OPTIMUM SEISMIC PROTECTION FOR NEW BUILDING CONSTRUCTION IN EASTERN METROPOLITAN AREAS

NSF Grants GK-27955 and GI-29936

Internal Study Report No. 29

SCENARIOS OF BUILDINGS IN GIVEN EARTHQUAKE DAMAGE STATES

Revision 1

Michael Ackroyd

6 February 1973

Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. NSF-RA-E-73-577	2.	3. Recipient's Accession No. PB 80-106156

4. Title and Subtitle
Scenarios of Buildings in Given Earthquake Damage States, Revision 1 (Optimum Seismic Protection for New Building Construction in Eastern Metropolitan Areas, Internal Study Report 29)

5. Report Date
February 6, 1973

6.

7. Author(s)
M. Ackroyd

8. Performing Organization Rept. No.
No. 29

9. Performing Organization Name and Address
Massachusetts Institute of Technology
Department of Civil Engineering
Cambridge, Massachusetts 02139

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) GK27955
(G) GI29936

12. Sponsoring Organization Name and Address
Engineering and Applied Science (EAS)
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

13. Type of Report & Period Covered
Revision

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This update of damage states of earthquake-affected buildings replaces an earlier set of December 7, 1972. Based upon discussions with building owners and tenants in Los Angeles, the report matches specific damage states with incident state categories A through E. Scenario recaps include information tabulated on cards according to: motions and sounds perceived; occupants' ability to stand, walk, etc.; books and bookshelves; conventional suspended ceilings; conventional suspended light fixtures; walls and partitions; fraction of elevators out of service; stairways; structural damage; time to restore order; length of time building is out of function; fraction of building unusable (when opened); fraction of occupants seriously injured or killed; fraction of occupants killed. Specific replies to each of these scenarios determines the incident state.

17. Document Analysis a. Descriptors

Earthquake resistant structures
Civil engineering
Damage assessment
Stairways
Fractures
Injuries
Destruction
Walls
Earthquakes
Buildings
Ceilings

b. Identifiers/Open-Ended Terms

Damage states
Incident states

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
NTIS		17
	20. Security Class (This Page)	22. Price PC A02 MF A01

PREFACE

This set of scenarios replaces an earlier set dated December 7, 1972. The updating is based upon the experience of the author during discussions with building owners and tenants in Los Angeles.

Damage States 1, 2 → Incident State A

Depending on the type of structure and the building function, one may hear such sounds as the creaking of the steel frame and loose joints, cracking of partition walls, squeaking of window panes in their casings, the breaking of some pane glass windows, or dishes rattling in cupboards. In many cases, occupants are knocked down by the shaking and have difficulty standing. They can feel a rocking movement of the building and observe hanging light fixtures or chandeliers swinging like pendulums. In buildings with conventional suspended ceilings and lights (i.e., suspended ceilings and lights not designed to withstand seismic forces) in a few rooms, some panels may be disturbed but don't fall to the floor. Several suspended lights may be displaced or left hanging askew; in isolated instances a few suspended lights may fall to the floor.

Some books fall from shelves throughout the building varying from a few books on lower stories to many books on the uppermost stories. In isolated instances, unbraced bookshelves may collapse or overturn. File cabinet drawers may slide open resulting in some cabinets tipping over. Cupboard doors and drawers occasionaly open and some of the contents fall out. Desks and chairs slide about on the floor, but no furniture is overturned. There are isolated instances where falling objects, such as ash trays, desk lamps, and knick-knacks are broken, especially in areas where the floors are not carpeted. During the shaking, the occupants stop what they are doing and walk/run to lobbies or outside, using stairways in many cases, since about half the elevators have gone out of service. As a result of the shaking, some walls show localized plaster cracking.

Immediately after the quake, the building is opened and is entirely usable except in unusual circumstances in office buildings when disruption of files and desks may be so extensive as to make it impossible to carry on normal activities until the working areas are cleaned up: resulting in as much as a day's delay in returning to work. In these cases, the building is entirely usable by the next day with only minor inconveniences. When the people return, they may spend several hours returning fallen items to their proper places and straightening up the desks, while maintenance men make temporary repairs on the dangling lights and clean up fallen ceiling panels and plaster chips. In apartment buildings, cleanup is done by the tenants.

Final repairs of ceilings, lights, partitions, and windows cause little inconvenience: either repairs are made around the occupants or the occupants move aside temporarily. Damaged elevators are back in service in about 5 days.

Damage States 3, 4, 5 → Incident State B

The occupants hear sounds and perceive motions similar to those described in Incident State A. In buildings with conventional suspended ceilings, the shaking causes about half of the panels to be disturbed, with a few panels actually falling. On one or two floors, a few ceiling brackets may break loose and as many as one-third of the ceiling panels may fall. Also, as many as one-third of the conventional suspended light fixtures in the building are left hanging, with a few fixtures falling to the floor.

As in Incident State A, varying numbers of books fall from the shelves; occasionally unbraced bookshelves collapse or overturn; file cabinet drawers may slide open, resulting in some cabinets tipping over; cupboard doors and drawers occasionally open and the contents may fall out; desks and chairs slide about on the floor with no furniture actually overturning. There may be isolated instances of ash trays, desk lamps, or knick-knacks falling and breaking, especially in areas that are not carpeted. During the shaking, the occupants stop what they are doing and walk/run to lobbies or outside, using stairways in many cases, since about half of the elevators have gone out of service. As a result of the shaking, structural damage may range from a few cracked beams or columns to substantial structural damage requiring repair or replacement of some structural members. There is wide-spread plaster cracking resulting in corridors and exit stairways being substantially littered with plaster debris. Falling items, ceiling panels, etc. may injure 1 occupant in 100 with no one being killed or permanently disabled.

Immediately after the quake, the building is opened, except in unusual circumstances in office buildings when disruption of files and desks may be so extensive as to make it impossible to carry on normal activities until the

working areas are cleaned up: resulting in as much as a day's delay in returning to work. However, in all buildings, there is the possibility that local areas (such as rooms on one floor) are closed as long as a week in order to repair localized disruption of suspended lights and ceilings or to repair/cleanup areas in which there is an unusually large amount of fallen plaster debris. During this time, the people normally occupying this space relocate temporarily to another area of the building until the closed area is cleaned up and made usable. When the people return to the opened areas, they may spend several hours returning fallen items to their proper places and straightening up desks, while maintenance men make temporary repairs on damaged suspended lights and ceilings and clean up plaster debris, except in apartment buildings where cleanup is done by the tenants.

Final repairs of ceilings, lights, partitions, windows, and damaged structural members cause little inconvenience: either repairs are made around the occupants or the occupants move aside temporarily. Damaged elevators are back in service in about 5 days.

Damage State 6 → Incident State C

Obvious evidence of an earthquake can be seen, felt, and heard throughout the building. In buildings with conventional suspended ceilings and light fixtures, many ceiling brackets break or buckle, and most ceiling panels are disturbed or fall to the floor. About half of the suspended light fixtures fall or are left hanging by their wiring. There are frequent instances of ash trays, desk lamps and other small objects shaking off desks and shelves; all books probably fall from the shelves and unbraced bookshelves may collapse or overturn; chairs and file cabinets may be overturned throughout the entire building. Also, the walls and partitions not only crack extensively, but begin to break in some areas with chunks of plaster or concrete falling, possibly causing damage to furniture. Exit stairways and corridors are heavily littered with fallen plaster. The occupants stop what they are doing and walk/run outside, using the stairways since most or all the elevators are out of service. One person in 50 may be seriously injured or killed (1 person in 500 being killed). There is major structural damage requiring repair or replacement of many structural members.

The building is closed for inspection by a structural engineer and is vacated for repairs for as long as 3 months. During this time, the occupants must relocate (temporarily) to another building.

Damage State 7 → Incident State D

Serious shaking of the entire building occurs, loud sounds of cracking and snapping are heard in many areas, and it is very difficult to stand or walk without losing one's balance. All portions of the building suffer serious nonstructural damage; furniture overturning, most suspended ceiling panels and suspended light fixtures falling, and chunks of concrete breaking off the walls. Escape from the building becomes difficult, since all elevators are out of service, corridors and exit stairways are heavily littered with fallen debris, and some areas of the building may have suffered local collapses. One person in 10 may be seriously injured or killed (1 person in 100 being killed) in buildings with conventional suspended ceilings and light fixtures. In other buildings, 1 person in 20 may be seriously injured or killed (1 person in 150 being killed).

The building is condemned. If it is decided to repair the building, it may require several months or longer to reopen and allow the people to move in and carry on the normal routine again.

Damage State 8 → Incident State E

Violent shaking of the building occurs; loud cracking sounds are heard throughout the building as a result of the breaking of plaster walls and yielding of structural members. It is very difficult to maintain one's balance. All non-stationary objects are moving about or falling to the floor; suspended ceiling panels and light fixtures are continually dropping out of the moving suspension system. Escape becomes quite difficult and is impossible in some areas where actual collapse occurs. The entire building may collapse to the ground, and people may be buried or trapped in the fallen debris. Most people in the building will be injured and 1 person in 5 will be killed. The building is left a pile of twisted and broken steel and/or concrete with the building contents and trapped occupants buried in the rubble. Rescue activities ensue in order to recover those people trapped or killed. The building is a complete loss.

Scenario recaps include information tabulated on cards according to the following topics (one card per incident state):

1 • Motions and sounds perceived

2 • Occupants' ability to stand, walk, etc.

3 • Books and bookshelves

4 • Conventional suspended ceilings

5 • Conventional suspended light fixtures

6 • Walls and partitions

7 • Fraction of elevators out of service

8 • Stairways

9 • Structural damage

10 • Time to restore order

11 • Length of time building is out of function

12 • Fraction of building unusable (when opened)

13 • Fraction of occupants seriously injured or killed

14 • Fraction of occupants killed

INCIDENT STATE A

1 • Chandeliers swing like pendulums
Creaking of steel frame
Cracking of partition walls (local areas)
Squeaking of window panes
Breaking of glass
Dishes, etc. rattling

2 • Standing is difficult

3 • A few books to many books fall; unbraced bookshelves collapse in isolated instances

4 • Some panels disturbed in a few rooms - none fall

5 • Several lights displaced or left hanging - a few fall in isolated instances

6 • Localized plaster cracks in some walls

7 • 1/2 of elevators out for 5 days

8 • Clear

9 • None

10 • 3.5 $\frac{\text{man-hrs.}}{100\ \text{s.f.}}$? (not consistent with that reported)

11 • Normally zero (maybe 1 day)

12 • None

13 • None

14 • None

INCIDENT STATE B

1 • Chandeliers swing like pendulums
Creaking of steel frame
Cracking of partition walls (throughout building)
Squeaking of window panes
Breaking of glass
Dishes, etc. rattling

2 • Standing is difficult

3 • A few books to many books fall; occasionally unbraced bookshelves collapse

4 • Half of panels disturbed; a few panels fall

5 • Up to 1/3 of fixtures left hanging; a few fixtures fall

6 • Widespread plaster cracking

7 • 1/2 of elevators out for 5 days

8 • Substantially littered with plaster debris

9 • A few beams or columns cracked to substantial structural damage requiring repair or replacement of some structural members

10 • 4.5 $\frac{\text{man-hrs.}}{\text{100 s.f.}}$

11 • Normally zero (maybe 1 day)

12 • Possibly 30% for 1 week (but not likely)

13	• 1 in 100	Susp. Ceilings & Lights		No Susp. Ceil. & Lights	1 in 500
14	• None				None

INCIDENT STATE C

1 • Chandeliers swing like pendulums
Creaking/snapping of steel frame
Cracking and some breaking of partition walls (throughout building)
Squeaking and breaking of window panes
Dishes, etc. rattling, falling, breaking

2 • Standing is difficult

3 • All books fall from shelves; unbraced bookshelves overturn or collapse

4 • Many brackets break or buckle; most panels are disturbed or fall

5 • Half of fixtures are left hanging or fall

6 • Widespread cracking; in some areas, chunks of plaster/concrete break out and fall

7 • Most or all elevators out for about 7 days

8 • Heavily littered with fallen plaster

9 • Major structural damage requiring repair or replacement of many structural members

10 • 4.5 to 6.5 $\frac{\text{man-hrs.}}{100\ \text{s.f.}}$

11 • Up to 3 months

12 • None

13	• 1 in 50	Susp. Ceilings & Lights		No Susp. Ceil. & Lights	1 in 75
14	• 1 in 400				1 in 500

INCIDENT STATE D

1 • Chandeliers swing and hit ceiling/may fall
Creaking/snapping of steel frame
Cracking and breaking of partition walls (throughout building)
Squeaking and breaking of window panes
Dishes, etc. rattling, falling, breaking

2 • Standing/walking is very difficult

3 • All books fall from shelves; unbraced bookshelves overturn or collapse

4 • Many brackets break or buckle; most panels are disturbed or fall

5 • Half of fixtures are left hanging or fall

6 • Widespread cracking; in many areas, chunks of plaster/concrete break out and fall

7 • Most or all elevators out more than 7 days

8 • Heavily littered with fallen debris; some stairways may partially collapse

9 • Building is condemned

10 • 4.5 to 6.5 $\frac{\text{man-hrs.}}{100\ \text{s.f.}}$

11 • 3 months or more

12 • None

		Susp. Ceilings & Lights	No Susp. Ceil. & Lights
13	• 1 in 10		1 in 20
14	• 1 in 100		1 in 150

INCIDENT STATE E

1 • Chandeliers swing and hit ceiling/may fall
Creaking/snapping of steel frame
Cracking and breaking of partition walls (throughout building)
Breaking of window panes
Various nonstationary items falling and breaking
Ceilings, walls crashing after collapsing

2 • Very difficult to maintain one's balance

3 • All books fall from shelves; unbraced bookshelves overturn or collapse

4 • Many brackets break or buckle; most panels are disturbed or fall

5 • Half of fixtures are left hanging or fall

6 • Widespread cracking and breaking; chunks of plaster/concrete falling

7 • Most or all elevators out more than 7 days

8 • Heavily littered with fallen debris; some stairways may collapse

9 • Building is collapsed

10 • Days to clear away rubble

11 • 1 to 2 years to design/construct new building

12 • None

13 • Most people

All buildings

14 • 1 in 5