

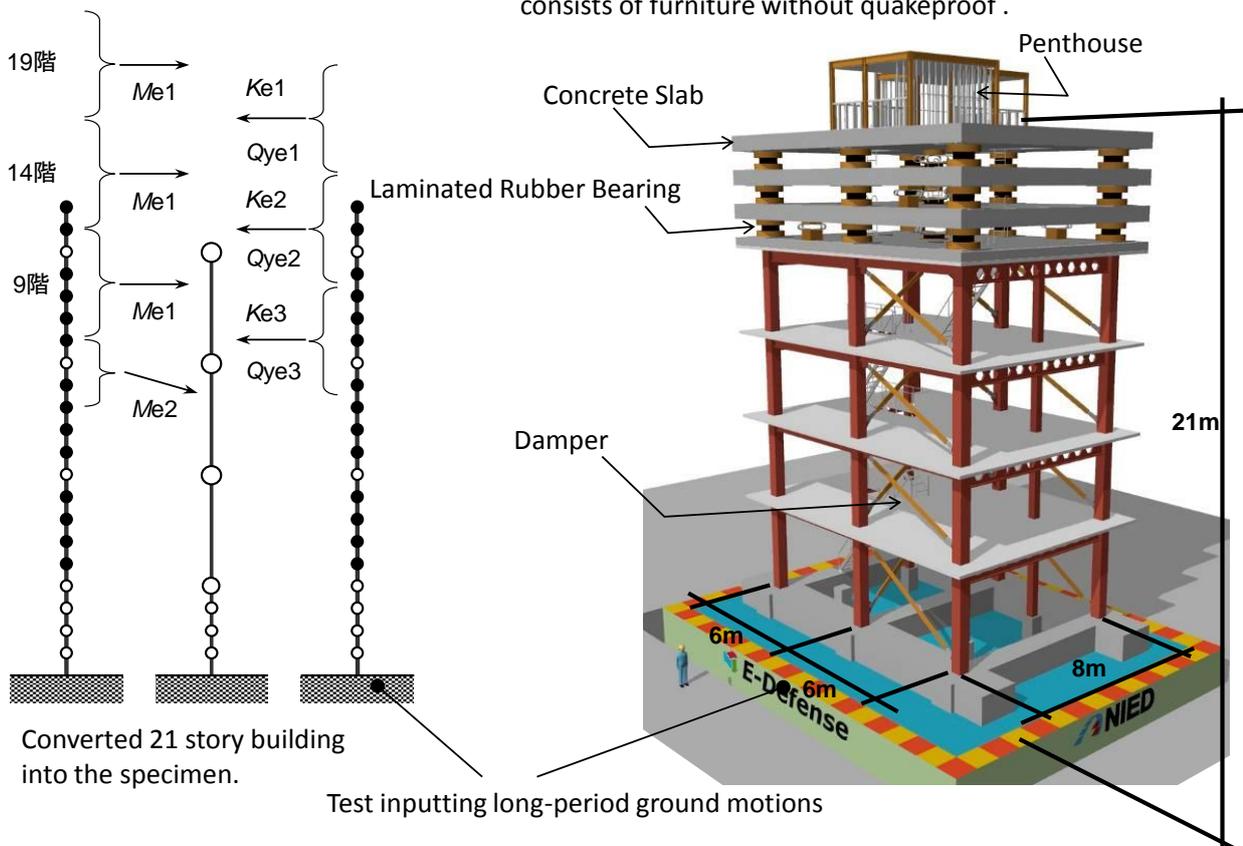
## Shaking Table Test on High-Rise Steel Building: Response Reduction by Retrofit with Dampers and Countermeasures for Nonstructural Components in Rooms

A four-story steel frame structure was prepared as the test frame, and concrete slabs and laminated rubber bearings were placed on it as the substitute layers. Dampers were incorporated in the test frame. In the test, response of 19<sup>th</sup> floor appears at the roof of the test specimen. A pair of penthouses were set including furniture to study the damage of rooms.

(a) Three kinds of rooms were prepared in the penthouse for each sequential tests.

- (1) Meeting room of the office complex.
- (2) Working space of the office complex.
- (3) Dining kitchen of the apartment complex.

(b) Almost the same layouts were adopted in a pair of penthouses for each kind of room. One consists of furniture with quakeproof countermeasures, and the other consists of furniture without quakeproof.



Experimental specimen for a 21-story high-rise building

\*Detail conditions of shaking table tests are referred in the other papers.

## Office/Meeting Room



In meeting rooms, furniture tends to be wheeled in order to change layout depending on the purpose of meetings.

### Before Experiment

Without a countermeasure	With countermeasures
 <p>The tables, chairs and board, with wheels were left unlocked and a telephone was left as it was.</p>	 <p>The wheels were locked to stop wheeling. The chairs were exchanged to folding chairs without wheels. The telephone and the stand were fixed with sticky quakeproof mats.</p>

### Countermeasures

			
<p>4 pieces of sticky quakeproof mats (two of 3cm square and two of 2cm square) were used to fix the telephone stand on the floor and to fix the telephone on the stand. The wheels of the tables were locked.</p>			

## After the experiment

Without a countermeasure



The furniture kept moving for long time and hit on walls repeatedly insomuch as to make holes on them.

With countermeasures



The tables, chairs and board with rocked wheels fell down. But they did not slide or move around. The telephone and the telephone stand did not move at all.

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## Office / Workspace



Behaviors of furniture in a workspace of office was examined. Almost the same layouts were adopted a pair of rooms, and effects of countermeasures were verified. In each room, three desks, three chairs with wheels, five steel bookshelves, a steel cabinet and a copy machine were set up. A desktop personal computer, a laptop and a printer were placed on the desks. Two bookshelves were placed to play roles of partition and blindfold so that a trend of ordinary office rooms was reproduced.

## The Copy Machine Before the Experiment

Without a countermeasure	With countermeasures
 <p style="text-align: center;">The casters were unlocked.</p>	 <p style="text-align: center;">The casters were fixed by special stoppers.</p>

## Countermeasures

		
<p>Sticky quakeproof mats were used to fix metal fixers on the floor. Four fixer were plugged to each casters for restraining the movement of casters.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>The copy machine kept running and hitting on things around for long time, and finally broke into 2 pieces by cumulative impulsions.</p>	 <p>The copy machine fixed by a special tool didn't move neither fell.</p>

## The Book Shelves Before Experiments

Without a countermeasure	With countermeasures
	
<p>Supposing to be used as a partition, bookshelves were set apart from the wall so that their front and back become open space.</p>	

## Countermeasures

 <p>Base of a shelf was clamped by fixers utilizing sticky quakeproof mats.</p>	 <p>Four strut poles were set on the top of a shelf.</p>	 <p>Base of a shelf was clamped by bolted L-shape steel clasps.</p>
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## After Experiments

Without a countermeasure	With countermeasures
 <p>The shelves fell down to backward open space at the beginning of the experiment.</p>	 <p>The shelves showed effects of various countermeasures, and both of them didn't move or fall.</p>

## The Low Board Before Experiments

Without a countermeasure	With countermeasures
	
<p>Five cartons full with papers inside were placed on the top and folders were set inside of the low cabinet.</p>	<p>Five cartons full with papers inside were placed on the top and folders were set inside of the low cabinet.</p>

## Countermeasures

		
<p>Sticky quakeproof mats, 2x10cm, were used at four corners and the middle. The sliding doors were locked.</p>		

## After Experiments

Without a countermeasure	With countermeasures
	
<p>All of cartons were fallen down and things inside were scattered. The cabinet didn't move.</p>	<p>Nothing moved.</p>

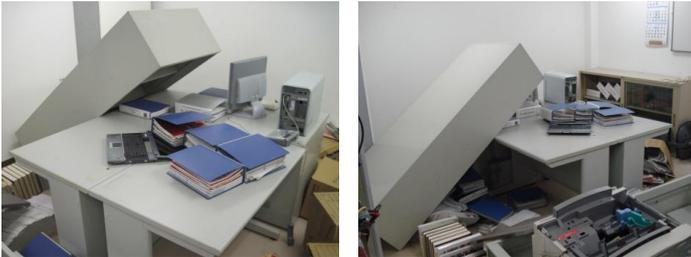
## The Book Shelves Before Experiments

Without a countermeasure	With countermeasures
 <p>Cartons full with papers inside were set on top of the shelves. Books and files were put inside the shelves.</p>	 <p>Nothing was left on top of the shelves, books and files were set lower part with extra space.</p>

## Countermeasures

		
<p>The left bookshelf; sticky quakeproof mats were used for fixers to clamp base to the floor. The middle and right shelves; The shelves were bolted to the wall at the top and bolted to the floor at the base by using L-shape steel claps. Poles, rubber bands and chains were laterally set in the width direction of open shelves.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>All the book shelves fell down and clashed against desks. Papers and files came out and scattered apart.</p>	 <p>All the book shelves fell down and clashed against desks. Papers and files came out and scattered apart.</p>

## The Office Room Before Experiments

Without a countermeasures	With countermeasures
 A photograph of an office desk with a laptop, a desktop monitor, and a printer. A bookshelf filled with binders is visible in the background.	 A photograph of the same office desk, showing the laptop, desktop monitor, and printer. The setup is similar to the 'Without countermeasures' photo.
<p>A desk top PC, a lap top PC and a printer were set on desks.</p>	

## Countermeasures

 A photograph showing the underside of a laptop with a blue sticky mat attached to the bottom.	 A photograph showing the underside of a desktop PC case with a blue sticky mat attached to the bottom.	 A photograph showing the underside of a printer with a blue sticky mat attached to the bottom.
<p>Sticky quakeproof mats were set to bottoms of the desk top PC, the lap top PC and the printer, everything on the desks. And also quakeproof mats were set to the underneath of all desk legs.</p>		

## After Experiments

Without a countermeasures	With countermeasures
 A photograph of the office desk after the experiment without countermeasures. The desk is cluttered with papers, folders, and boxes, and the chairs are moved.	 A photograph of the office desk after the experiment with countermeasures. The desk is clean and organized, and the chairs are moved.
<p>Things on the desks were displaced slightly in consequence of clashing by the bookshelf nearby, but not significantly moved.</p>	<p>Only chairs with casters bumped around, but other things didn't move at all.</p>

# House



For experiment of a house, places where persons gather, such as dining, kitchen and living room were reproduced to study the behaviors of the furniture and household articles.

## The TV and TV board Before Experiments

Without a countermeasure	With countermeasures
	
<p>A 29-inch tube TV was set on a TV stand with casters. The casters were unlocked.</p>	<p>A 37 inches liquid crystal television was set on a TV stand without casters.</p>

## Countermeasures

		
<p>Sticky quakeproof mats were applied to the underneath of TV stand and the underneath of liquid crystal television.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>TV stand was moving around all the room, after a little while, TV dropped off, even after that, the stand kept moving all over the room and hitting things around repeatedly.</p>	 <p>The TV stand didn't move. The neck of the TV turned back and forth, left and right though it didn't break. The sliding door of the TV stand came off.</p>

## Dining room Before Experiment

Without a countermeasure	With countermeasures
 <p>An electric pot, a toaster oven, a rice cooker, a telephone and a stand mirror were set on a low board.</p>	 <p>Similar things as the case of "without a countermeasure" were set on a low board, except a stand mirror.</p>

## Countermeasures

		
<p>Sticky quakeproof mats were set directly to the bottom of things and low board itself as well.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>Things set on the low board were slid down and scattered apart, but the low board didn't move.</p>	 <p>Neither things on the low board nor the low board moved.</p>

## The Cupboard Before Experiments

Without a countermeasure	With countermeasures
	
<p>Two sets of separate-type commonly used cupboards were placed along the wall. Dinnerware was stored inside.</p>	<p>Two sets of separate-type cupboards were placed along the wall. Earthquake countermeasures were taken for them.</p>

## Countermeasures

		
		
<p>Commercially-available products were adopted preventing spring out of hinged doors and sliding drawers. The left cupboard; sticky quakeproof mats paired with L-shaped steel clasps were used to clamp the bottom. And the same mats were incorporated between top and bottom parts. The right cupboard; the top part was diagonally pulled up to the wall with resistant belts, and the bottom was bolted to the floor with L-shaped steel clasps. The top and bottom parts were bolted together with steel clasps.</p>		

## After Experiments

Without a countermeasure	With countermeasures
	
<p>Right after the shaking start, the top parts of the cupboards were tipped over, and broken dinnerware was scattered apart. After that, the bottom parts of the cupboards start moving and tipped over as well.</p>	<p>Both of the right and left cupboards didn't move or tip. Owing to the countermeasures taken to the hinged door, dinnerware didn't come out.</p>

## The Refrigerator Before Experiments

Without a countermeasure	With countermeasures
 <p>A common refrigerator has casters on its back bottom for easy-moving. The same type of refrigerator was set, whose casters had no lock function.</p>	 <p>A common refrigerator with casters, which have no lock function, was fixed with additional stopper.</p>

## Countermeasures

		
<p>The sticky quakeproof mats coupled with L-shaped steel clasps were incorporated at bottom of the refrigerator. The stopper belts were applied to all the hinged doors and the sliding drawers to prevent springing out.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>The refrigerator was moving around with the doors banging, and its contents sprang out and scattered apart. After a while, the refrigerator toppled over.</p>	 <p>The refrigerator stayed at the original position, and the doors and drawers didn't move at all.</p>

## The Dining Table Before Experiments

Without a countermeasure	With countermeasures
 <p>A dining table and chairs were set reproducing COF 01.-0.3, supposing condition between wood floor and wood furniture.</p>	 <p>A dining table was specially treated to fix on the floor. Chairs having adjunctive mats at the bottoms of their feet were set.</p>

## Countermeasures

		
<p>Sticky quakeproof mats were incorporated to the bottom of the dining table. Sixteen pieces of 2cm square mats were used.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>At the start of shaking, the dining table was covered by the overturning cupboard. After that the table and chairs kept sliding and scattering with other things.</p>	 <p>They stayed at their original position.</p>

## House Plants Before Experiments

Without a countermeasure	With countermeasures
 <p>A tall house plant was set with a saucer.</p>	 <p>A similar tall house plant.</p>

## Countermeasures

The flower pot saucer	The flower pot	
		
<p>The sticky quakeproof mats were applied directly on the flower pot saucer and the flower pot.</p>		

## After Experiments

Without a countermeasure	With countermeasures
 <p>The house plant tipped over and kept rolling around from the beginning.</p>	 <p>The house plant stayed its original position.</p>