



Government of Nepal
Department of Urban Development and Building Construction
and
Nepal Engineers' Association



TRAINING WORKSHOP
POST DAMAGE ASSESSMENT, REPAIR & STRENGTHENING
OF
MASONRY AND REINFORCED CONCRETE STRUCTURES

May 20, 2015 to May 22, 2015
 Engineer Bhawan, Pulchowk



Technical Support
 IOE, NSET & CoRD



Supporting Institutions

SCAEF, SONA, RUPSON, SEANep, SERDEN, NGS, ngs, NELS, NSC/DMG & AITAAN





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Technology-Nepal (NSET)

Damage of Masonry Buildings



Objectives

At the end of the session, participants will be able to:

- Identify past earthquake damage patterns in masonry buildings
- Understand the reason behind such failures
- Damage Grades of masonry buildings



Why Buildings fail in an earthquake?

➤ Lack of

- Strength
- Ductility

And

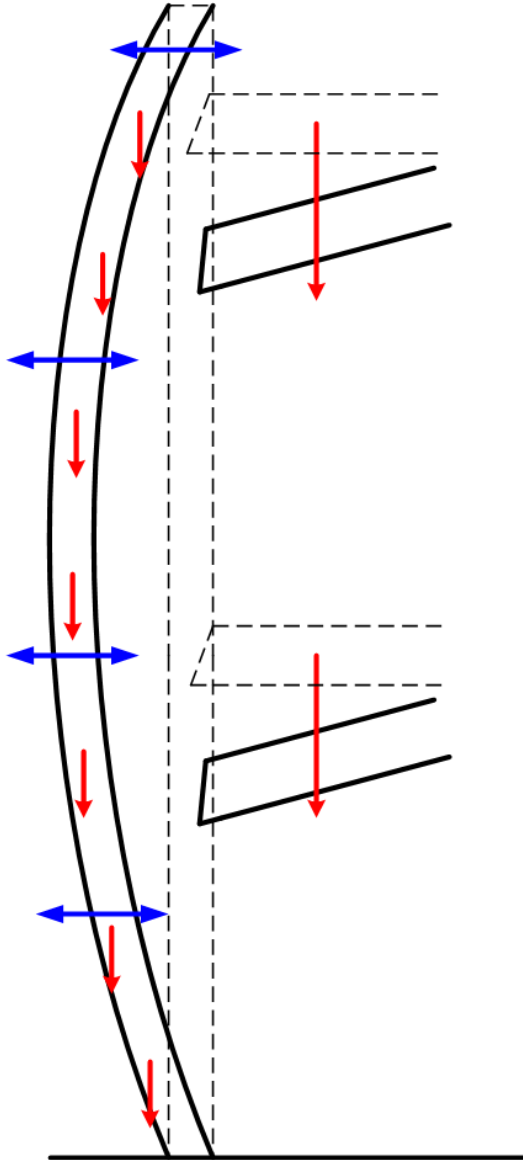
- Inappropriate Configuration and Connection



Failure mode of masonry buildings in earthquake

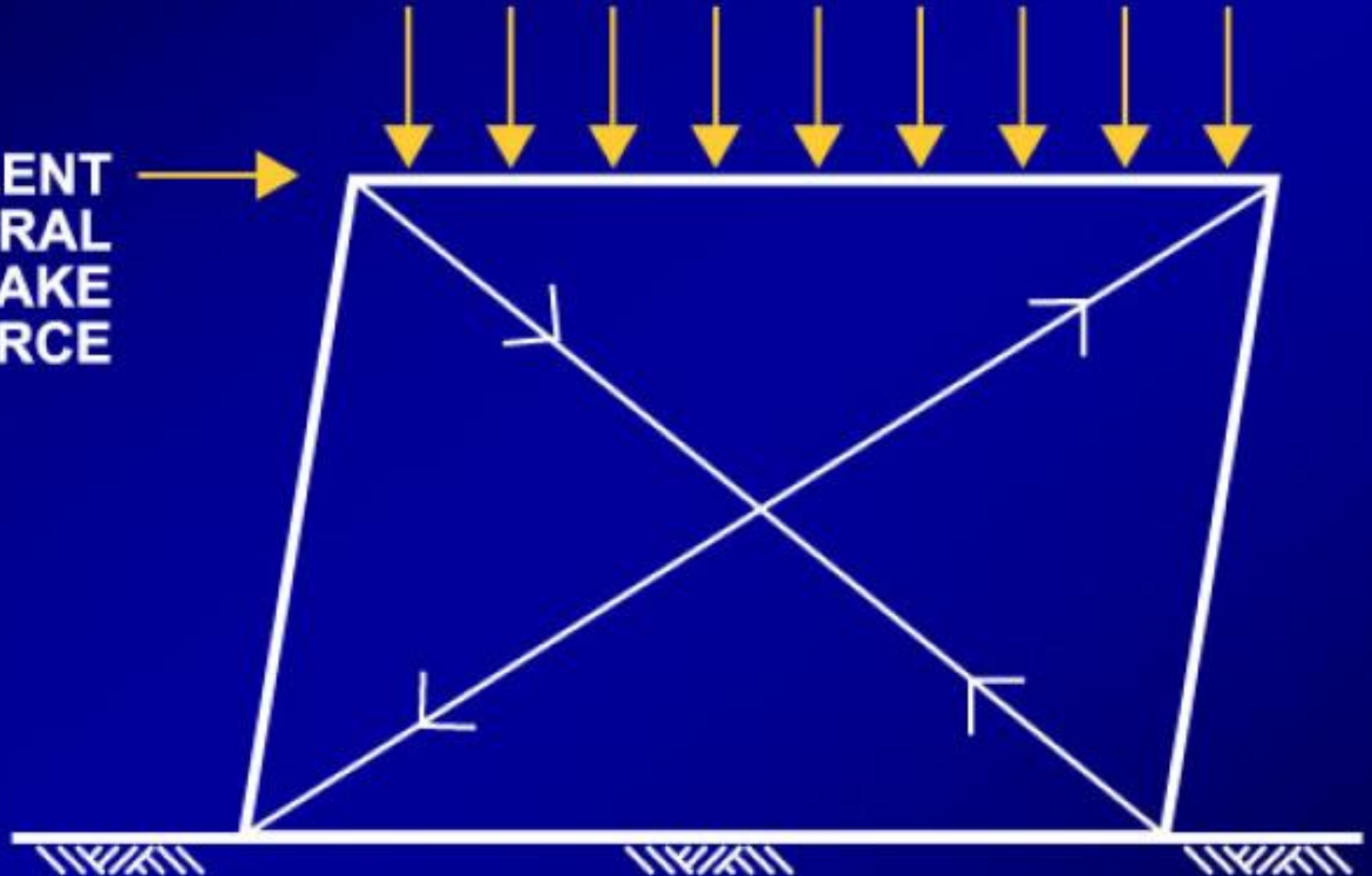
- Out of plane failure
- In plane failure
- Diaphragm failure
- Failure of connection

Out of plane failure



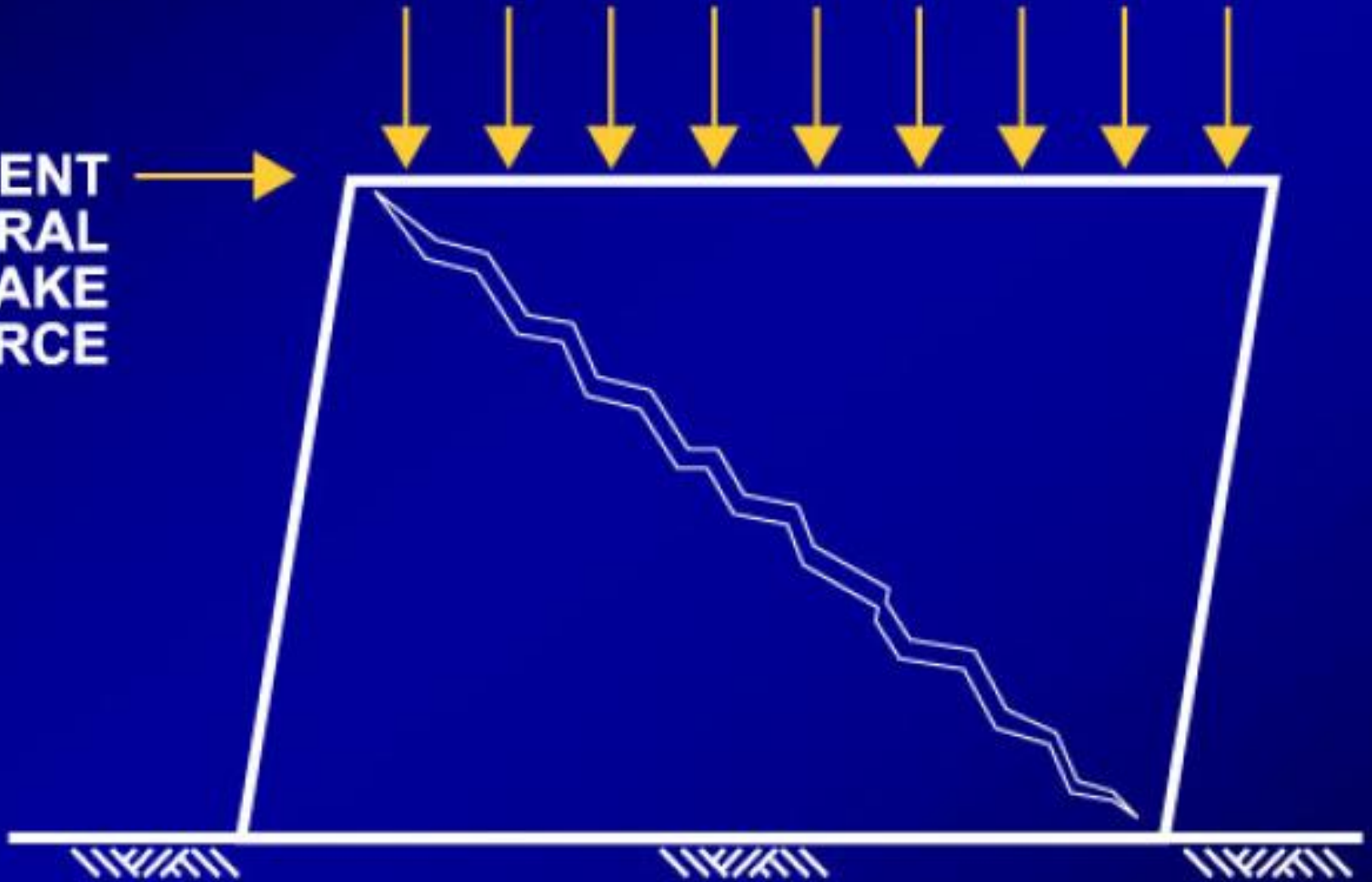
VERTICAL GRAVITY FORCES

EQUIVALENT
LATERAL
EARTHQUAKE
FORCE



VERTICAL GRAVITY FORCES

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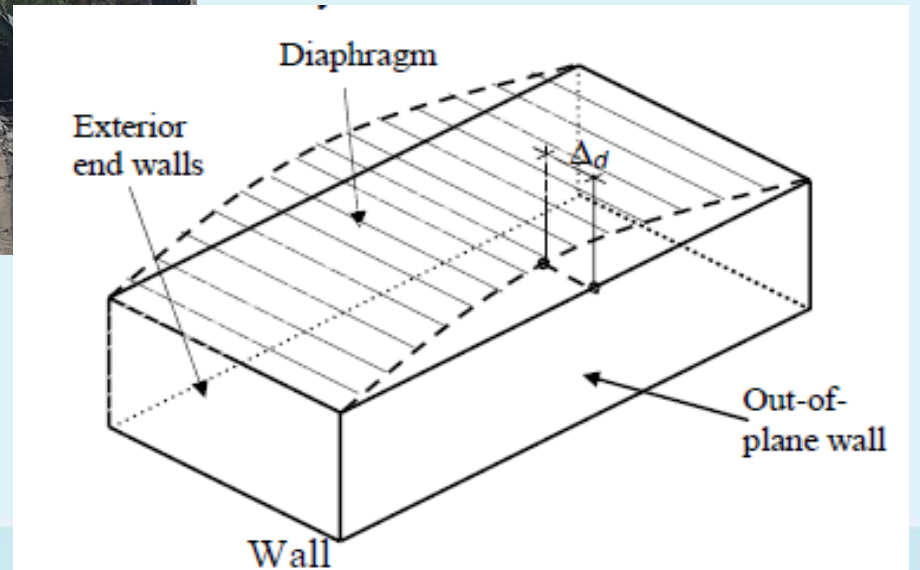


In plane failure





Diaphragm failure





Connection failure





Reasons of failure



Configuration problem



Irregular shape: L-shape building



Configuration problem





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Large Doors and Windows





Unbalanced openings



Front

Back





Openings at corners of walls





Failure of Long Walls



Long and high walls

Failure of Gable Walls



Failure of gable walls due to the high height and lack of support at the top



Lack of Vertical bars!!





Pounding effect





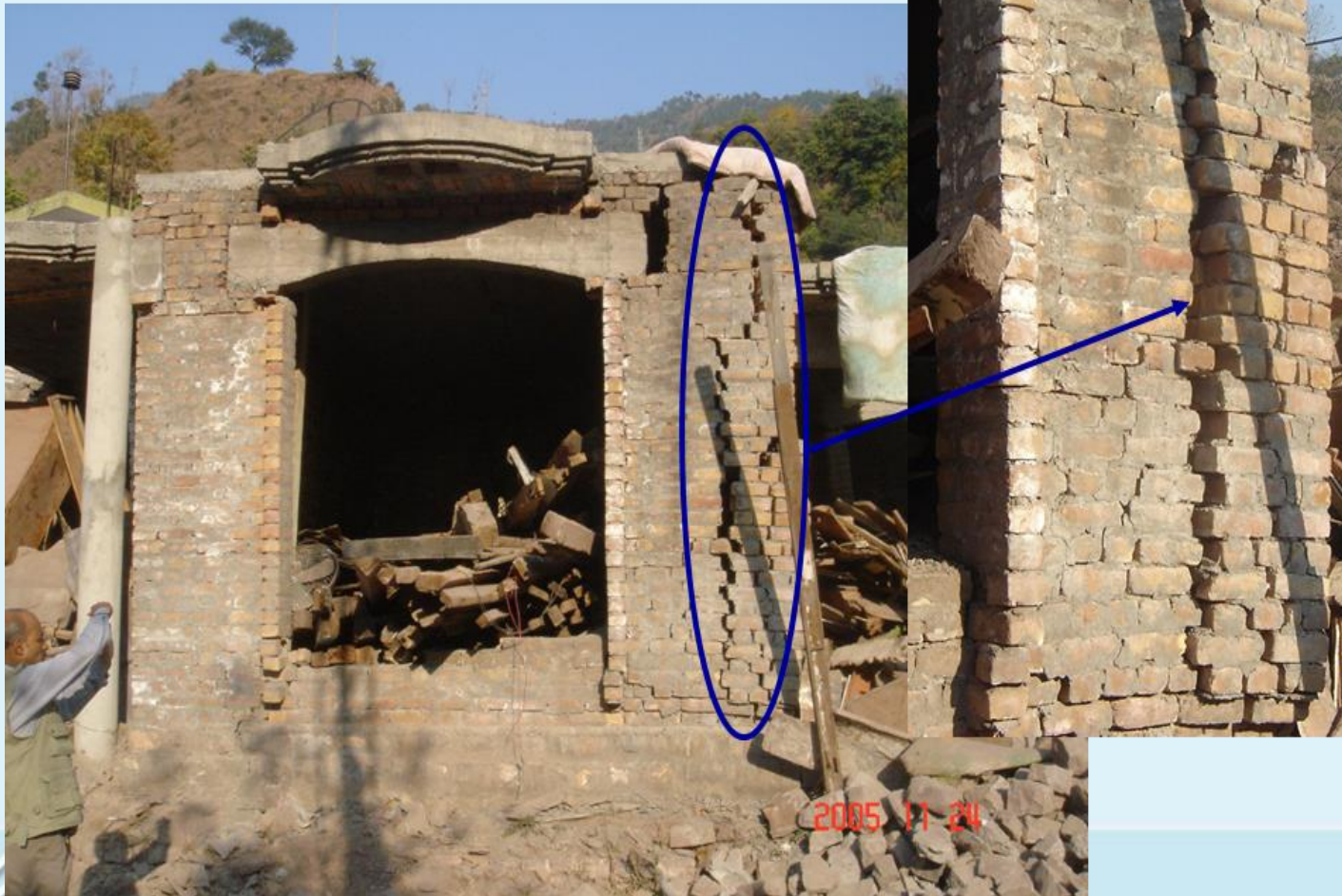
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Delamination





Lack of bonding





Weak Floor-Roof connection





Integrity?





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Damage Grades of Masonry buildings



LEVEL AND DESCRIPTION OF FAILURE

Level and description of Out-of-plane flexural failure:

LEVEL OF DAMAGE	DESCRIPTION OF DAMAGE
Insignificant-Slight	1. Hairline cracks at floor/roof lines and mid-height of stories.
Moderate	1. Cracks at floor/roof lines and midheight of stories may have mortar spalls up to full depth of joint and possibly: <ul style="list-style-type: none">• Out-of-plane offsets along cracks of up to 1/8".



LEVEL AND DESCRIPTION OF FAILURE

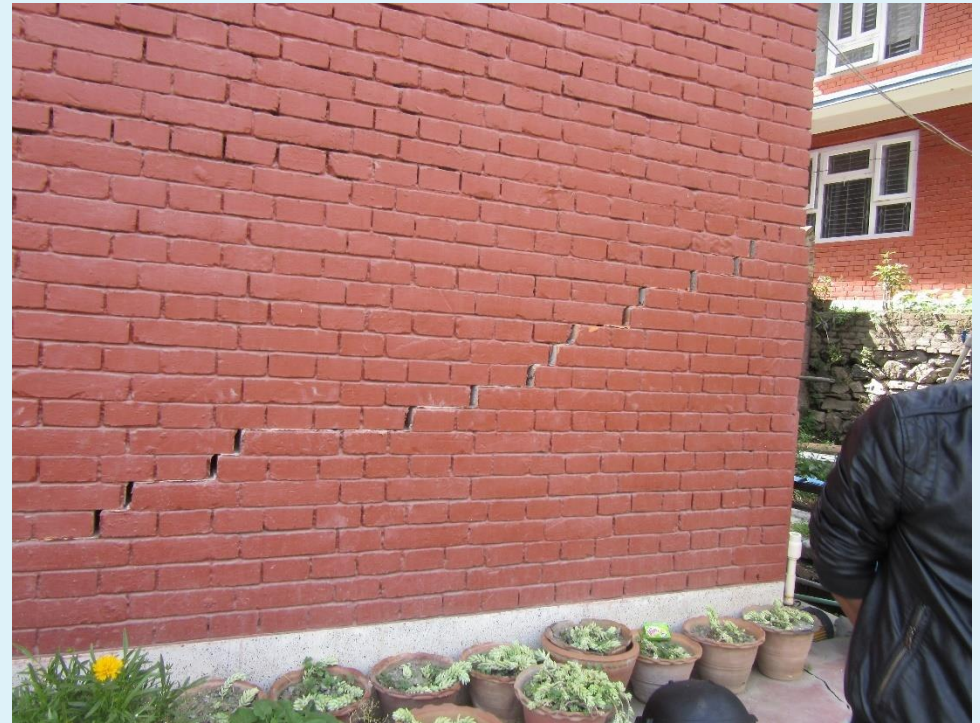
Level and description of Out-of-plane flexural failure:

Heavy	<ol style="list-style-type: none">1. Cracks at floor/roof lines and midheight of stories may have mortar spalls up to full depth of joint.2. Spalling and rounding at edges of units along crack plane.3. Out-of-plane offsets along cracks of up to 1/2".
Extreme	<ol style="list-style-type: none">1. Vertical-load-carrying ability is threatened:<ul style="list-style-type: none">• Significant out-of-plane or in-plane movement at top and bottom of piers "walking").• Significant crushing/spalling of bricks at crack locations.

LEVEL AND DESCRIPTION OF FAILURE

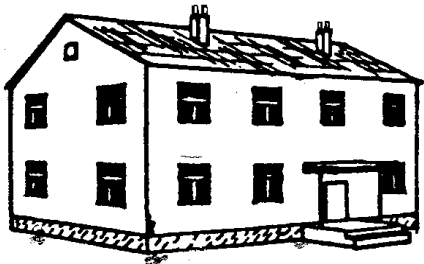
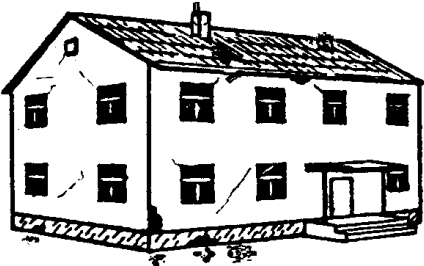
Masonry Wall Pier in diagonal cracking on bed joint sliding mode

LEVEL OF DAMAGE	DESCRIPTION OF DAMAGE
Insignificant-Slight	<ol style="list-style-type: none"> 1. Hairline cracks/spalled mortar in head and bed joints either on a horizontal plane or in a stair stepped fashion has been initiated, but no offset along the crack has occurred and the crack plane or stair-stepping is not continuous across the pier. 2. No cracks in masonry units.
Moderate	<ol style="list-style-type: none"> 1. Horizontal cracks/spalled mortar at bed joints indicating that in-plane offset along the crack has occurred and/or opening of the head joints up to approximately 1/4", creating a stair-stepped crack pattern. 2. 5% of courses or fewer have cracks in masonry units.

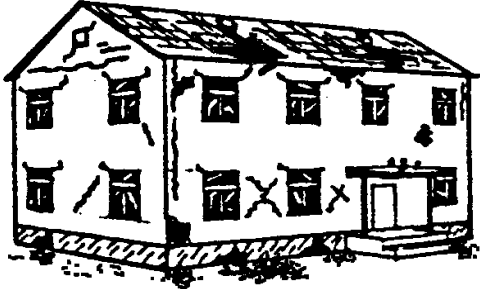



Damage Grades: Masonry Buildings


EMS Classification of Damage

Damage Grades		Extent of Damage	Suggested post-earthquake actions
G1	<p>Negligible-slight damage (no structural, slight non-structural)</p> 	<p>Hair-line cracks in very few walls, falling of small pieces of plaster only, fall of loose stone from upper part of building in rare cases</p>	<p>Building need not be vacated, only architectural repairs needed</p>
G2	<p>Moderate damage (slight structural, moderate non-structural damage)</p> 	<p>Thin cracks in many walls, fall of fairly large pieces of plaster, damage to non-structural parts like chimney, projecting cornices; The load carrying capacity is not reduced appreciably.</p>	<p>Architecture repairs needed, Restoration/Seismic strengthening advised.</p>

Damage Grades: Masonry Buildings

Damage Grades		Extent of Damage	Suggested post-earthquake actions
G3	<p>Substantial to heavy Damage (moderate Structural, heavy non-structural damage)</p> 	<p>Large and extensive cracks in most walls, roof tiles detach, tilting or falling of chimneys, failure of individual non-structural elements such as partition/ gable walls. Load carrying capacity of structure is partially reduced.</p>	<p>Cracks in wall need grouting, architectural repairs required, Seismic strengthening advised</p>
G4	<p>Very heavy damage (Heavy structural, very heavy non-structural damage)</p> 	<p>Gaps occur in walls, walls collapse, partial structural failure of floor/ roof, Building takes a dangers state.</p>	<p>Vacate the building, demolish and construct or extensive restoration and strengthening</p>

Damage Grades: Masonry Buildings

Damage Grades		Extent of Damage	Suggested post-earthquake actions
G5	Destruction (Very heavy structural damage) 	Total or near total collapse	Clear the site and reconstruction

Damage Grade DG1



Extent of Damage

Thin cracks in plaster, falling of plaster bits in limited parts

Suggested Action

Building need not be vacated, only architectural repairs needed, Seismic strengthening advised

Damage Grade DG2



Extent of Damage

Thin cracks in many walls, falling of plaster in last bits over large area, load carrying capacity is not reduced appreciably.

Suggested Action

Architecture repairs needed, Seismic strengthening advised.

Damage Grade DG3



Extent of Damage

Large and extensive cracks in most walls, roof tiles detach, Load carrying capacity of structure is partially reduced.

Suggested Action

Cracks in wall need grouting, architectural repairs required, Seismic strengthening advised , Vacate the buildings for possible aftershock

Damage Grade DG4



Extent of Damage

Partial collapse of building, large cracks in many walls; Building takes a dangers state.

Suggested Action

Vacate the building, demolish and construct or extensive restoration and strengthening

Damage Grade DG5



Extent of Damage

Total or near total collapse

Suggested Action

Clear the site and reconstruction







DG2



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DG4



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DG3

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AGI
CHO
NGH

AUG 12 2006

DG3



AUG 12 2006

DG3



AUG 12 2006

DG3



SEP 7 2006

DG4



DG4





Objectives review

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Thank You!