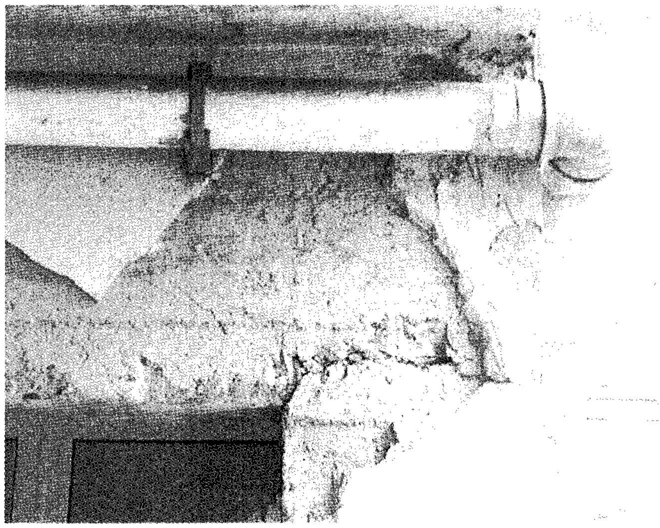


7) Visibly narrow shear crack and flexural crack occur in beam. No shear cracks are observed in the beam-column joint.

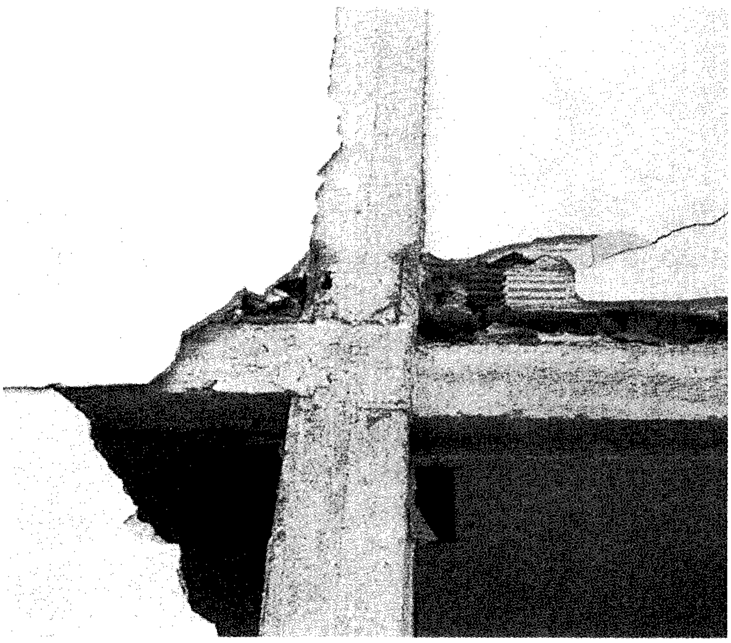
(b) Damage Rank II

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

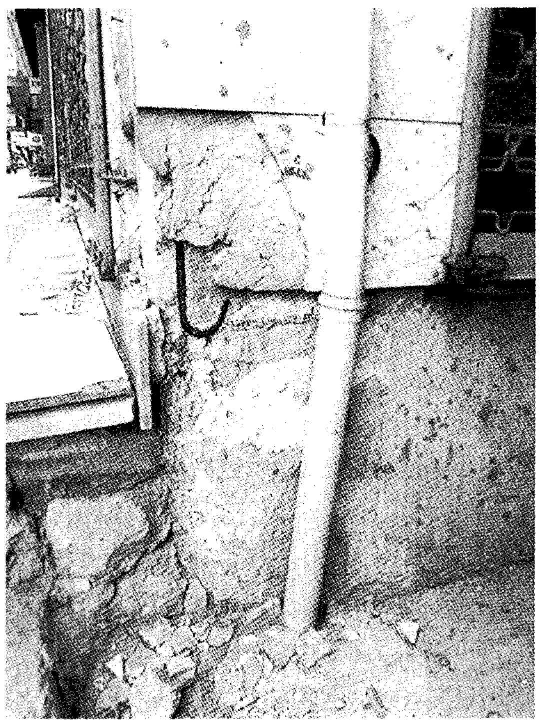
1) Mortar does not fall down, and only small cracks are observed on mortar.



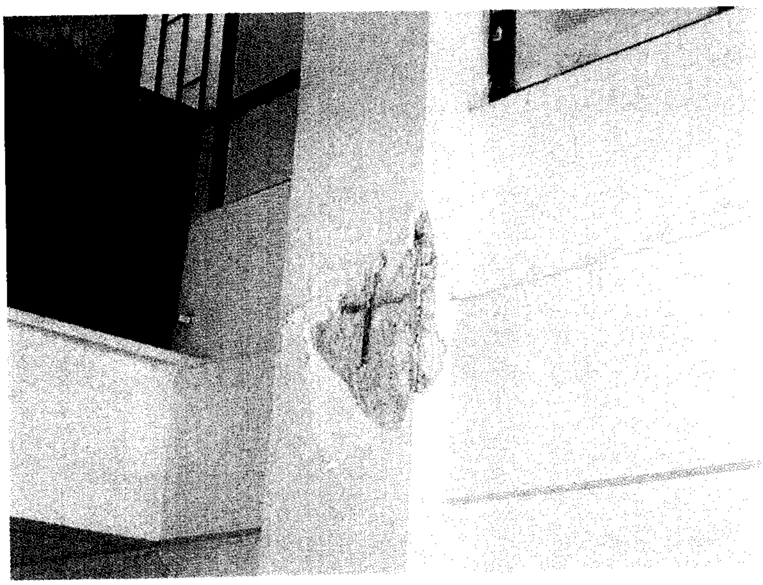
2) Construction joint is observed but negligible. Visible clear shear crack in the beam is observed.



3) Beam has a visible clear crack. (Rank II)
Beam-column joint has no cracks. (Rank I)
Spalling of corner cover concrete of column is negligible.
So, totally the column is Rank II.

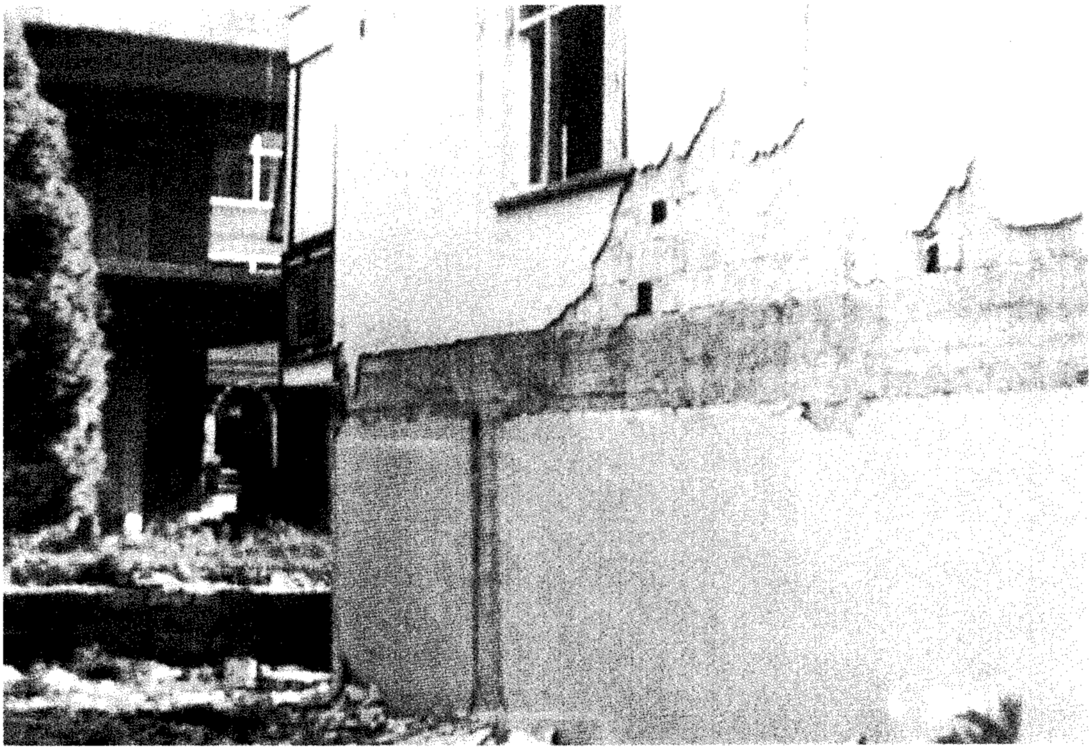


4) Evaluation of damage of this column is difficult. Spalling of cover concrete occurs at only corner. So, damage rank is II.



5) Construction quality is not so good. But almost no damage is observed in structural members.

6) Mortar is fallen down. There was no cover concrete initially, so the reinforcing bars are exposed easily, but there is almost no cracks in concrete. So, damage rank is II



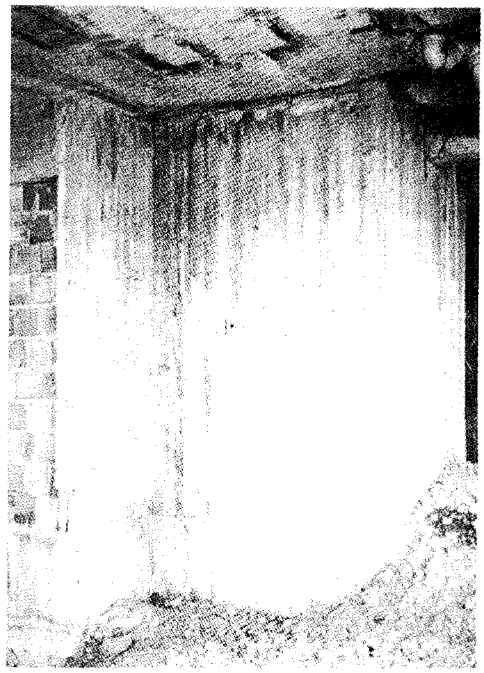
7) Mortar is fallen down extensively, but no severe damage and no wide cracks are obsearved. So. the inner two columns are estimated as Rank II.

(c) Damage Rank III

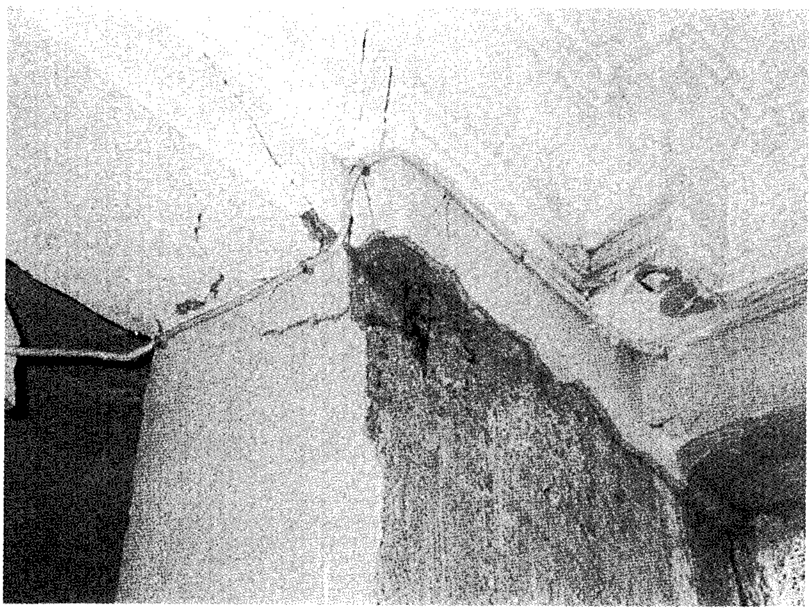
Wide cracks (Average crack width is around 1.0~2.0 mm)

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

1) Wide shear cracks and local crush of cover concrete are observed at the upper part of column.



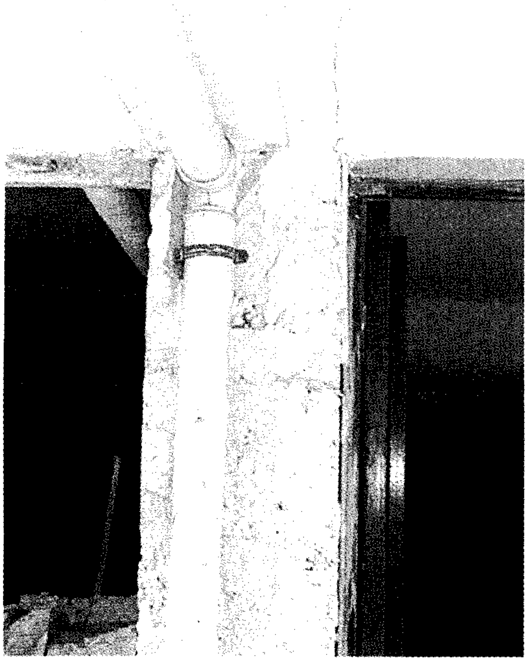
2) Wide shear cracks, local crush of cover concrete and small exposure of reinforcing bars may be observed are observed.



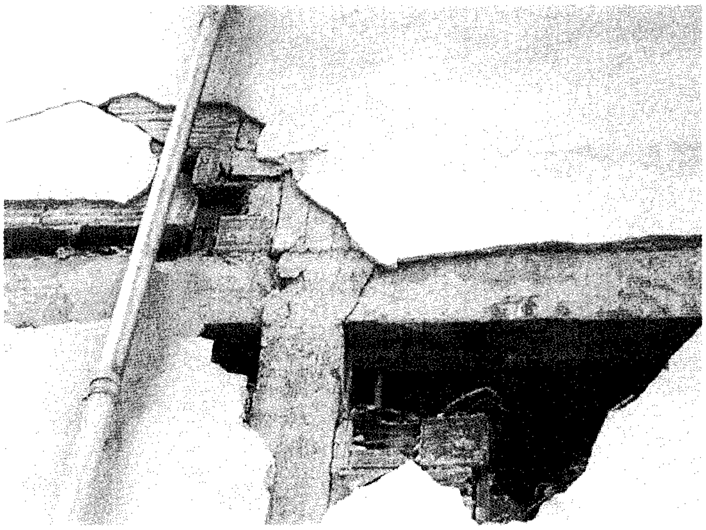
3) Wide flexural crack and local crush of cover concrete and small exposure of reinforcing bars are observed.

4) Local crush of cover concrete and exposure of reinforcing bars are observed. But no cracks are observed in core concrete.

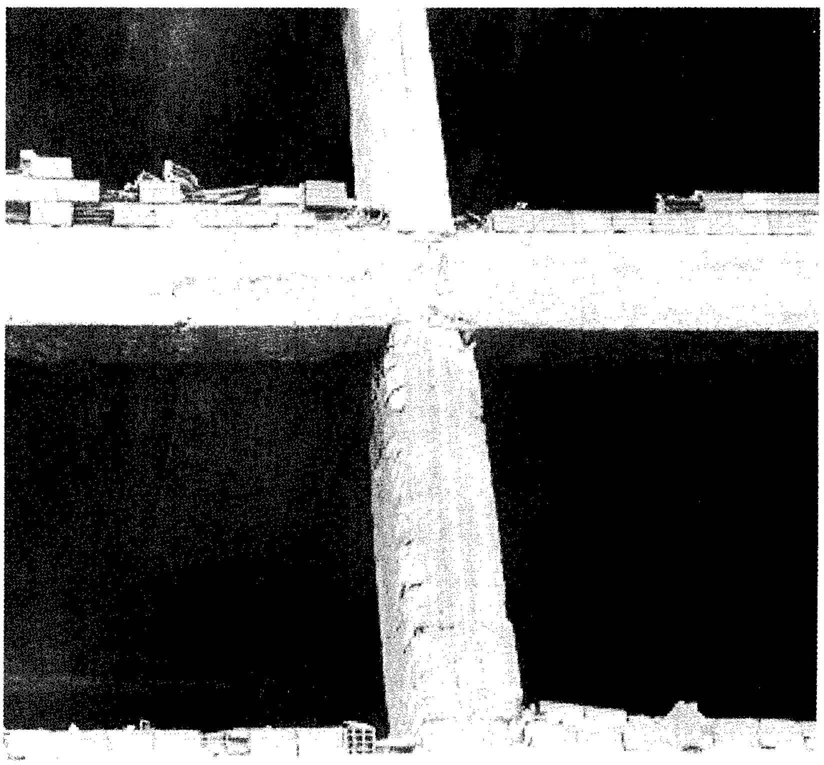
This column is Rank III as Fig.4.1.3.1 a)



5) Visibly clear shear crack occurs at the top of the narrow face of the column.



6) Wide shear crack and big flexural crack occur at beam end.



7) Some corner cover concrete are spalled off in the column damage, but damage mainly occurs beam-column joint. Cover concrete is spalled off but no diagonal shear cracks are observed.

(d) Damage Rank IV

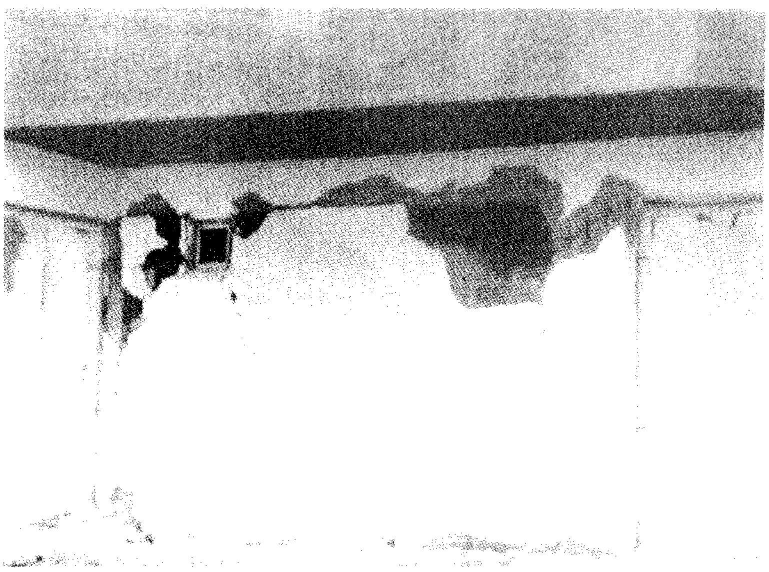
Big cracks (Average crack width is more than 2.0 mm)

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

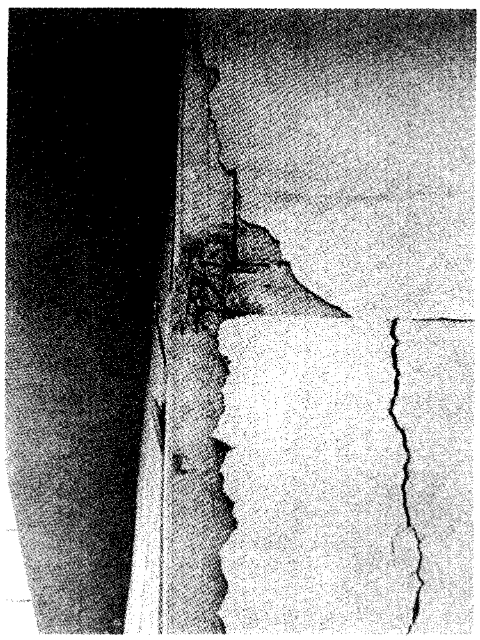
But buckling of the reinforcing bars is not observed.

1) Big cracks, Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed. But buckling of the reinforcing bars is not observed.

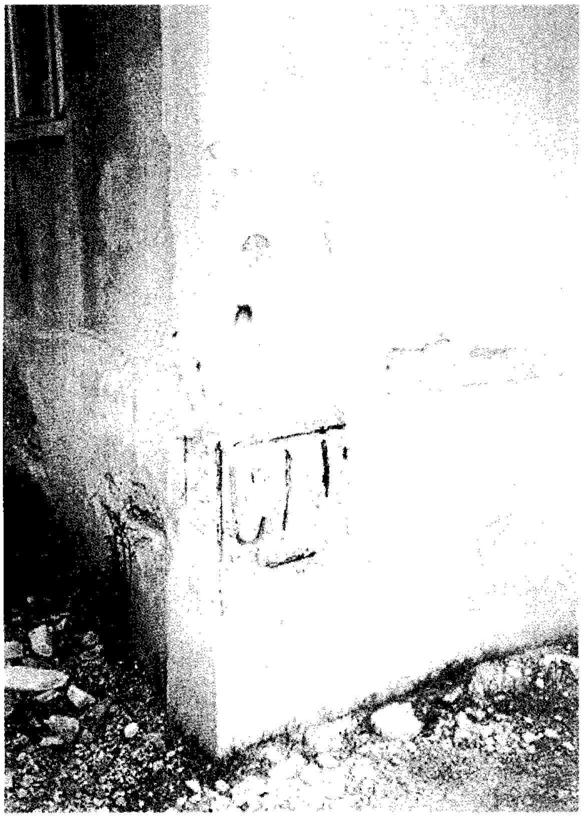
2) Big shear crack is observed on the narrow face of column



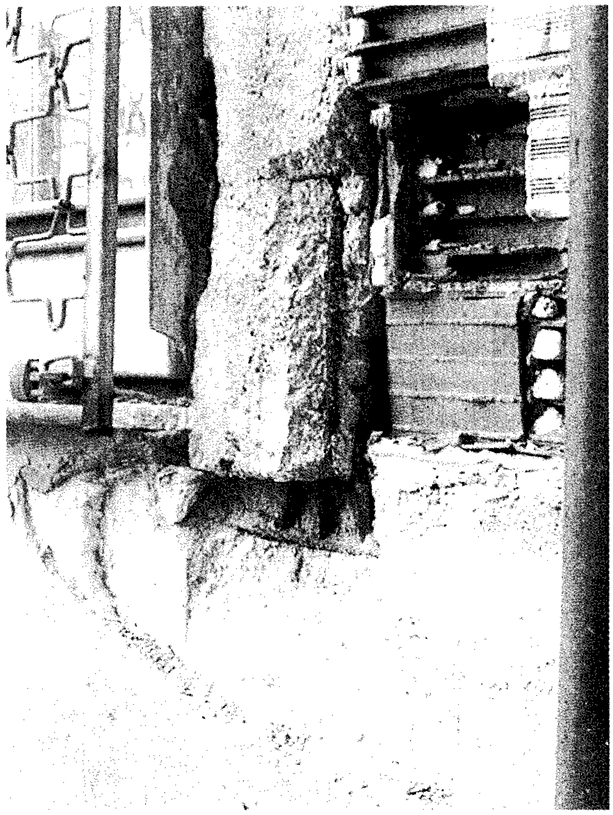
3) Big cracks, Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed.



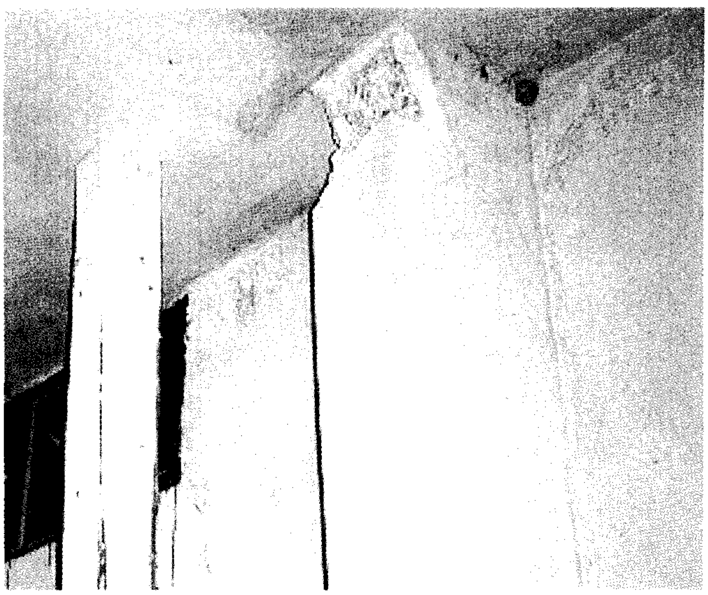
4) Diagonal shear crack is observed in beam-column joint.



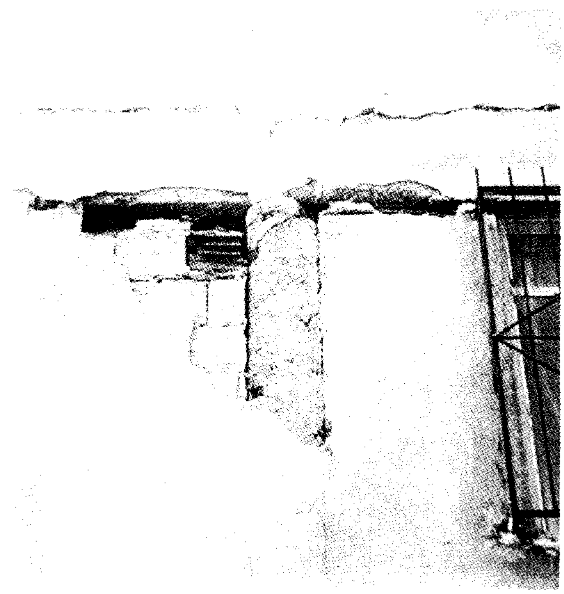
5) Massive Spalling of cover concrete and extensive exposure of reinforcing bars are observed, but buckling of the reinforcing bars is not observed.



6) Damage is almost same as Fig.4.1.3.1 a). But the damage is heavier and there are cracks in core concrete.

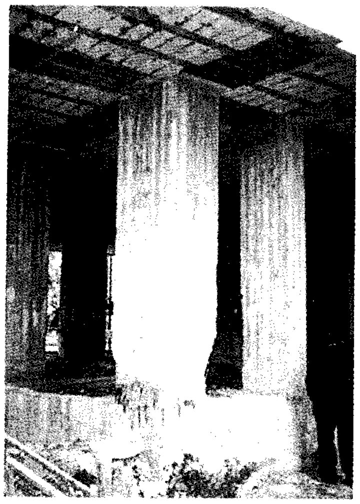


7) Big shear crack and spalling of cover concrete is observed at the top of column.



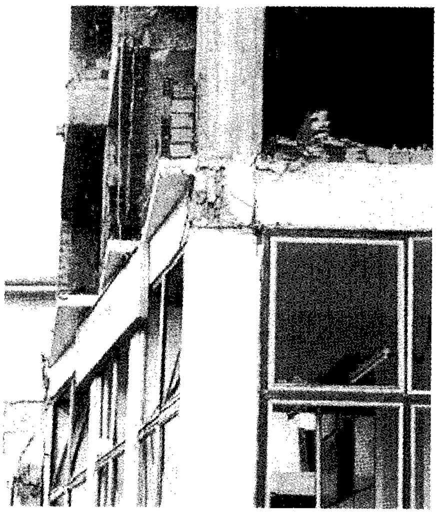
8) Big shear crack is observed at the top of the narrow face of column.

9) Following structural members are evaluated in the Damage Rank IV

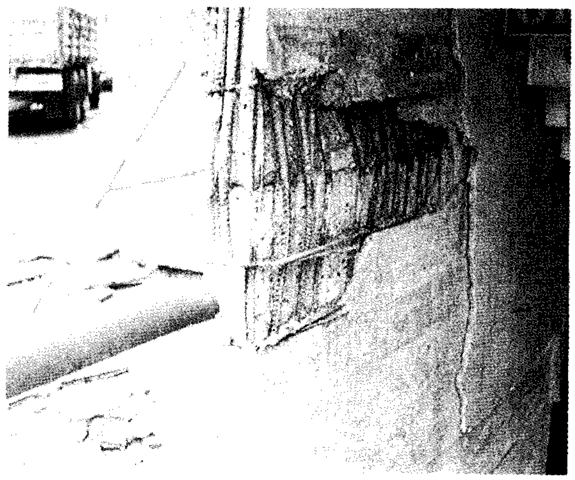


Concrete crush at the bottom of column

Concrete crush at the bottom of column and foundation beam-column joint.



Diagonal shear cracks at the beam-column joint



Tensile crack at the middle height of column

Big shear crack at the top of column

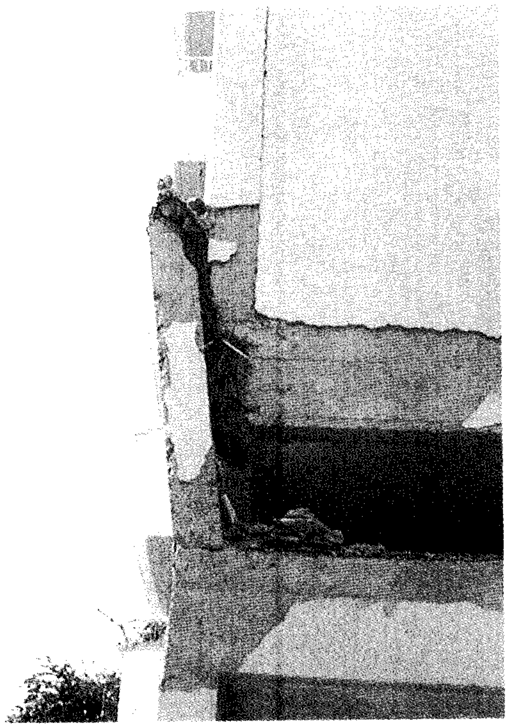
Big shear crack at the top of column

(e) Damage Rank V

Buckling of reinforcing bars

Crush of core concrete

Visible settlement and/or inclination of floor



1) Visible settlement and/or inclination of floor

2) Buckling of reinforcing bars
Crush of core concrete

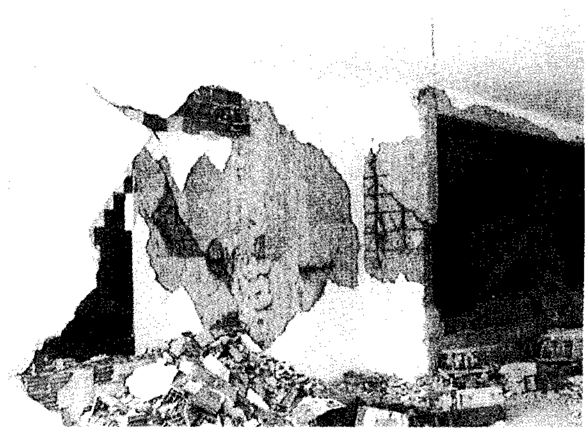
3) Buckling of reinforcing bars
Visible settlement and/or inclination of floor

4) Buckling of reinforcing bars
Crush of core concrete

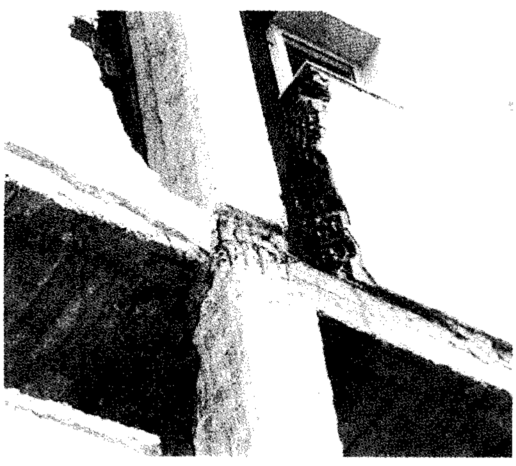
5) Visible settlement and/or inclination of floor

6) Crush of core concrete

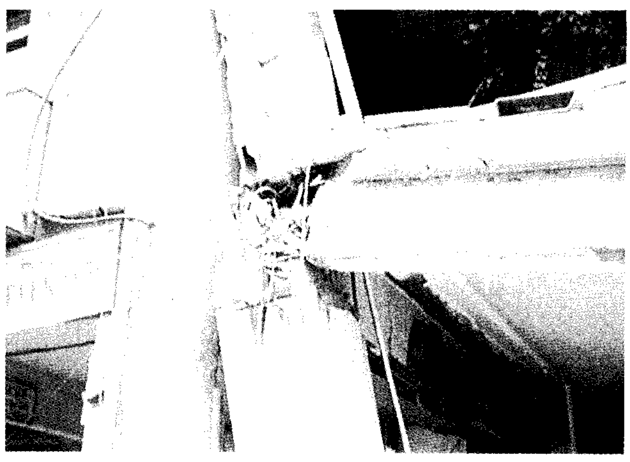
7) Buckling of reinforcing bars



8) Buckling of reinforcing bars
Crush of core concrete



9) Heavy damage at beam-column joint



10) Crush of core concrete of beam-column joint

4.2 Damage Rank of Nonstructural Walls

4.2.1 Definition of Damage Rank and Damage State of Nonstructural Walls

Nonstructural walls are mainly constructed by hollow brick called "tugla" in Turkey. These nonstructural walls show a brittle failure mode. But the walls are incorporated in the reinforced concrete frame structures those have a ductile performance. Therefore the nonstructural walls fail in the early stage of building response to earthquakes and the nonstructural walls change to hazardous elements to the occupants and residents. Damage rank of nonstructural walls is divided into three levels; hazard rank A to C, considering the potential of hazard to the occupants and residents. Definition of the hazard rank is as follows.

a) Framed nonstructural walls

Rank A: No Damage or
Local and small crack and/or cracks at the boundary between wall and RC frame

Rank B: Cracks observed but no out-of-plane deformation

Rank C: Extensive cracks penetrated and/or
Offset from RC frame or out-of plane deformation

b) Unframed nonstructural walls

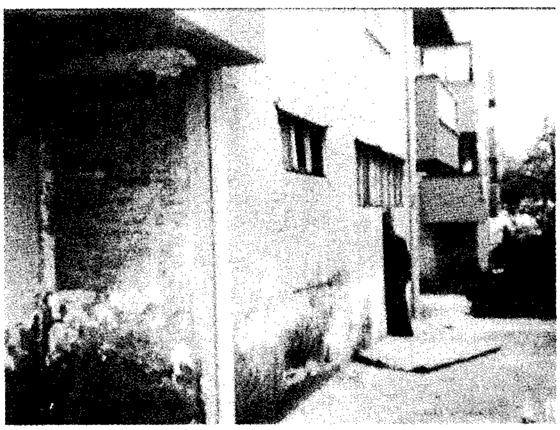
Rank A: No Damage

Rank B: Local and small crack and/or cracks at the top and/or bottom boundary of walls

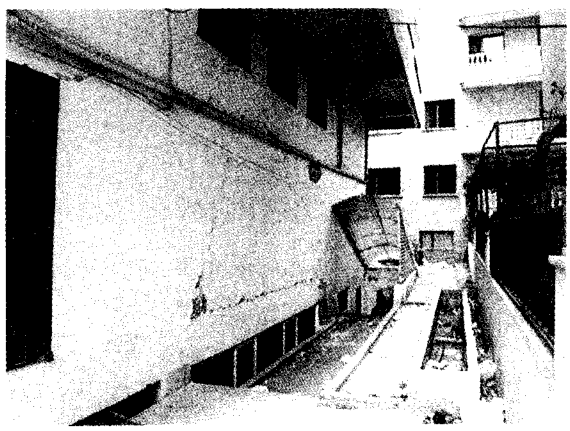
Rank C: Diagonal cracks observed and/or Extensive cracks penetrated or
Offset from RC frame or out-of plane deformation

4.2.2 Examples of Nonstructural Walls

a) Framed nonstructural walls



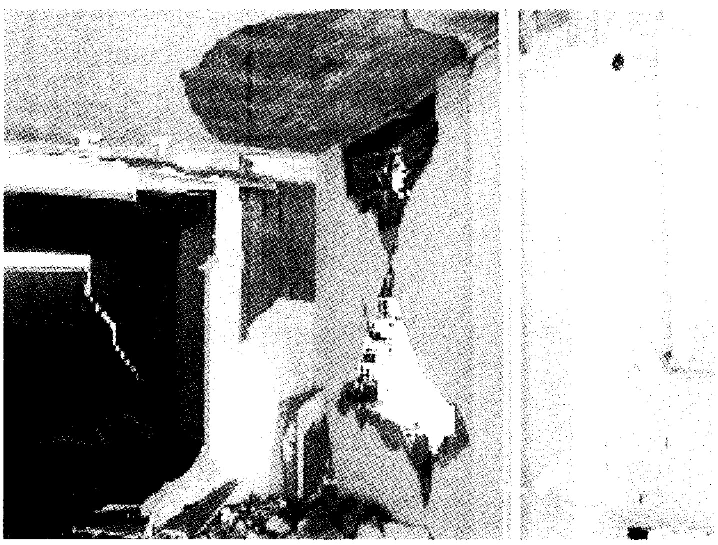
1) Rank A: Local crack and cracks at the boundary between wall and RC frame



2) Rank B: Cracks observed but no out-of-plane deformation

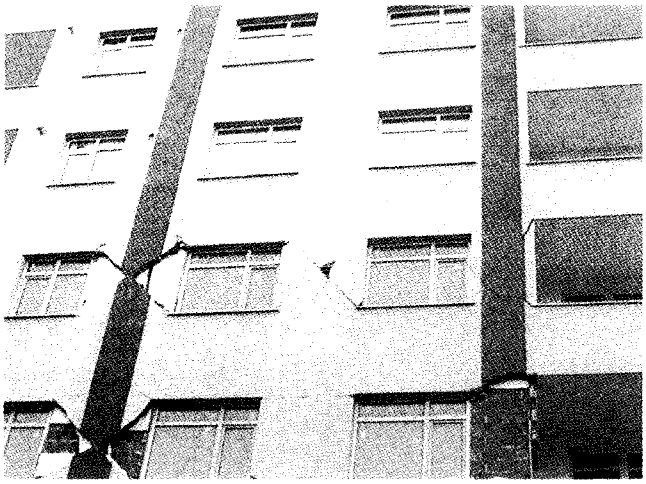
3) Rank C: Offset from RC frame

4) Rank C: Extensive cracks penetrated

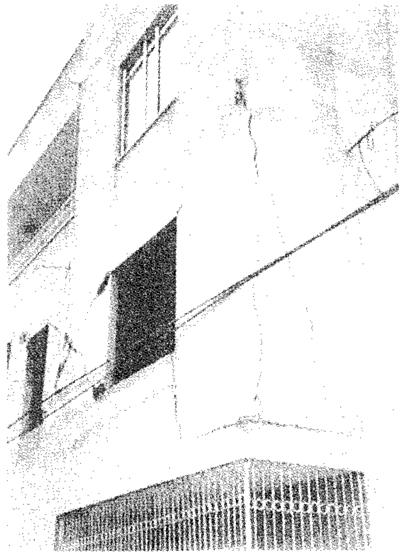


5) Rank C: Extensive diagonal cracks penetrated and
Offset from RC frame

b) Unframed nonstructural walls



1) Rank C: Diagonal cracks observed



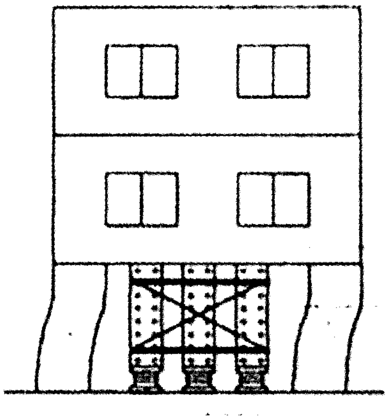
2) Rank C: Diagonal cracks observed
and offset from RC frame

3) Rank C: Diagonal cracks observed

4) Rank C: Diagonal cracks observed in upper stories. Keeping out is needed near the building.

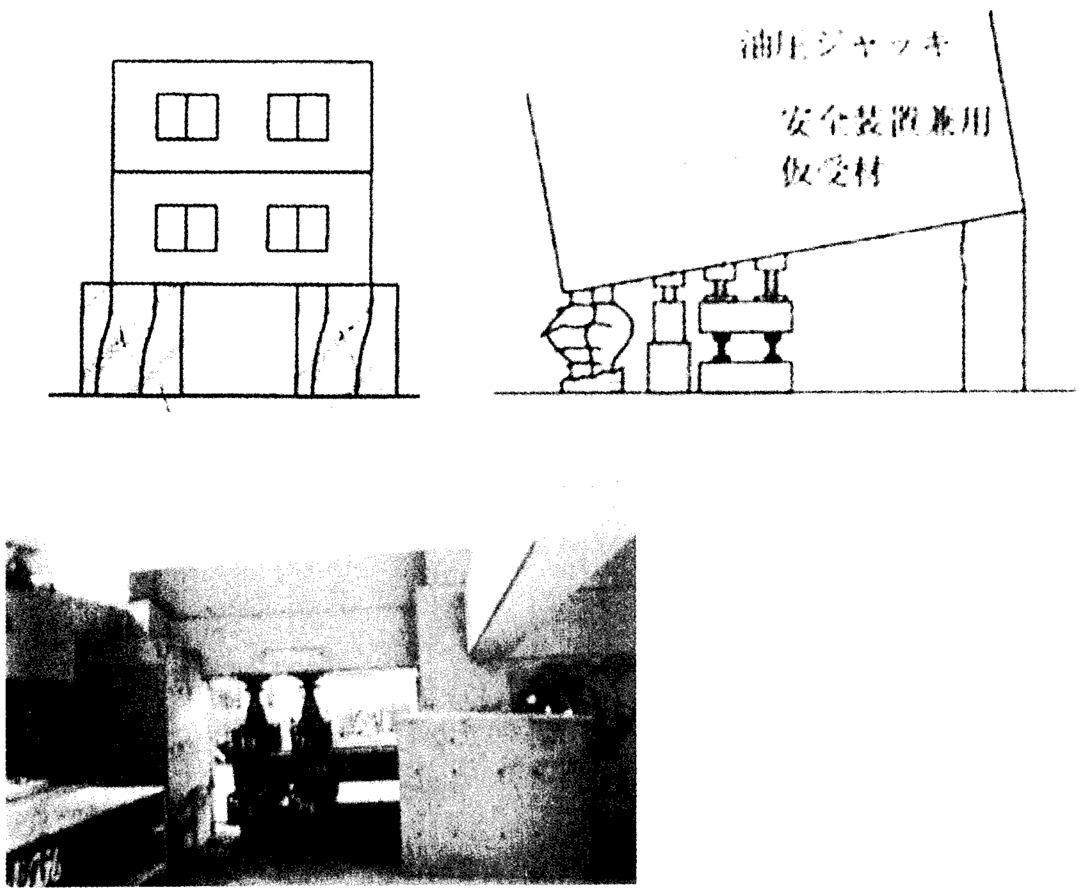
APPENDIX I

EMERGENCY AND TEMPORARY RETROFIT EXAMPLES

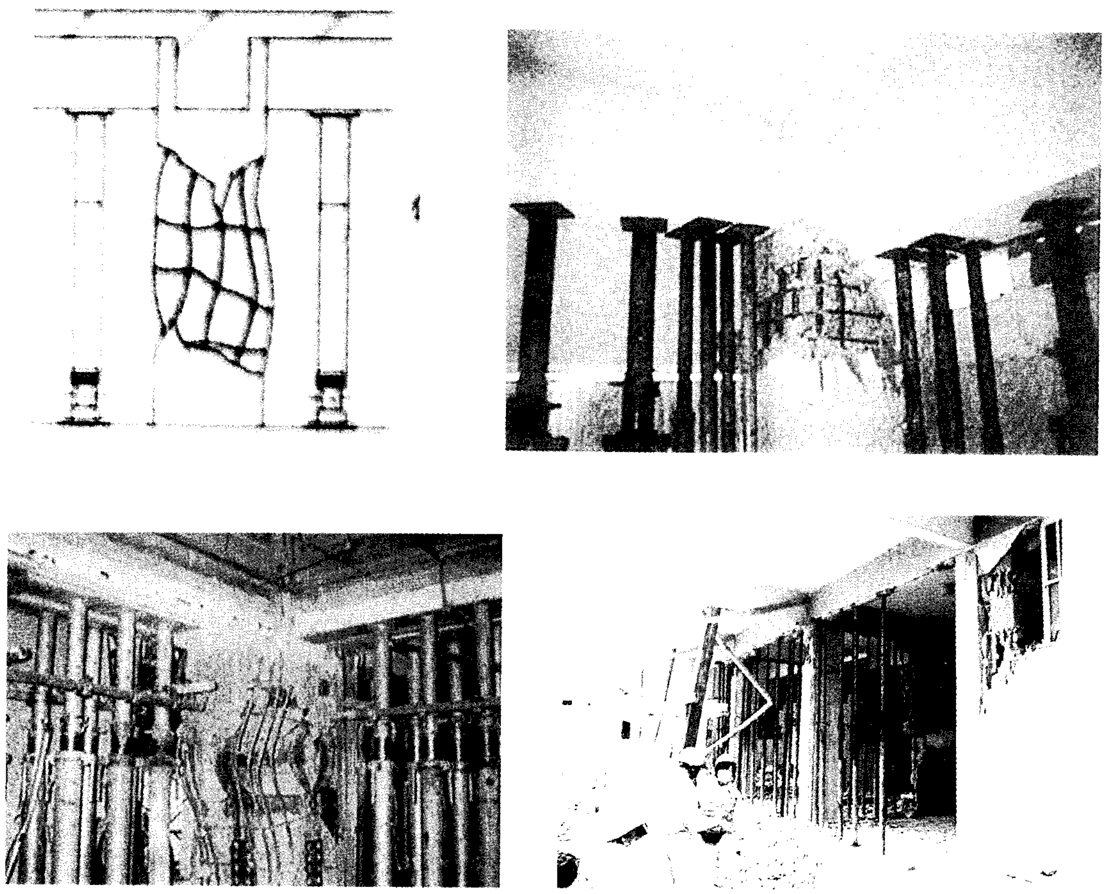


(1) Shoring upper stories
with H-shaped Steels and Screw Jacks

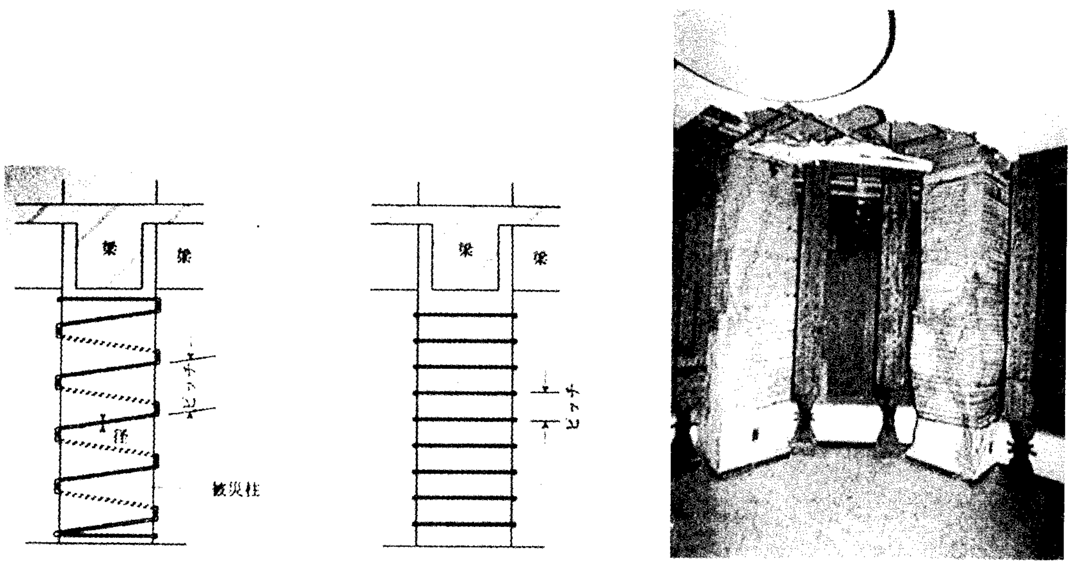
(2) Shoring with double crossed wooden layers



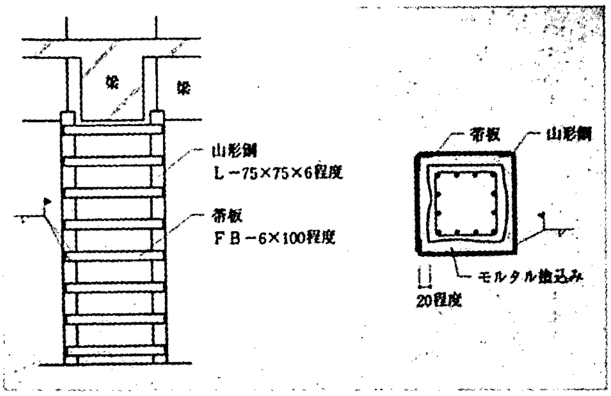
(3) Shoring by additional concrete sections through placing additional columns or wall



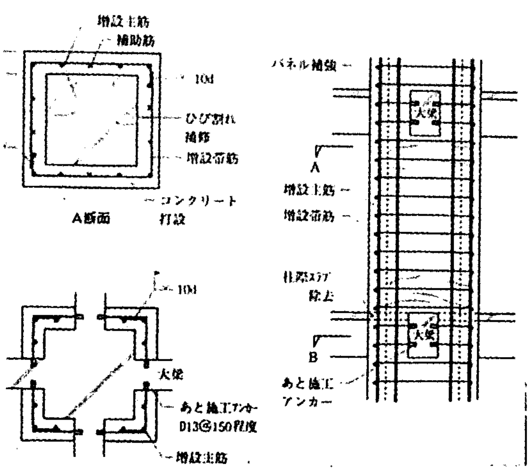
(4) Shoring with steel pipes or screw jacks around heavily damaged column



(5) Jacketing of damaged column with steel wires

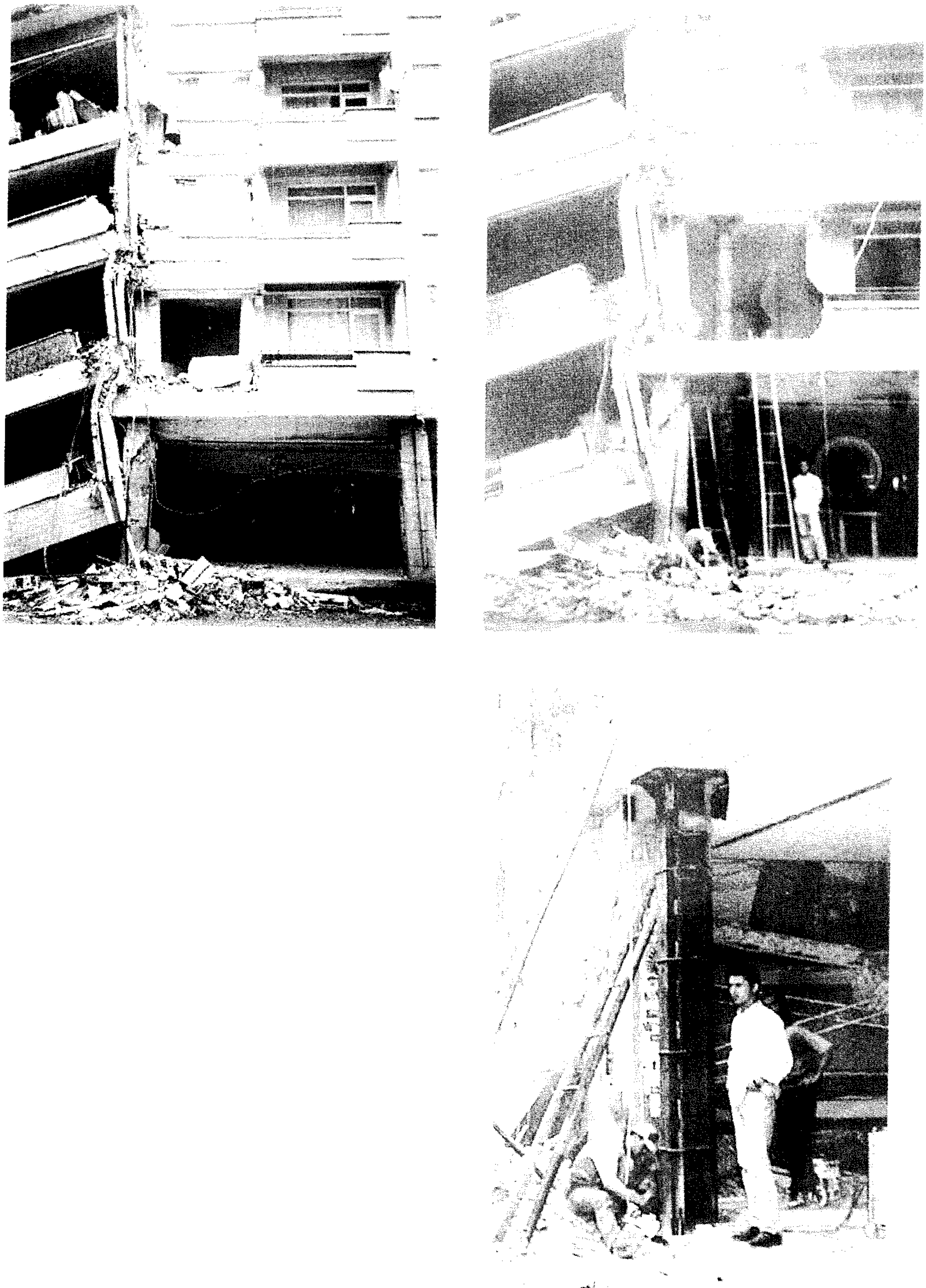


(6) Jacketing of damaged column with steel sections



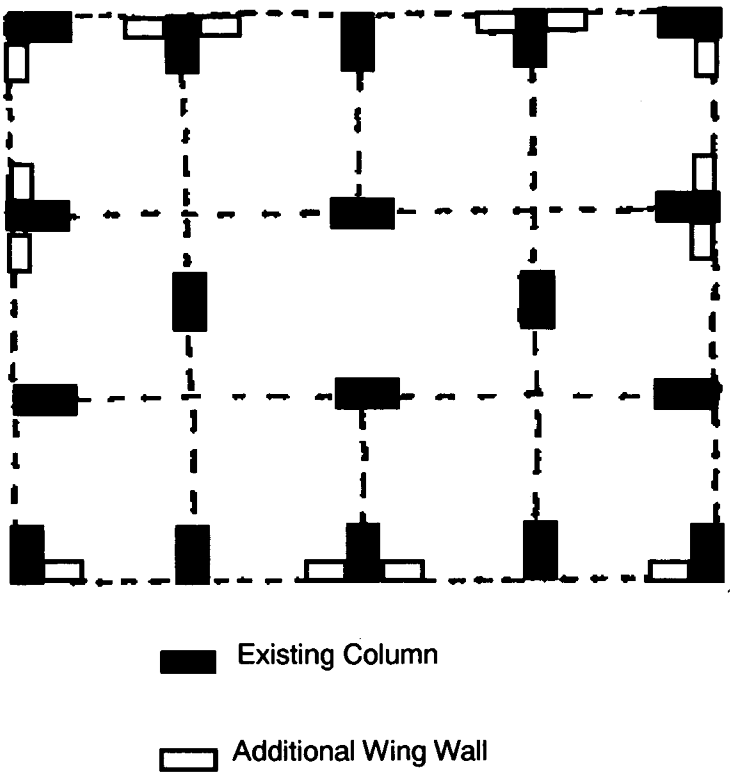
(7) Jacketing with newly cast RC section

(8) Barricade around the hazard striking area



(9) Shoring with steel sections around a column damaged due to pounding
(left: before retrofit / right: after retrofit)

(10) Conceptual temporary retrofit design of damaged columns with wing walls



[COMMENTARY]
The most conventional retrofit strategy applied to existing reinforced concrete buildings, both for emergency or temporary use and long-term use, can be installation of new RC shear walls within bare frames. The scheme described above can be a primary candidate for damaged buildings.

It should be noticed that new RC shear walls can not be effective unless the shear wall panels are sufficiently confined by boundary members (i.e. beams and columns) around the panel, since the seismic actions may concentrated on and around the newly placed wall members. As was often found in RC buildings damaged due to 1999 Kocaeli Earthquake, however, RC residential buildings in Turkey ordinarily have framing system with relatively low resistance, and the conventional scheme mentioned above may not be the best solution.

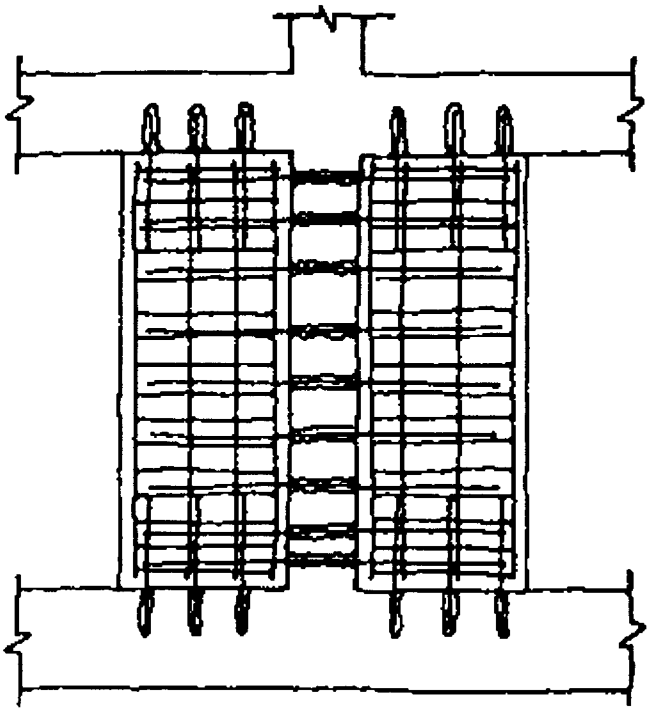
A sketch shown above is a conceptual retrofit design proposal to overcome such problems for temporary use that is believed to be applicable to buildings rated "LIMITED ENTRY". This concept is based on the following considerations.

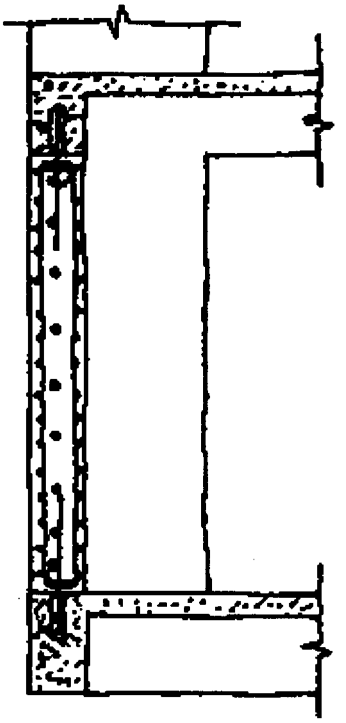
1. Wing walls can be distributed and placed adjacent to damaged columns. This may lead to seismic actions on structural members less concentrated than in the case of new RC walls.
2. New RC walls inevitable cause problems related to residential environment such as difficulties in providing natural light, ventilation etc. Wing wall system, however, may minimize such problems.

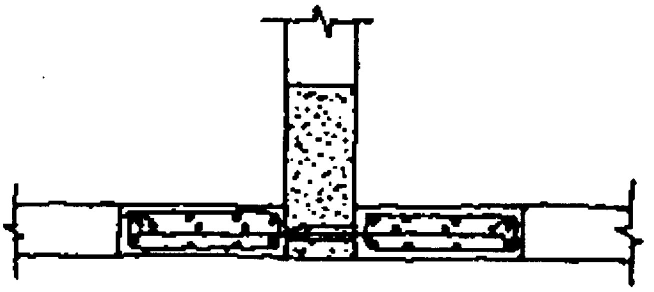
Although wing walls proposed herein may be provided primarily around the damaged members for temporary retrofit, it is of course favorable to place them in a well-balanced manner as shown in plan view above, if possible.

Although the detailed arrangement of reinforcement is not explicitly determined yet, it is strongly emphasized that the following general remarks should be carefully taken into account when this scheme is applied in practice.

1. Re-bars should be deformed bars. They would be placed through drilled holes in existing columns, and epoxy mortar should be injected into gaps around re-bars for smooth action transfer.
2. Longitudinal bars in wing walls should be properly confined with lateral reinforcement having 135 degree hooks. They should be jointed (lap splice joint) with anchoring bars embedded in upper and lower beams at the top and bottom of the wall. Bonded anchors (epoxy adhesive anchors) may be most preferable to connect anchoring bars with existing RC members. When honey-combs are found in existing members, repair them before installing anchors. It should be also noted that embedded length of anchors should be deeper than usual.
3. Quality of concrete for new wing walls should be carefully controlled.







APPENDIX II

BACKGROUND OF CRITERIA FOR BUILDING DAMAGE RATING

The Japanese quick inspection guideline[1] was first developed in 1985 after 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.

To disseminate the knowledge and techniques of post-earthquake inspection, "Standard for Evaluation of Damage Level of Earthquake Damaged Buildings and Guideline for Repair Techniques[2]" was developed based on the guideline and published by the Japan Building Disaster Prevention Association in 1991. The Standard was applied to several hundred buildings affected by 1993 Kushiro-oki and 1994 Sanriku-haruka-oki Earthquakes. It was, however, the first time to apply the Standard to a huge number of damaged buildings immediately after the 1995 Hyogo-ken Nambu (Kobe) Earthquake and problems involved in the inspection system were revealed. After many discussions and much thought on lessons learned from Kobe Earthquake Disaster, the quick inspection procedure was revised and "Quick Inspection Manual for Earthquake Damaged Buildings[3]" was published in 199*. A background history of Japanese quick inspection system and experiences after the 1995 Hyogo-ken Nambu Earthquake can be found in some literatures[4][5].

The quick inspection procedure presented in this report is primarily based on the Quick Inspection Manual[3], lessons learned from post-earthquake inspection activities in Japan, damage surveys and field trials after 1999 Kocaeli Earthquake. Although the basic concept and procedure developed for reinforced concrete residential buildings in Turkey is basically the same as Japanese procedure, criteria for potential hazard rank (Rank A through C) for columns are slightly modified as follows.

The Japanese procedure defines the rank as shown in ***Table A1*** depending on the damage observed in columns and its ratio. As was often found in damaged buildings after 1999 Kocaeli Earthquake, however, columns of typical RC residential buildings in Turkey generally have less lateral resistance and ductility than those in Japan, and visible clear cracks may lead to significant loss of residual capacity of columns.

Considering the above fact, the rank proposed in this report is modifies as shown in ***Table A2***. As can be found in the Table, damage ranks IV and V are categorized into one group and new criteria for rank III is additionally introduced. The new criteria for damage rank III (e.g. more than 30 % corresponds to Rank C) are tentatively determined according to the following assumptions.

1. Columns with damage rank IV or V are assumed to have no residual capacity while those with rank III 60 % of the original capacity.

2. A damaged building has therefore 90 % of the original lateral capacity when its 10 % columns are rated rank IV or V and the others have no damage (i.e. Rank C building).
3. A damaged building also has 90 % of the original lateral capacity when its 25 % (= 1/4) columns are rated rank III and the others have no damage. The residual capacity of this building is, therefore, equivalent to the building described in 2. and categorized into Rank C.
4. Less than half of the ratio, 12.5 % (= 1/8) of damage III is assumed Rank A.

It should be noted that the criteria described above, especially of rank III, are tentative proposal determined through discussions within a short period of time, and further experimental researches, literature surveys, field applications and calibrations are needed to set more rational criteria for buildings in Turkey.

Table A1: Definitions of Potential Hazard Rank in Japanese Procedure[3]

	A	B	C
Ratio of Damage V	[ ] < 1 %	[ ] 1 - 10 %	[ ] > 10 %
Ratio of Damage IV	[ ] < 10 %	[ ] 10 - 20 %	[ ] > 20 %

Table A2: Definitions of Potential Hazard Rank Proposed in This Report

	A	B	C
Ratio of Damage IV or V	[ ] < 1 %	[ ] 1 %- 10 %	[ ] > 10 %
Ratio of Damage III	[ ] < 12.5 %	[ ] 12.5% - 25 %	[ ] > 25 %

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[1] The Ministry of Construction "Manual for Rehabilitation Techniques for Earthquake Damaged Structures," Report on the National Research Program on the Development of Rehabilitation Techniques for Earthquake Damaged Structures, March 1986.

[2] The Japan Building Disaster Prevention Association "Standard for Evaluation of Damage Level of Earthquake Damaged Buildings and Guidelines for Repair Technique," February 1991.

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[4] Masaya Murakami "Post-earthquake Inspection and Evaluation of Earthquake Damage in Buildings for Countermeasure," Proceedings of the 8th International Research and Training Seminar on Regional Development Planning for Disaster Prevention Emergency Assessment System of Damaged Buildings, 16 January 1995, Osaka, Japan, United Nations Center for Regional Development.

[5] Yoshiaki Nakano "Quick Inspections of Damaged Buildings Due to 1995 Jan. 17 Hyogoken-Nanbu Earthquake," Bulletin of ERS (Earthquake Resistant Structure Research Center), Institute of Industrial Science, the University of Tokyo, No. 29, pp. 45-49, March 1996.

TECHNICAL NOTE of N I L I M
No. 40 March 2002

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