

NSF-RA-E-72-306

PB80-150949



MIT CIVIL ENGINEERING BOSTON QUAKE PROJECT

SCENARIOS OF BUILDINGS IN GIVEN EARTHQUAKE

DAMAGE STATES - December 7, 1972

(Subject To Periodic Revision)

REPRODUCED BY: **NTIS**  
U.S. Department of Commerce  
National Technical Information Service  
Springfield, Virginia 22161

EAS INFORMATION RESOURCES  
NATIONAL SCIENCE FOUNDATION



<b>REPORT DOCUMENTATION PAGE</b>	1. REPORT NO. NSF-RA-E-72-306	2.	3. Recipient's Accession No. <b>PB80 150949</b>	
4. Title and Subtitle Scenarios of Buildings in Given Earthquake Damage States (MIT Civil Engineering Boston Quake Project)			5. Report Date December 7, 1972	
7. Author(s)			6.	
9. Performing Organization Name and Address Massachusetts Institute of Technology MIT Civil Engineering Boston Quake Project Cambridge, Massachusetts 02139			8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address Engineering and Applied Science (EAS) National Science Foundation 1800 G Street, N.W. Washington, D.C. 20550			10. Project/Task/Work Unit No.	
15. Supplementary Notes			11. Contract(C) or Grant(G) No. (C) (G)	
16. Abstract (Limit: 200 words)  Eight descriptions of buildings in given earthquake damage states are presented. Scenario recaps include information about the following topics: motions and sounds perceived; books and bookshelves; conventional suspended ceilings; conventional suspended light fixtures; walls and partitions; stairways; structural damage; repair cost ratio; time to restore order; length of time building is out-of-function; fraction of occupants seriously injured or killed; fraction of people killed. The consequences of the earthquake based on each damage site are summarized in chart form.			13. Type of Report & Period Covered	
17. Document Analysis a. Descriptors  Earthquakes                      Ceilings (architecture) Buildings                         Walls Stairways                         Costs Death  b. Identifiers/Open-Ended Terms          c. COSATI Field/Group			14.	
18. Availability Statement NTIS			19. Security Class (This Report)	21. No. of Pages
			20. Security Class (This Page)	22. Price



## State I

The occupants notice a slight trembling over some portions of the building. This trembling causes items on shelves, such as books, cans, lamps, and sculptures to shake, with as many as half of the items falling onto the floor. Light fixtures that are suspended from the ceiling are shaking, but they do not fall to the floor during the 30 to 40 second period of trembling. However the shades on the light fixtures have been disturbed. A few cracks may appear in walls and partitions. Possibly the electrical and mechanical systems will experience minor local damage.

Immediately after the quake, the occupants straighten out the minor disorder: return books and small items to their appropriate shelves, straighten up desks and counter tops. People may congregate in small groups to discuss what they have just experienced. In an office building these post-quake activities result in about an hour of no production, followed by the normal routine. Maintenance men will clean up any plaster chips and straighten those light shades that have been disturbed, except in apartments, where the tenants do it for themselves.

Any opinions, findings, conclusions  
or recommendations expressed in this  
publication are those of the author(s)  
and do not necessarily reflect the views  
of the National Science Foundation.

## State II

The occupants feel a definite trembling throughout the building, with most shelf items (books, cans, etc.) being shaken off and falling onto the floor. Conventional suspended light fixtures (i.e., those fixtures not designed to withstand seismic forces) swing on their brackets, several brackets break, and some of the light fixtures are left dangling by the electrical wiring; however, no light fixtures actually fall to the floor. Some walls show localized cracking. In buildings with conventional suspended ceilings, several of the ceiling panels are dislodged and fall to the floor, possibly causing slight injuries to a few occupants. In buildings without conventional suspended ceilings, it is unlikely anyone will be injured. During the quake, the people leave the building, using the stairways in the event some elevators have gone out of function- as may well be the case.

Immediately after the quake, the people return and may spend several hours returning fallen items to their proper places, straightening up the desks, and gossiping about the quake. Maintenance men make temporary repairs on the dangling lights and clean up fallen ceiling panels and plaster chips, causing little additional interruption of the normal routine in office buildings; cleanup in apartments is done by the tenants. By the next day, the occupants can resume their normal activities.

Final repairs to ceilings, lights, and elevators are done after business hours or on the weekend in order not to cause unnecessary inconvenience, except in apartments where little inconvenience will be caused by the final repair process.

### State III

The occupants not only feel the building shake, but also see its slight movement with respect to near-by buildings and may hear the walls creak as a result of the motion. Everybody vacates the building, probably by the stairways, since some of the elevators are out-of-function. The shaking causes widespread non-structural damage in several areas; shelves and bookcases are overturned, desks and cabinets slide on the floor, conventional suspended light fixtures swing on their brackets with some brackets breaking (however the lights don't fall to the floor), and in some portions of the building, most of the ceiling panels have been dislodged from conventional suspended ceilings and fall. In buildings without conventional suspended ceilings, there may be cracking and chipping of plaster ceilings or partial disturbance of acoustical ceiling materials. The widespread cracking of plaster surfaces results in a shower of plaster chips and dust, with floors and exit stairways becoming littered with the plaster debris. There is little chance of anyone being killed or injured, except in buildings with conventional suspended ceilings, where as many as 2 to 5 people in a hundred may be injured by falling ceiling panels.

After the quake, the building may be closed for 2 or 3 days in order to have it inspected by a structural engineer to determine the extent of structural damage. During this time, maintenance men clean up the debris, pick up the overturned bookshelves, replace fallen ceiling panels in the suspension framework, and make temporary repairs on damaged light fixtures. Since the inspector finds only hairline cracks in a few columns and beams, the building is reopened, the occupants return and spend almost a half-day

to reshelve the books, straighten up the work areas, and prepare to resume the normal routine. In office buildings, final repairs are made after work hours or on weekends in order not to interfere with normal work routine.

#### State IV

The occupants feel a noticeable shaking of the building, see a definite motion with respect to nearby buildings, and in some areas of the building hear the creaking and snapping of cracking walls. Everybody vacates the building, probably by the stairways since most elevators are out-of-service. The shaking causes substantial non-structural damage (with widespread cracking plaster throughout the building), and minor structural damage (with obvious cracking or yielding in a few beams, columns, or slabs). In some portions of the building bookshelves overturn, most hangers of conventional suspended light fixtures are broken and the lights crash to the floor. Also, in some portions of buildings with conventional suspended ceilings, most or all of the ceiling panels are dislodged from the damaged suspension framework and fall to the floor. Exit stairways are heavily littered with broken plaster and possibly concrete masonry blocks or tiles. There may be as many as 5 to 10 persons injured or killed (less than 1 in 100 being killed) in buildings with conventional suspended ceilings and being substantially less in other buildings.

#### State V

Occupants see, feel, and hear evidence of the quake of intensities greater than those perceived in damage State IV. Also, these motions and sounds are noticed over a larger portion of the building rather than in



particular areas. Similarly, there is a widespread occurrence of events such as overturning bookcases, falling light fixtures, and falling pieces of plaster. In addition, entire suspended ceilings may fall to the floor and several exit stairways may be completely buried by fallen walls and debris, making evacuation of the building more difficult and dangerous. In buildings with conventional suspended ceilings and fixtures there may be as many as 10 to 20 persons in 100 occupants seriously injured or killed (1 in 400 being killed). Substantial structural damage is sustained requiring repair or replacement of some members.

After the quake, the building is closed and inspected by a structural engineer. The building is out-of-function until the damaged members are repaired or replaced (about 2 weeks) after which the building is opened and activities are resumed: maintenance men cleaning up and making temporary repairs, occupants restoring order. Final repairs are made on weekends for office buildings, and at as convenient times as possible for hospitals and apartments.

#### State VI

Obvious evidence of the quake is seen throughout the building and a major portion of the interior suffers from falling light fixtures, overturning bookshelves, sliding furniture, and extensive damages to suspended ceilings. Also, the walls and partitions not only crack extensively, but begin to break in some areas with chunks of plaster or concrete falling to the floor. Exit stairways may be buried in debris. Evacuation of the building ensues and 20 to 30 persons in 100 may be seriously injured or killed

(1 of them being killed) in buildings with conventional suspended ceilings and light fixtures. There is major structural damage requiring repair or replacement of many structural members.

The building is closed for inspection by a structural engineer, is vacated for repairs, and remains out-of-function until repairs are made to make the building usable (about 1 month). The building is reopened and the people move back in.

#### State VII

Serious shaking of the entire building occurs, loud sounds of cracking and snapping are heard, and it becomes difficult to walk steadily. All portions of the building suffer serious non-structural damage: overturning furniture, suspended ceilings and light fixtures falling, concrete chunks breaking off the walls, and exit stairways covered with debris. Escape from the building becomes difficult and some areas may suffer local collapses. Thirty persons in a hundred may be seriously injured or killed (3 per 100 being killed).

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

#### State VIII

Violent shaking of the building occurs; loud cracks and pops are heard as a result of breaking of plaster walls and yielding of structural members. It is difficult to maintain one's balance and all objects within the building

are moving about or falling to the floor. Escape becomes more difficult and impossible in some instances where actual collapse occurs. People may become buried or trapped in debris and the entire building may collapse to the ground. Effectively everyone will be injured and half of them will be killed. The building is left a pile of twisted and broken steel and concrete with contents and people buried in debris. Rescue activities ensue in order to recover those trapped or killed. Complete loss of the building.



CONSEQUENCES OF EARTHQUAKE BY DAMAGE SITE

DAMAGE STATE	REPAIR COSTS (RATIO TO CONST. COST)	TIME TO RESTORE ORDER TO BLDG. CONTENTS (CLEANUP TIME)	LENGTH OF TIME BLDG. IS OUT-OF-FUNCTION	FRACTION OF PEOPLE INJURED OR KILLED		FRACTION OF PEOPLE PERMANENTLY DISABLED OR KILLED	
				BLDGS. WITH CONVENTIONAL SUSPENDED CEILING AND LIGHT FIXTURES	BLDGS. WITHOUT CONVENTIONAL SUSPENDED CEILING AND LIGHT FIXTURES	BLDGS. WITH CONVENTIONAL SUSPENDED CEILING AND LIGHT FIXTURES	BLDGS. WITHOUT CONVENTIONAL SUSPENDED CEILING AND LIGHT FIXTURES
1	.001	1-1.5 <u>Man-Hrs.</u> 100 sq. ft.	0	0	0	0	0
2	.005	2-2.5 "	0	1/50-1/100	0	0	0
3	.02	2.5-4.0 "	0	1/20-1/50	1/400	1/2000	0
4	.05	3.5-5.5 "	1 week	1/10-1/20	1/60	1/1000	1/2000
5	.10	4.0-6.0 "	2 weeks	1/5-1/10	1/20	1/400	1/500
6	.30	4.5-6.5 "	1 month	1/3-1/5	1/9	1/150	1/200
7	1.0	4.5-6.5 "	3 months (Relocation of Occupants)	1/3	1/3	1/40	1/50
8	1.0	~	~	ALL  8	ALL	1/2	1/2

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

- Motions and sounds perceived,
- Books and bookshelves,
- Conventional suspended ceilings.
- Conventional suspended light fixtures.
- Walls & partitions.
- Stairways.
- Structural damage.
- Repair cost ratio.
- Time to restore order.
- Length of time building is out-of-function.
- Fraction of occupants seriously injured or killed.
- Fraction of people killed.