

Case Studies of **Seismic Nonstructural** Retrofitting in

School Facilities

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Retrofitting of School Facilities"

## Case Studies of Seismic Nonstructural Retrofitting in School Facilities

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Reference 1      Bibliography

Reference 2      Investigative Research for Promoting the Seismic Retrofitting of School Facilities (Purpose of the Study Group)

## Case Studies of Seismic Nonstructural Retrofitting in School Facilities

### 1. Introduction

Securing the safety of school facilities against earthquakes is important, because children spend a large part of the day studying and playing at schools, which also act as emergency evacuation facilities for the local community.

This document is intended for local authorities that establish schools, and for school teachers and staff. It introduces examples of seismic retrofitting on nonstructural members that could be identified and implemented through daily inspections.

With the introduction of the new seismic codes (1981) in the Building Standard, seismic retrofitting of buildings has made progress. For school facilities, the Ministry of Education, Culture, Sports, Science and Technology (hereafter called; the Ministry) has established the Guideline for Improving the Seismic Resistance of School Facilities (July 2003).

At the investigative research cooperator meeting for establishing the Guideline for Improvement of School Facilities, which was held in March 2005, a proposal was made for the urgent improvement of seismic resistance in school facilities. It is believed that further measures for improving the seismic performance of school buildings will proceed in the future.

Through these efforts, damages to the school main structure from earthquakes would be reduced. However, when retrofitting is insufficient, nonstructural members, such as ceiling material, equipment, and various fixtures could fall or topple, and could cause significant harm to children and others.

In recent years, people have been harmed by falling nonstructural members from earthquakes, such as from the Geiyio Earthquake (March 2001), Mid-Niigata Prefecture Earthquake (October 2004) and the Fukuoka Prefecture West Offshore Earthquake (March 2005). It is still fresh in our memories that many people, who were inside a sports facility, were hurt from falling ceiling material during the earthquake (Magnitude 7.2, maximum seismic intensity 6 lower), that occurred in August 16, 2005, with a hypocenter off the coast of Miyagi Prefecture.

This case study is based on the "Investigative Survey Report on the Seismic Inspection of Nonstructural Members in School Facilities" (March 2002) (hereafter called the "Academic Report on Nonstructural Members"), which the Ministry commissioned the Architectural Institute of Japan to develop.

The examples of seismic non-structural retrofitting in school facilities show the conditions of damages from previous earthquakes, as well as retrofit examples, by using photos and illustrations to make them easier to understand.

It is our hope that this case study, together with the "Academic Report on Nonstructural Members", will help increase the awareness among school founders, administrators, teachers and staff, toward the need for seismic retrofitting of non-structural members as well as toward retrofitting methods. Consequently, it is hoped that this will contribute in securing the safety of students and children.

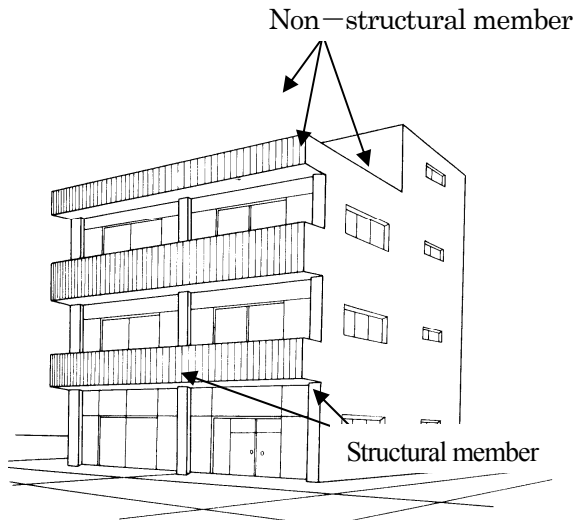
## 2. Definition of Nonstructural Member

"Nonstructural member" refers to members other than major structures that are such as columns, beams, walls and floors. In the narrow sense, the term indicates portions of structures, such as exterior walls, which are not major structures, but in the broad sense, this could include items, such as fixtures and furniture.

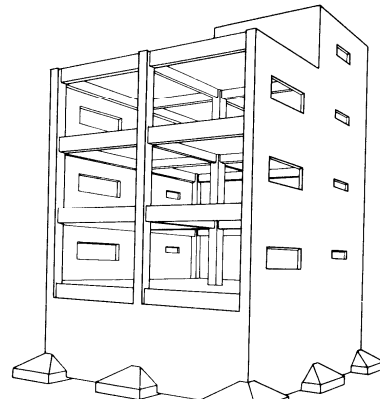
In this document, nonstructural members include all members and components (nonstructural member in the broad sense that includes fixtures and furniture), excluding structural members. Such items will be referred to as "nonstructural members".

Table 1 Classification of members and components that compose structures

Categories	Sub-categories		Items	Specific examples	
Main structure	Structural element	Structure	Major structural item	Column, Horizontal member, Foundation, Piling	
			Main structure	Roof, Column, Beam, Floor, Stair	
		Workpiece	Specific structure	Chimney (more than 6 m high), etc.	
Minor structure	Others		Secondary member	Precast panel frame	
			RC non-bearing wall	Wing wall, Hanging wall, Standing wall	
	Nonstructural construction element			Portion of structure	Roof, Exterior wall, Ceiling, Interior wall
				Building attachment	Billboard, Chimney (less than 6 m high), etc.
				Exterior items	Wall, Fence
				Attachment to main structure	Expansion joint, etc.
				Furniture and fixture	Furniture, Fixture, Ornaments
	Non-structural facility element			Equipment	Equipment unit
				Pipe and ductwork	Vertical ductwork, Horizontal ductwork, etc.
				Other facilities	Elevator, Escalator



Overall structure  
(structural + non-structural members)



Only structural member

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Figures were excerpt from the "Structural Training Materials" (Architectural Institute of Japan, ed.)

### 3. Case Studies of Seismic Retrofitting

This document looks into the following 19 cases of 'non-structural members' among school facilities that are relatively prone to damages from earthquakes. Seismic nonstructural retrofitting of such item is thought to be possible through daily inspections and at low costs. Then, the conditions of damage and cases of retrofitting will be shown.

For further information on retrofitting, please refer to related sections of the "Academic Report on Non-structural Members".

№	Cases of retrofitting
①	Ceiling material
②	Window and windowpane
③	Exterior wall and siding (concrete block and ALC walls)
④	Lighting fixture
⑤	Outdoor unit (air conditioner and heating unit)
⑥	Elevated water tank and cooling tower
⑦	Chimney
⑧	Refrigerator
⑨	Bookshelf and locker
⑩	TV and computer
⑪	Piano
⑫	Machine tool
⑬	Storage shelves in special classes
⑭	Gymnasium equipment and facility
⑮	Shoe locker
⑯	Wall and gate post
⑰	External staircase and surroundings
⑱	Retaining wall
⑲	Other items

## Ceiling Material

### ◆ Damages

- Falling ceiling materials at the special classroom
  - Ceiling boards fell together with the mounting brackets because of significant seismic motion.



2004 Chuetsu Earthquake, Niigata

- Fallen auditorium ceiling
  - Auditorium ceiling material fell together with the mounting brackets because of significant seismic motion.

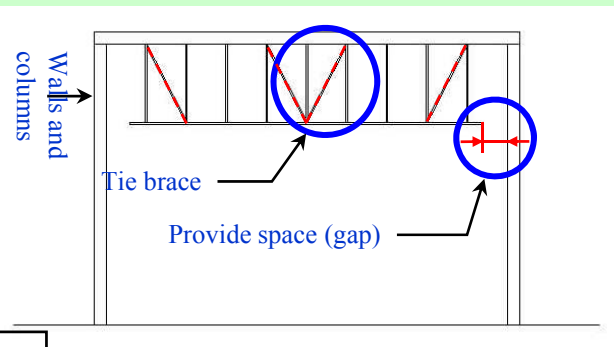


1993 Hokkaido Southwest Offshore Earthquake

### ◆ Retrofitting

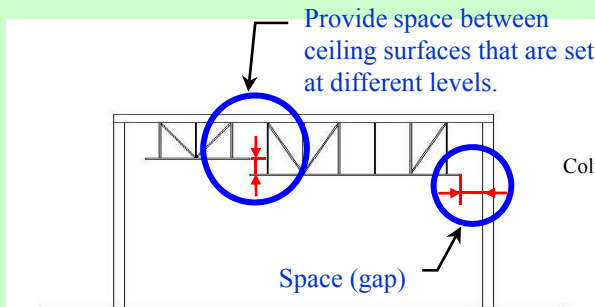
- Daily inspection
  - Verify that tie braces are installed by inspecting through access ports.
  - Verify that intervals between hanging bolts are sufficient and that the bolts are tightened.
  - Verify that ceiling board have not moved, cracked or deformed, and that fasteners are not loose or rusted.
- Retrofitting
  - Provide sufficient space between ceiling material and wall or column.
  - Hanging bolts are long ( $\geq 1500$  mm) in gymnasiums where there are significant space between the roof and ceiling). Horizontal and diagonal tie braces should be installed to prevent the ceiling from moving.

#### Ceilings with even surfaces

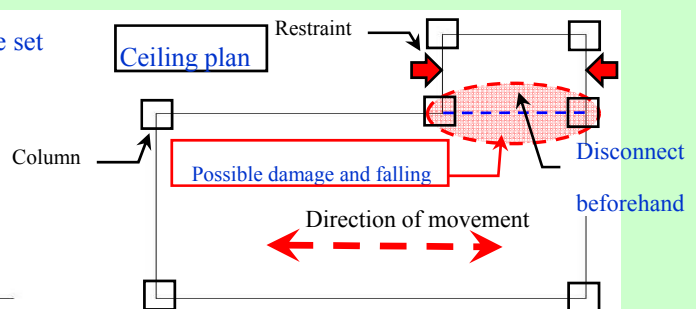


#### Ceiling surfaces that are uneven or set at different levels

- Ceiling surfaces set at different levels
  - This results in some portions of ceilings with high or low rigidity, which requires retrofitting, such as by securing space between portions with different rigidity.



- Ceiling with irregular horizontal layout
  - Ceilings with irregular horizontal layout could be damaged at the joint between the rectangular portions of ceilings. Disconnecting the restraint at such joint is effective.



### ◆ Note (Reference)

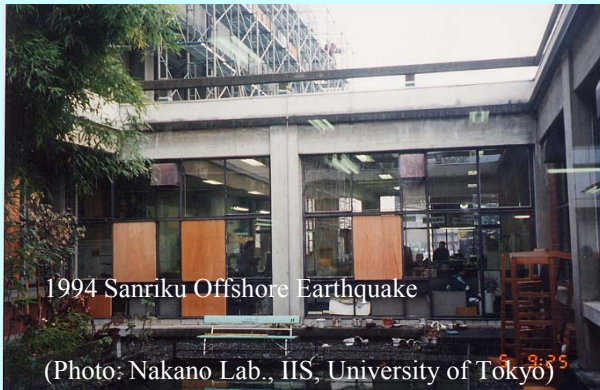
- For retrofitting, refer to the "Survey report on ceiling damages at the airport terminal building from the 2003 Tokachi-oki Earthquake", cited in the "Measures against falling ceilings in buildings with large open spaces (Ministry of Land, Infrastructure and Transport, Oct. 14, 2003)".

◇ <http://www.nilim.go.jp/japanese/report/journal/tenjou.pdf>

## Window and Windowpane

### ◆ Damages

- Damages attributed to the windowpane installation method
  - Fixed windows were damaged, when installed with hard sealants according to the previous method in use before the current provision\*, and the windowpanes could not follow structural deformation.
  - When wire-reinforced glass is cracked, it does not fall, but normal sheet glass becomes shattered and fall.



- Damaged windowpane hit by braces.
  - Buckled bracing members at the gymnasium protruded in the lateral direction, hit the windowpane, and broke the glass (Photo a).



### ■ Derailed windows and doors

- The earthquake impact derailed the fixtures and broke windowpanes.



### ◆ Retrofitting

- Prevent sidings from falling
  - Apply antishattering film on normal sheet glass, to make it act like wire-reinforced glass, and prevent the glass from shattering and falling.
  - Inspect that there are no degradation or loosening of fixtures. Adjust fixtures if necessary.
- Allow deformation of adjacent members
  - Stop using hard sealants to fix sheet glass to the window frame. Install windowpanes in accordance to the current design provision\*.
  - Use bracing connections that prevent buckling of tie braces in the lateral direction (Right photo).



### ◆ Note (Reference)

- For details, refer to the "Measures against earthquakes for windowpanes", Japan Building Disaster Prevention Association.

◇ <http://www.kenchiku-bosai.or.jp/topics/madogarasuNEWS.html>

\*Design provision: Since Notification No.109, No.3, No.4 of 1978 by the Ministry of Construction, external curtain walls that are more than three stories high should not use hard sealants to install windowpanes into fixed windows. However, this could be exempt when wire-reinforced glass or other safety measures are implemented.



### ✦ Damages

#### ■ Collapsed concrete block sidings

- Staircase roof was directly hit by block sidings that collapsed from the gymnasium gable wall.



#### ■ Collapsed ALC\* and precast panel sidings

- Exterior sidings was damaged and had fallen, when they could not follow the seismic deformation, or when they collided with adjacent structures (main structures were steel in both cases).



### ✦ Retrofitting

#### ■ Daily inspection

- Verify that exterior sidings have not degraded, such as loosening, uplifting, spalling, or cracking.
- Verify that the shape and dimensions of fasteners (mounting hardware for siding materials) are appropriate.

#### ■ Prevent sidings from falling

- Repair spalling and cracked sidings by injecting resin, replacing fasteners, reinforcing to prevent collapse, or refurbish with other building methods. (If immediate implementation is difficult, apply emergency measures, such as by restricting entrance or passage by considering the potential area affected by falling material.)

### ✦ Note (Reference)

- For refurbishment, refer to the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

\*ALC panel: Autoclaved lightweight (aerated) concrete panel. The high temperature and high pressured steam cured 'autoclaved aerated lightweight concrete' panel, which is a factory-fabricated building material that is light, fireproof, and has high insulation performance. The material is frequently used as exterior sidings, and the standard panel size is about 600 mm wide and 100 mm thick.

Precast concrete panel: A collective term for standardized reinforced concrete panels prefabricated in factories.

The material is used as columns, beams, wall panel, roof panel, etc., that are assembled at site to form structures.

◆ Damages

■ Fallen lighting fixture (chain pendant type)

- Lamps fell to the floor together with mounting brackets (chain pendant type).



■ Fallen lighting fixture (pipe hung type)

- Lamps were left dangling when mounting brackets in the ceiling failed.



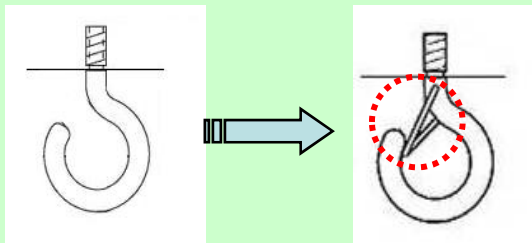
◆ Retrofitting

■ Daily inspection

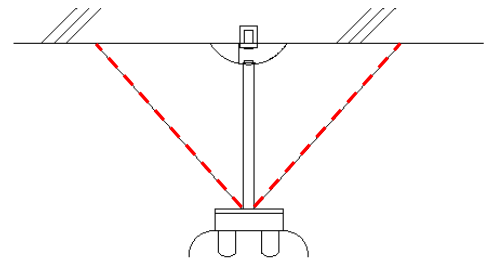
- Verify that lamp mounting brackets are not loose.
- Verify that there is no rust or deterioration of mounting brackets.
- Verify that lamp shades are not left loose.

■ Retrofitting

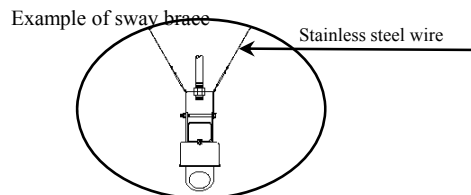
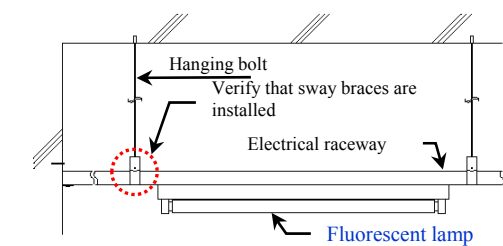
- Modify hooks on mounting brackets to those with safety latches (See figure below).
- By covering lamp chains with commercially available plastic tubes, the earthquake impact on fixtures could be reduced.\*
- Installing sway braces to pendant lights is effective, and electrical raceways should be fixed to columns or walls (See right figure).



Modify hook



Install sway braces



Example of mounting an electrical raceway

◆ Note (Reference)

■ Retrofitting methods above are excerpts from the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

■ Replacing lamps with 'shatter-resistant fluorescent lamps' is also effective.

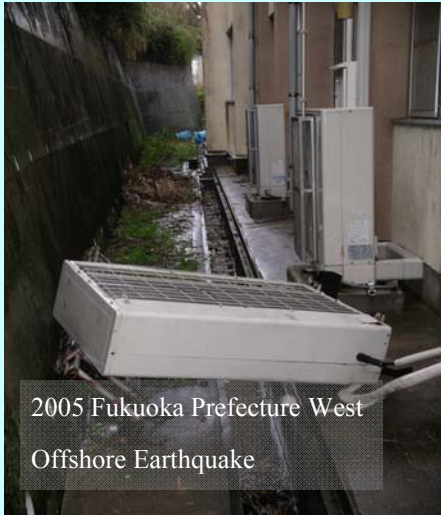
\*Excerpt from the "Research and development on fall prevention", Fire Research Institute, Tokyo Fire Department.

◇ <http://www.tfd.metro.tokyo.jp/ts/skk/02-3.htm>

### ◆ Damages

#### ■ Overturned air conditioner outdoor unit

- The outdoor unit overturned when the mounting fixture failed during the seismic impact.



#### ■ Dangers of placing outdoor units on eaves and roofs.

- Falling air conditioner outdoor units that are installed on roofs and balconies could harm pedestrians.



### ◆ Retrofitting

#### ■ Daily inspection

- Verify that there is no rust or deterioration of mounting fixtures.
- Verify that mounting fixtures are intact and sufficiently anchored to the base.

#### ■ Prevent overturning

- Install restrainer to prevent uplift of outdoor units (See right photo).



### ◆ Note (Reference)

- Sufficient care is needed for installing air conditioner outdoor units on roofs and balconies at the second floor and above, since they could fall from the seismic impact and harm pedestrians.

Elevated Water Tank and Cooling Tower

◆ Damages

■ Shifting on concrete base

- Insufficient anchoring of elevated tanks and cooling towers result in shifting and displacement from the impact of the seismic motion.



2004 Chuetsu Earthquake, Niigata

■ Shifting and displacement on concrete base.

- Seismic motion shifted the elevated water tank, which fell off the base.
- The seismic motion shifted and overturned the concrete base itself.

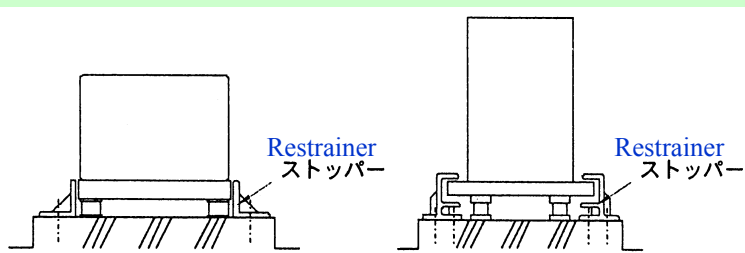


2004 Chuetsu Earthquake, Niigata

◆ Retrofitting

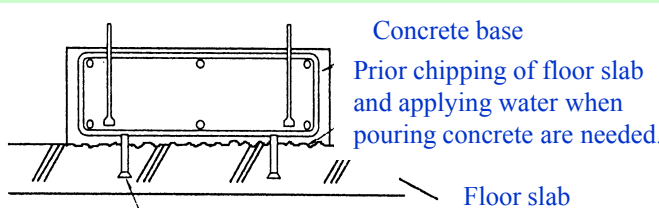
■ Daily inspection

- Verify that there is no rust, deterioration or loosening of anchor bolts or uplift restrainers.
- Verify that there are no defects or damages on the concrete base where anchors or uplift restrainers are fixed.
- To continue the use of items from immediately after the earthquake, verify that the pipe connectors use flexible joints.



For a unit with relatively low center of gravity, a retractor that could restrain horizontal displacements is sufficient.

For units with high center of gravity, it is advisable to use restrainers that could restrain horizontal displacement and uplift.



Prior chipping of floor slab and applying water when pouring concrete are needed.

Insert and fix with concrete anchor (obtain solid connection between rebar and anchor head)

Typical flexible joint



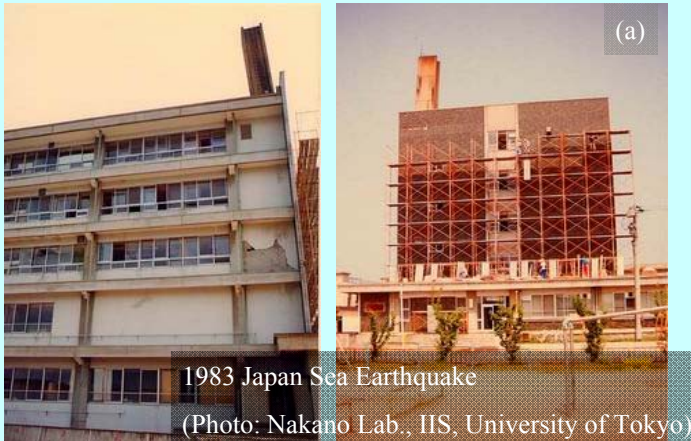
◆ Note (Reference)

- Countermeasures that are shown are excerpts from the "Disaster Management Manual", Institute of Industrial Science, University of Tokyo (April 2002).

### ◆ Damages

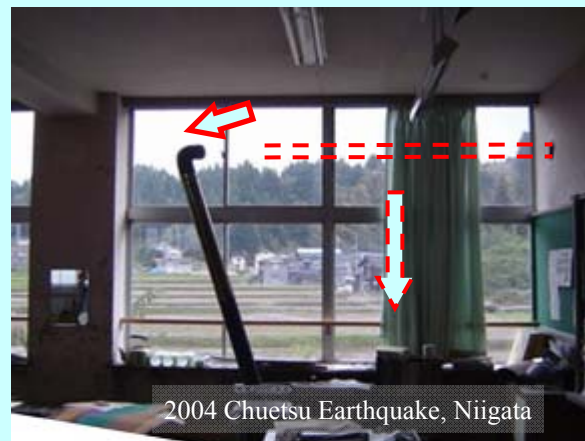
#### ■ Damage on reinforced concrete outdoor chimney

- Damage at the base of reinforced concrete chimney positioned above the roof (See photo a)
- Fallen chimneys that had stood along the school building.



#### ■ Tilted metal chimney

- The top of indoor and outdoor metal chimneys have tilted.



### ◆ Retrofitting

#### ■ Daily inspection

- For concrete chimneys, verify that there are no degradations, such as cracks, detachment or spalling of surface mortar, rusting rebars, and deterioration.
- For metal chimneys, verify that there are no rusting or degraded fixing brackets, loose fixing wires, or moving chimneys.
- Inspect that old or unused chimneys are not left remaining in school.

#### ■ Prevent chimneys from overturning and falling

- If possible, remove chimneys that have no plans to be used.
- Install sway brace on chimneys. For heavy concrete chimneys, the fixed end of fixing stay or wire should be sufficiently bound or anchored.
- Chimneys that are difficult to reinforce should be removed when refurbishing the building. Until then, the chimney should be reinforced as mentioned before, or for chimneys with small influence areas when they fall, entrance to the potential influence areas should be restricted.

### ◆ Note (Reference)

- For refurbishment, refer to the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

Kitchen Equipment, such as Refrigerator and Oven

◆ Damages

■ Overturned refrigerator

- Large kitchen refrigerator fell forward because of the seismic motion.



■ Overturned oven

- The seismic motion caused the large kitchen oven to moved forward, hit the trolley and tilt steeply.



◆ Retrofitting

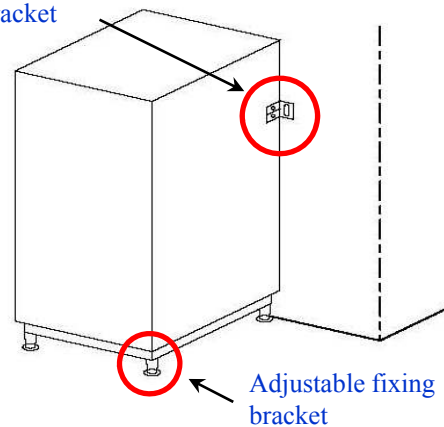
■ Daily inspection

- Verify that the equipment is fixed to the floor with fixing brackets at the support base, and the top part is fixed to the wall.
- Verify that the fixing brackets are not rusted or degraded.
- Verify that fixing brackets are not loose.
- Install equipment on flat surfaces to restrict overturning.
- To store heavy items, store items in low positions to keep the center of gravity as low as possible.

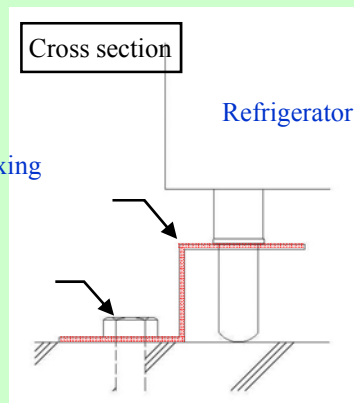
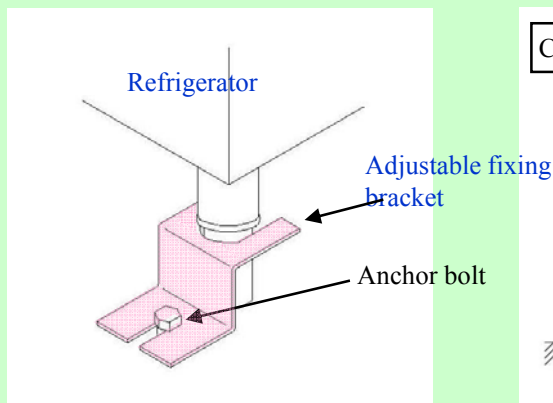
■ Retrofitting

- Equipment that is not fixed to the floor or wall, should be secured with fixing brackets.
- Fix equipment to the floor with adjustable fixing brackets.

Fixing bracket



Fix to the floor slab



Example of adjustable fixing bracket

◆ Note

- Seismic retrofitting of kitchen equipment, such as refrigerators, is important to prevent fires being caused by seismic motion, since fires are being used in the kitchen.
- Retrofitting methods above are excerpts from the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

## Bookshelf and Lockers

### ◆ Damages

- Prevent overturning of bookshelves and lockers, and prevent contents from bursting out.
- Overturned bookshelves and lockers by the seismic motion. The contents burst out and were scattered over the floor.



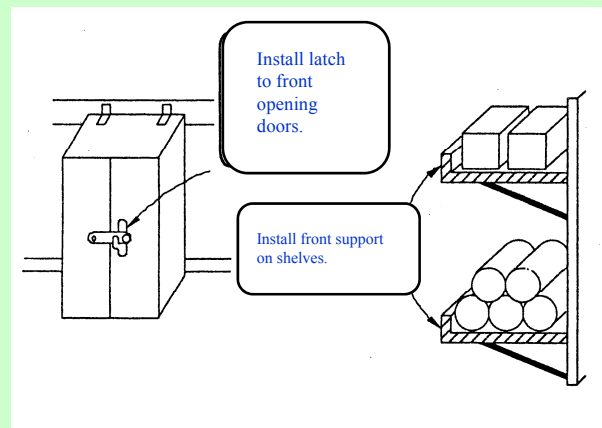
2004 Chuetsu Earthquake, Niigata



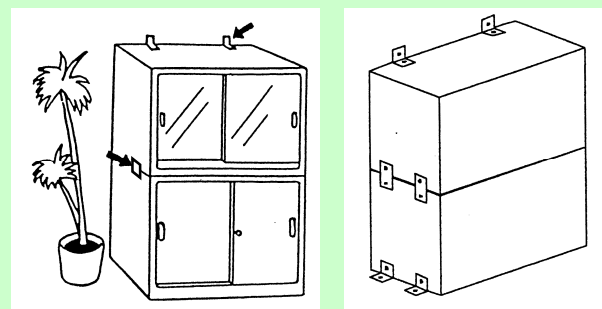
2004 Chuetsu Earthquake, Niigata

### ◆ Retrofitting

- Fixing and securing bookshelves and lockers
- Fix bookshelves and lockers to sturdy wall, beam or ceiling with metal brackets.
- Interconnect the top of tall and shallow bookshelves.
- Bookshelves or lockers that are stacked should be fixed at the base and at the joint.
- Install a latch at the center of front opening doors.



2004 Chuetsu Earthquake, Niigata



### ◆ Note (Reference)

- Countermeasures that are shown are excerpt from the "Disaster Management Manual", Institute of Industrial Science, University of Tokyo (April 2002)

➤ **Damage**

■ TV that fell from the shelf

- TV that was placed on the shelf toppled and fell.
- There were many cases of TV that did not topple, but skid off the shelf.
- Furthermore, TV and shelves that had toppled blocked the classroom entrance and became obstacles to evacuation. (See photo a)

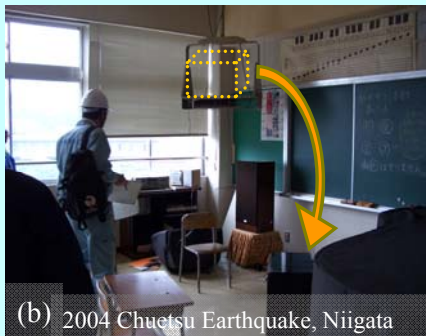
■ TV that fell from hanging shelf

- Seismic motions caused the TV to skid off the hanging shelf. (See photo b)
- TV falling off hanging shelves could cause serious head injuries.
- Seismic motions caused desktop computers to fall off the desk.

■ Computers that fell (See photo c)



(a) 2004 Chuetsu Earthquake, Niigata



(b) 2004 Chuetsu Earthquake, Niigata



(c) 2004 Chuetsu Earthquake, Niigata

➤ **Retrofitting**

■ TV placed on shelf

- The shelves should be relatively low and stable.
- When TVs are to be placed on relatively high shelves, the shelves should be prevented from overturning (See Case 9; bookshelves and locker).
- The TV should be sufficiently fixed to the shelf with belts or other means to prevent it from skidding and falling (See photo d and e)

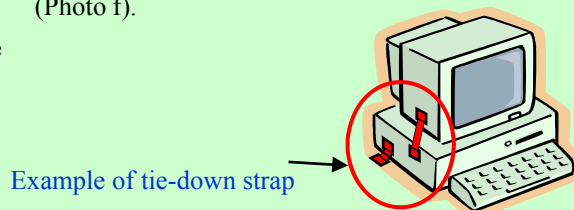
■ TV placed on hanging shelves

- Verify that the mounting brackets of hanging shelves are secure and not loose.
- The TV should be securely fixed to the shelf with belts or other means to prevent it from skidding off (See photo d and e)

- It is important to verify that hanging shelves are sufficiently anchored to the concrete slab above the ceiling board.

■ Computer

- To prevent desktop computers and displays from overturning, it is effective to secure their movement by using tie-down straps and self-adhesive cushion pad (Photo f).



(d)



(e)



(f)

➤ **Note (Reference)**

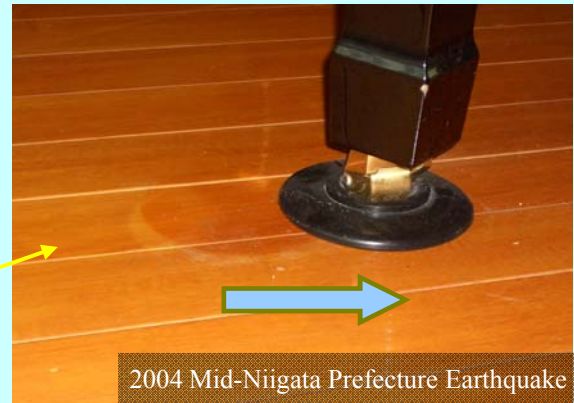
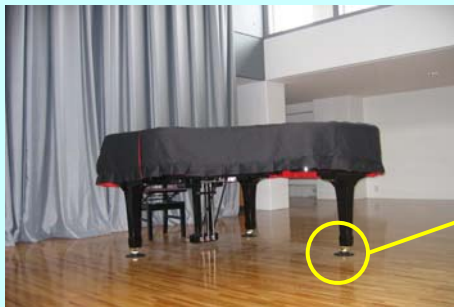
- TV stands on wheels could move significantly. Therefore, such TV stands should be fixed to prevent moving or overturning.
- Many commercially available TV stands could be fixed at the back. In such cases, they should always be fixed.



✦ Damages

■ Skidding grand piano

- The grand piano side slipped from the seismic motion.
- In this case, the wheel restrainer and the piano slipped together, and therefore, the movement was not significant. However, if the wheel restrainer failed, the piano could have slipped far greater distances.



✦ Retrofitting

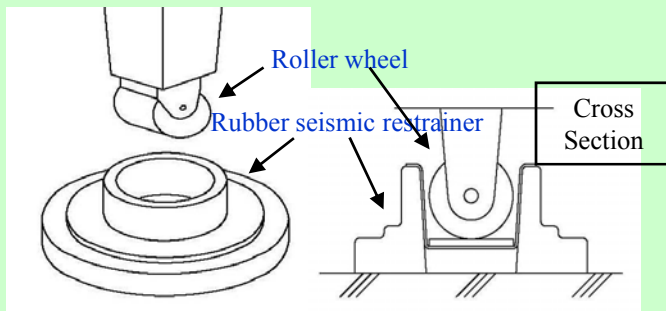
■ Grand piano

- The wheel restrainer of the grand piano was effective in restraining horizontal movement. However, large seismic motions accompanied by vertical movement could derail the wheels.
- To prevent the piano wheels from derailing, deeper seismic restrainers are more effective (See finger a).

- It is also effective to install a support frame (custom made) to prevent the grand piano from overturning (See photo b).

■ Upright piano

- Upright pianos are set with their backs against the wall.
- Fix the piano on a board to increase the area of the base to prevent overturning (Photo c and d).



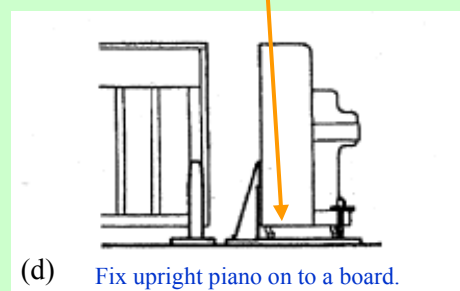
(a)



(c)



(b)



(d)

✦ Note (Reference)

- It is also advisable to inspect the conditions of instruments other than the piano.



### ✦ Damages

#### ■ Overturned machine tools

- Large machine tools used for training in a technical high school side slipped from the base and was overturned by the seismic motion.
- Machine tools were often not fixed to the floor and consequently sustained damages.



### ✦ Retrofitting

#### ■ Prevent machine tools from overturning

- Fix machine tools to the floor according to the manufacturer's specification (Photo a).
- When it is difficult to fix to the floor, increasing the base area, such as by using steel plates, is effective in preventing the machine from overturning (Photo b).
- Machine tools with relatively high center of gravity are prone to overturning, and therefore, the machine and its support frame (including the desk) should be fixed to the floor. Inspect that the mounting brackets are intact and not loose (Photos c and d).



### ✦ Note (Reference)

- When machine tools are renewed, old tools are often left at the training room corner or in corridors without being fixed. Large machine tools that are not in used should be discarded.
- If they have to be temporarily left, they should be set in places with few passers-by and should be restrained, such as with ropes, to prevent overturning.

## Storage Shelves in Special Classrooms

### ◆ Damages

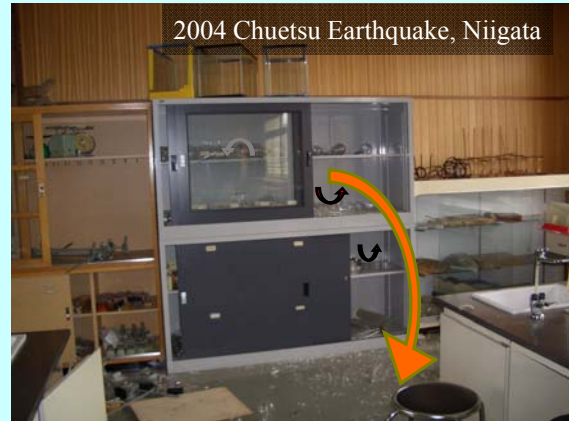
#### ■ Overturned dishes (Home economics classroom)

- The seismic motion opened the front doors of storage shelves and the dishes fell to the floor.



#### ■ Overturned lab equipment (Science classroom)

- The seismic motion opened the front doors of storage shelves, and the contents fell to the floor, destroying the lab equipment.



### ◆ Retrofitting

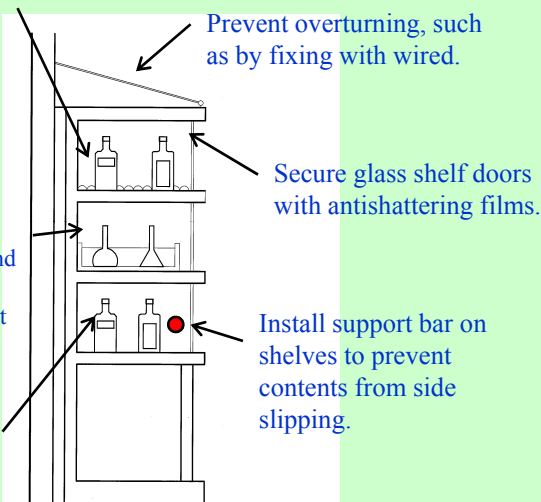
#### ■ Daily inspection

- Organize the contents of storage shelves.
- Do not place heavy objects on upper shelves.
- Verify that the front latches of storage shelves are not loose or rusted.

Spread soft liner sheets on shelves to prevent the contents from side slipping.

Support unstable equipment, such as by embedding in sand box or in divided containers to prevent overturning.

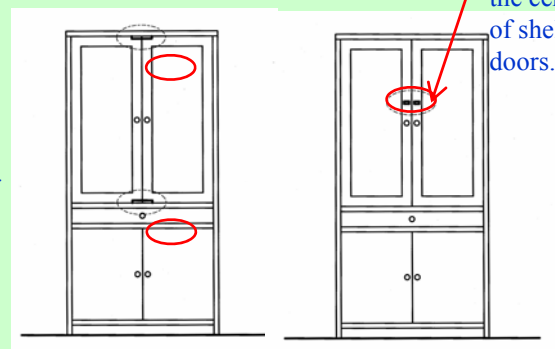
Replace glass containers with plastic ones as much as possible



Prevent shelves from overturning

#### ■ Retrofitting

- Using antishattering films on glass shelf doors is effective.
- Install latches on shelf doors to prevent them from opening. Support unstable equipment, such as by embedding in sand box or in divided containers to prevent overturning.
- Install support bars to the front of shelves to prevent contents from side slipping.



It is advisable to install latches at the top and bottom of shelf doors.

For only one latch, install at the center of the shelf door.

Positions of latches.

Install latch at the center of shelf doors.

### ◆ Note (Reference)

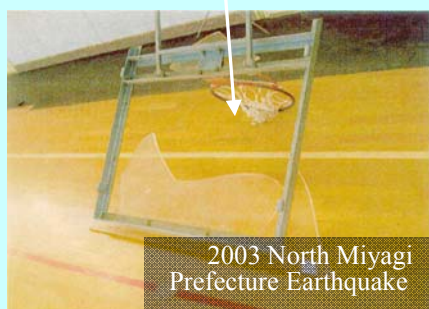
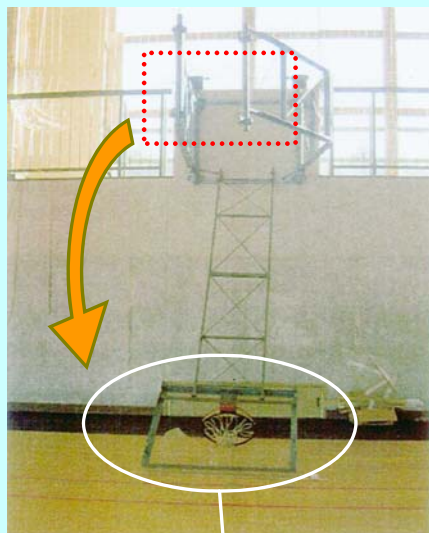
- Retrofitting methods above are excerpts from the report\*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

## Gymnasium Equipment and Facilities

### ◆ Damages

#### ■ Overturned and damaged basketball goal

- Seismic impact broke the support of the basketball goal and it fell to the floor.



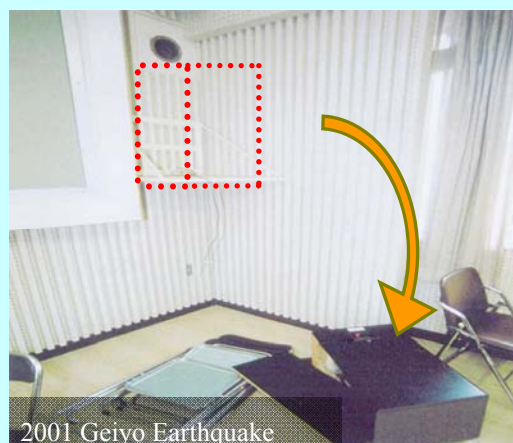
#### ■ Fallen gymnasium lights

- Many HID (high intensity discharge) lamps installed at the gymnasium ceiling have fallen.



#### ■ Fallen loudspeaker

- Loudspeaker that was set by the wall, fell from the support frame onto the floor.



### ◆ Case Study

#### ■ Daily inspection

##### Basketball goalpost, loudspeakers, etc.

- Verify that the mounting brackets and bolts are not loose or damaged.
- Verify that there is no rust or deterioration on mounting brackets.

##### Gymnasium lighting fixtures

- Verify that the mounting brackets of hanging lamps are not rusted.
- For arena lighting fixtures, verify the safety of mounting brackets for the hoist mechanism.

#### ■ Retrofitting

- Falling heavy objects, such as loudspeakers, could cause considerable damage. Therefore, these have to be securely fixed to the wall in at least two positions, at the top and bottom of the loudspeaker.



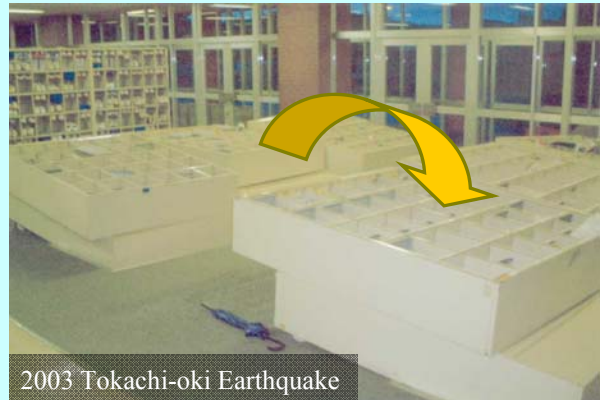
### ◆ Note (Reference)

- The retrofitting above are excerpts from the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".

### ◆ Damages

#### ■ Overturned shoe locker

- The student shoe lockers at the entrance, which were set back-to-back, were overturned like dominos by the seismic motion.
- Overturned shoe lockers could block the evacuation route and obstruct evacuation after the earthquake.



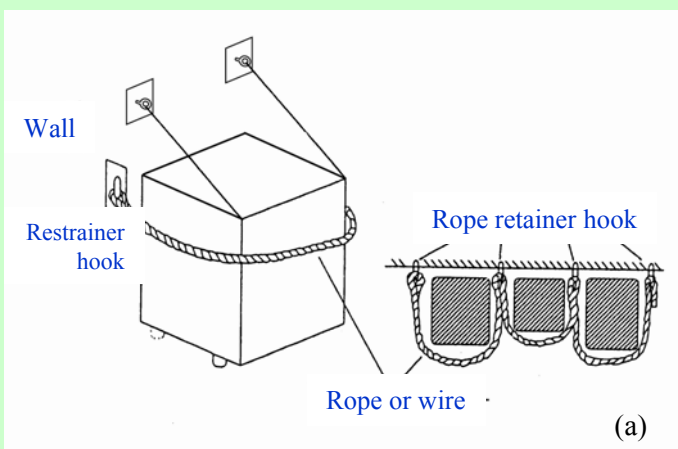
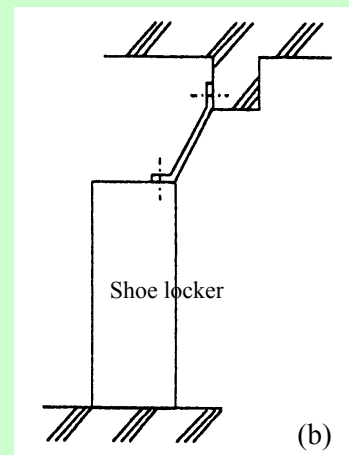
### ◆ Retrofitting

■ Securely fix shoe lockers near the student entrance to the wall, such as with support wires (Figure a).

- Shoe lockers that are not always set along the wall, such as those standing at the entrance. These should be fixed to the strong part of the ceiling or the beam with metal brackets (Figure b).

#### ■ Damaged aquarium

- When items set near the entrance, such as aquariums, topple and break, they could obstruct evacuation. Therefore, the support frame should be fixed with metal brackets. At the same time, to prevent the aquarium from side slipping, it should be fixed with support or wire, together with self-adhesive cushion sheets.
- When it is difficult to apply such measures, items that could obstruct evacuation should not be placed.



### ◆ Note (Reference)

- Illustrations of countermeasures that are shown are excerpt from the "Disaster Management Manual", Institute of Industrial Science, University of Tokyo (April 2002)

## Wall and Gatepost

### ✦ Damages

#### ■ Overturned or collapsed wall

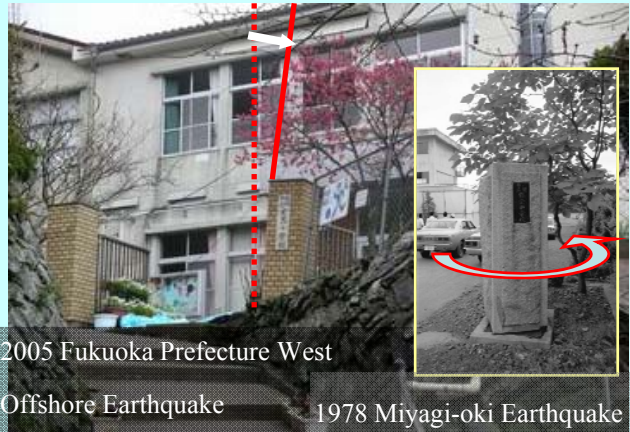
- Stone and concrete block walls were toppled and collapsed by strong seismic motions. Toppled or collapsed walls are frequently reported in other regions as well.



2004 Chuetsu Earthquake, Niigata

#### ■ Tilted, toppled or rotated gatepost.

- Gatepost that tilted by ground deformation in a school that stood on sloping ground.
- On grounds that are not sloped, there were cases of gateposts that rotated at the base and those that have tilted or toppled because of liquefaction.



2005 Fukuoka Prefecture West

Offshore Earthquake

1978 Miyagi-oki Earthquake

### ✦ Retrofitting

#### ■ Daily inspection

- Verify that the walls are not shaky, tilted, or unnecessarily high.
- Verify that the concrete block, masonry joint and steel rebars have not degraded or rusted.
- Verify that wall foundations are sufficiently embedded, and that the intervals between steel rebars, buttresses and stay posts are also sufficient.
- Verify that the heights of concrete block walls were not increased.

#### ■ Prevent overturning.

- Walls that are potentially dangerous should be rebuilt, or replaced with light fences, such as hedges or wire fence.
- Reinforce with buttresses or steel support frames (See right photo).



1997 Northwest Kagoshima Prefecture Earthquake

(Photo: Nakano Lab., IIS, University of Tokyo)

### ✦ Note (Reference)

- Concrete block walls are specified in Item 8, Article 62 of the Building Standards.
- For inspection and retrofitting of concrete block walls, refer to the pamphlet "Effort for building safe concrete block walls" (Subcommittee on concrete block wall systems, Working committee on masonry wall construction, Construction material committee of the Architectural Institute of Japan), which gives detailed information.

◇ <http://news-sv.ajj.or.jp/zairyou/s2/index.html>

◇ <http://news-sv.ajj.or.jp/zairyou/s2/pamphlet.PDF>

## External Staircase and Surroundings

### ◆ Damages

#### ■ Tilted steel external staircase

- The steel external staircase tilted from the foundation.



#### ■ Tilted reinforced concrete wall of the external staircase

- The exterior wall of the staircase was damaged and tilted outward.
- There are risks that these could collapse and fall from the aftershock.



#### ■ Tilted reinforced concrete wall of a staircase

- The staircase wall of a gymnasium, which was built on a sloped ground, was damaged and became tilted.
- This appears to be caused by the effect of cracks at the staircase floor from ground deformation. Heavy reinforced concrete walls could easily tilt or topple, once they are damaged by seismic motions (See right photo).



### ◆ Retrofitting

#### ■ Daily inspection

- Inspect and verify that the staircase is sufficiently and solidly joint to the structural frame, and that the staircase is structurally sufficient to support itself. The inspection and verification should be performed together with the seismic evaluation of school buildings and gymnasiums.
- Verify that staircases are not shaky and that the anchor bolts have not degraded. It should be noted that, walls that protrude or placed far from floor slabs or staircases, or walls that have no support members are prone to seismic motions.

#### ■ Retrofitting

- When cracks occur on staircases and walls, or when they tilt after earthquakes, they are at risk of overturning or falling. Therefore, these facilities should be prevented from being used, and considering their effects, entrance to nearby areas should be restricted.

## Retaining Wall

### ✦ Damages

#### ■ Damages on retaining wall

- Significant damage to retaining walls, such as the settlement of surrounding grounds, buckling or cracking that accompanies ground deformation on sloped or developed grounds have occurred frequently (Photo a).
- Shifting of retaining walls, even those that are relatively new, have been observed (Photo b).



#### ■ School ground that collapsed together with the cliff

- School ground, which stands on sloping ground that collapsed with deformation of the ground.



#### ■ School commuting route that was affected by the slope failure.

- The school commuting route was blocked as the slope in the mountainous region failed.



### ✦ Retrofitting

#### ■ Daily inspection

- Verify that there are no cracks or buckling of retaining wall
- When the building stands directly above or below a steep slope, and when people or vehicles travel such areas, the safety of the ground and retaining walls against earthquakes should be studied by an expert.

#### ■ Retrofitting

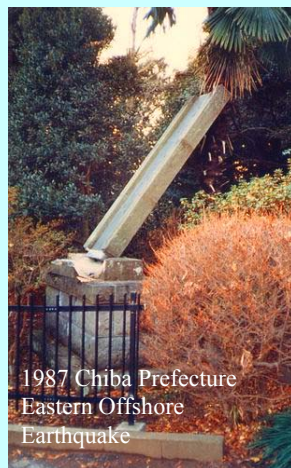
- When cracks or shifting of retaining walls are confirmed after an earthquake, the fact that the retaining walls are at risk of failing or tumbling should be clearly indicated at inside and outside the school. It is necessary to restrict passers-by immediately, and notify the danger to students and public who may pass near the retaining wall.



## ✦ Damages

### ■ Overturned monuments

- Monuments and statues in the school ground were overturned by earthquakes.
- There was a case in the past, where a stone lantern in a shrine was overturned and caused casualty. (1987 Chiba Prefecture Eastern Offshore Earthquake)



### ■ Overturned snow fence material

- Timber for snow fences that were propped up against the school building have toppled.
- Those that had been restrained by wires did not topple significantly.



## ✦ Retrofitting

### ■ Daily inspection

- Inspect inside and outside of buildings to see that there are no timber and long or wide stone plaques propped up against the building wall.
- Verify that monuments are not shaky and that their foundations are sufficiently embedded.

### ■ Prevent overturning.

- Implement measures to prevent timber and other material from collapsing. Then, they should be either piled flat, or restrained from toppling with wire, chain or rope.
- Verify that the restraining wire, chain and rope are of sufficient length (or height) and strength, considering the weight of the material. Then, the materials should not be tied loose and restrained by giving sufficient consideration to the lengths of the material.
- Heavy objects such as stone plaque or monuments should have their foundations sufficiently embedded or sufficiently reinforced to prevent them from toppling at the base.

\* If immediate implementation is not possible, apply emergency measures, such as by restricting entrance or passing the surrounding areas.



## ✦ Note (Reference)

- To prevent toppling, refer to the report \*1; "Investigative Survey on the Seismic Inspection of Nonstructural Members in School Facilities".