Seismic Response Modification of Urban Infrastructure

都市施設の免震設計

Chapter 2 Seismic Control Algorithms of Structure

第2章　応答制御法

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2.1 Control Algorithms

- Active control

Apply forces using energy outside of the structure so that response of the structure can be mitigated

- Passive control

Reduce the response of a structure by period shift and/or energy dissipation inside the structure

  - ✓ Response control (?): This is called **制震設計** in Japan

    Reduce response by energy dissipation of dampers

  - ✓ Seismic isolation **免震設計**

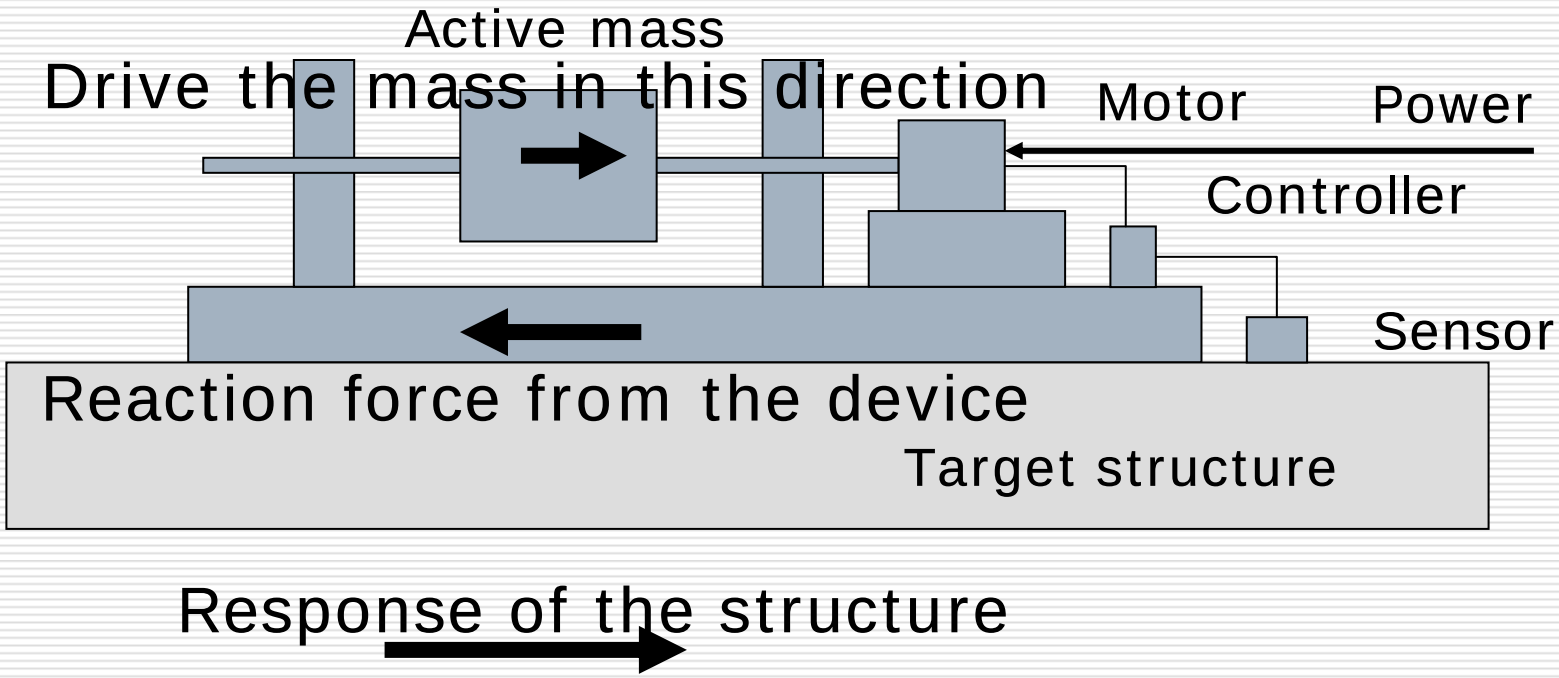
    Reduce response by period shift and energy dissipation of dampers

- Semi active control

In stead of directly producing driving force like active control, control motion of a large device by adjusting electrical circuit or valves of energy flow

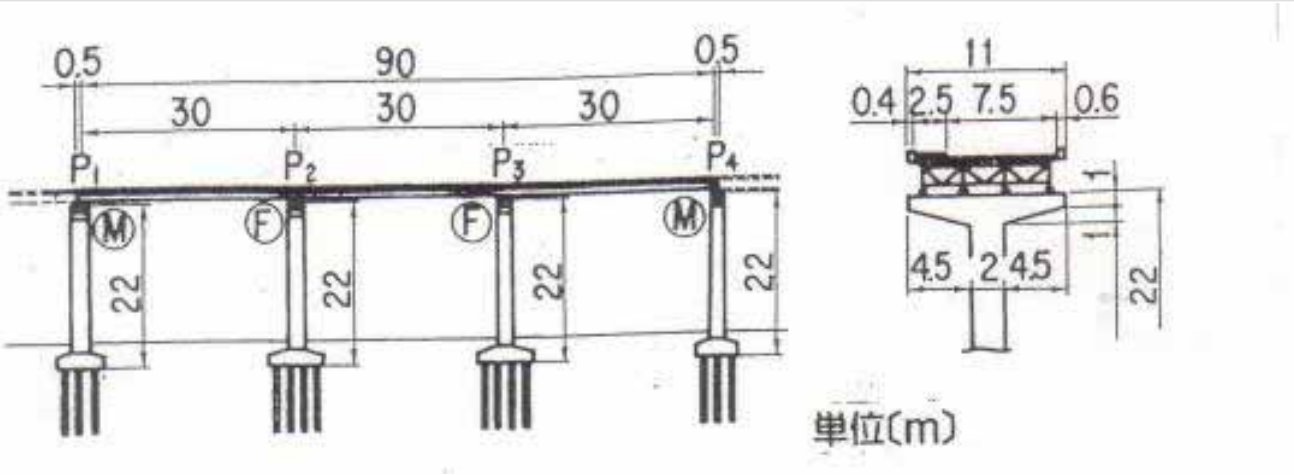
2.2 Active Control

1) Active mass damper: a typical device for active control

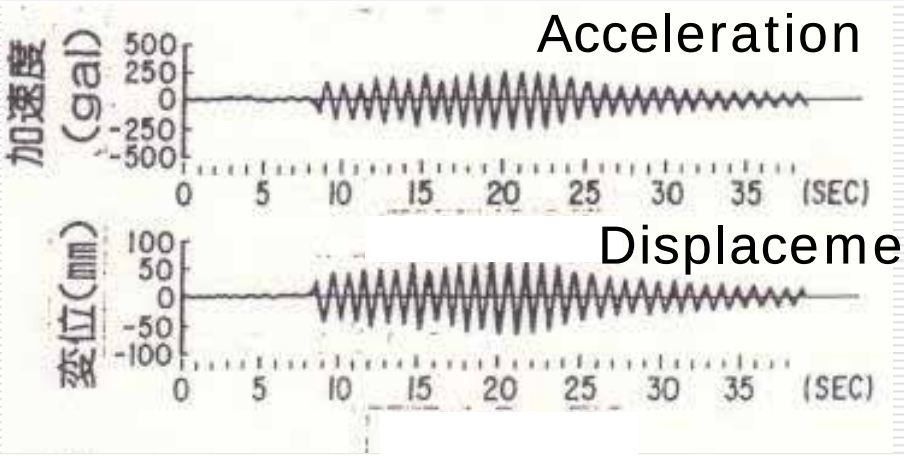


How effective is active mass damper?

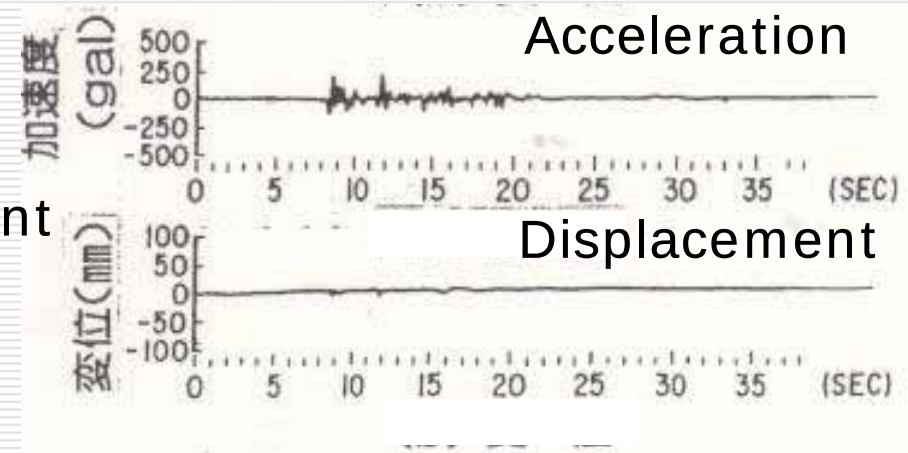
3 span continuous plate girder bridge



Without control



With control



How effective is active mass damper? (contd.)

Mass and stroke required to reduce seismic response displacement of a 90 m long 1,035 t mass 3 span continuous bridge from 70 mm to 20 mm

Mass ratio	Active mass	stroke
1/1,000	1t	+/- 37m
1/100	10t	+/- 3m
1/10	100t	+/- 0.42m

2) What is the problem inherent to active control?

- Energy required for control is extremely large

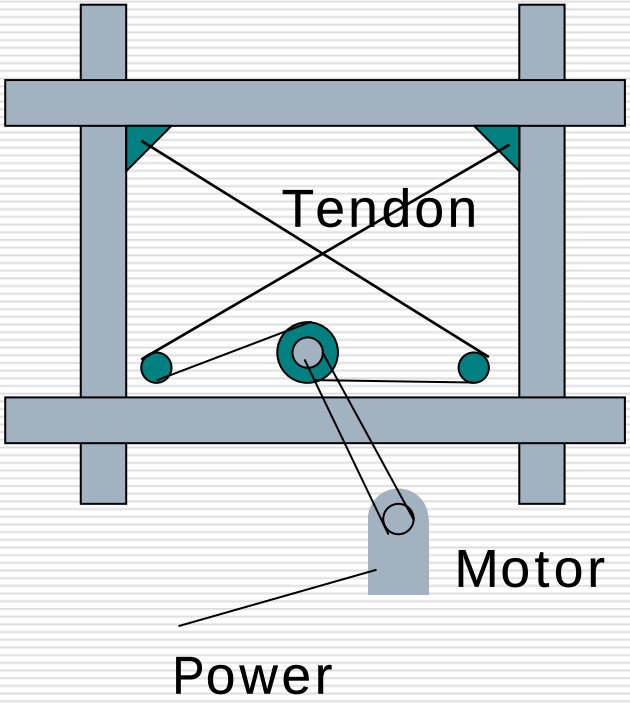
$$\frac{\text{Active mass}}{\text{Small}} \times \frac{\text{Stroke}}{\text{Large}}$$
$$\text{Large} \qquad \text{Small}$$

- Stable energy supply of electricity is generaly difficult under an extreme event
- Long term maintenance of devices and supply of electric devices (computer etc) are difficult

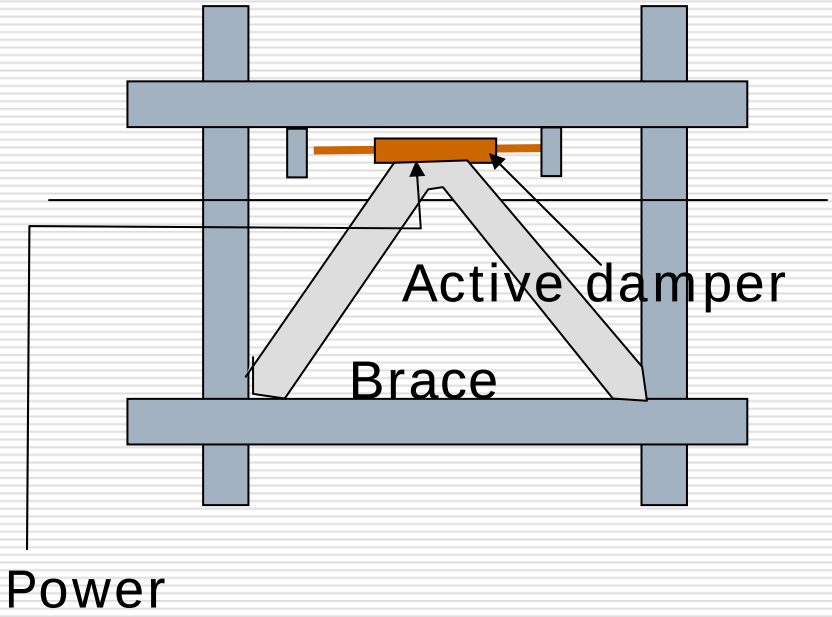
There is a case that the first owner of a building which was designed based on active control well maintained the devices, but the second owner did not understand the importance of maintenance. Thus this building is not now actively controlled in a dangerous mode

3) Other Passive Control

Active tendon



Variable stiffness control



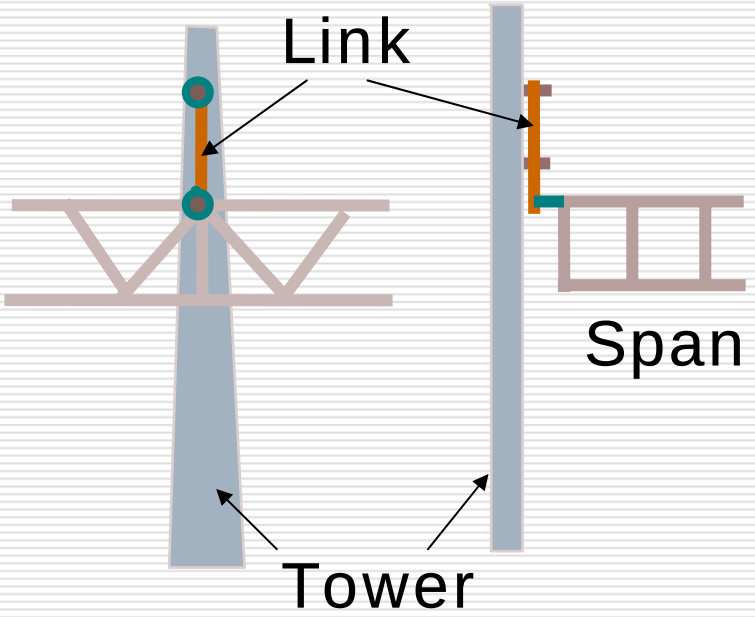
2.3 Passive Control

1) Principle

- Period shift (PS)
- Enhance the energy dissipation (ED)
- PS+ED

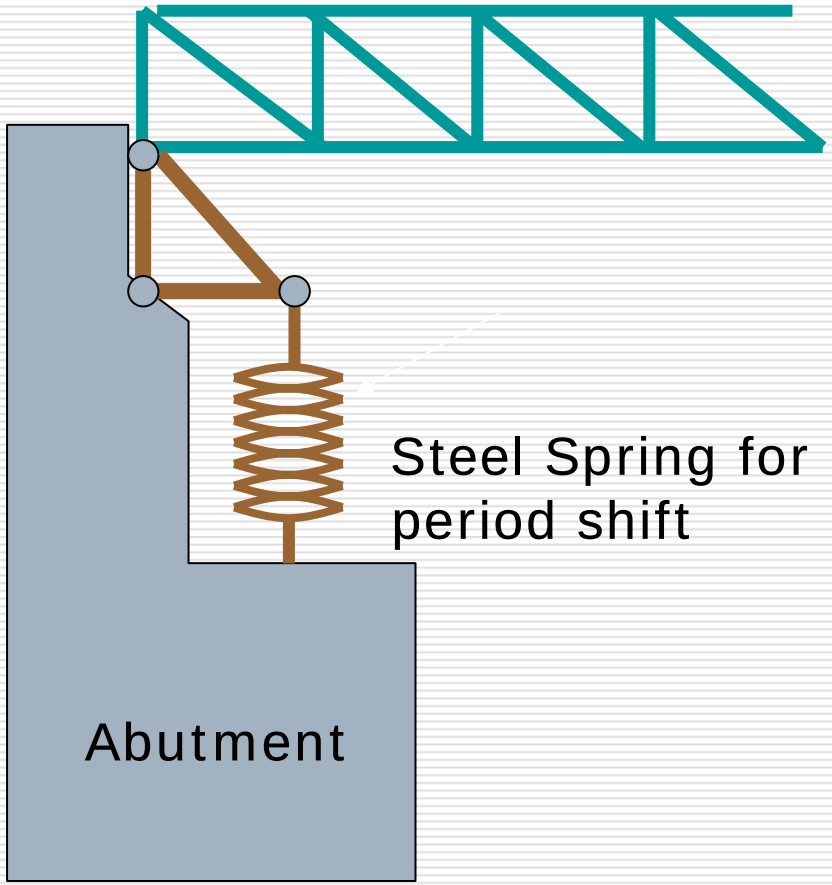
a) Period shift is well used in long-span bridges

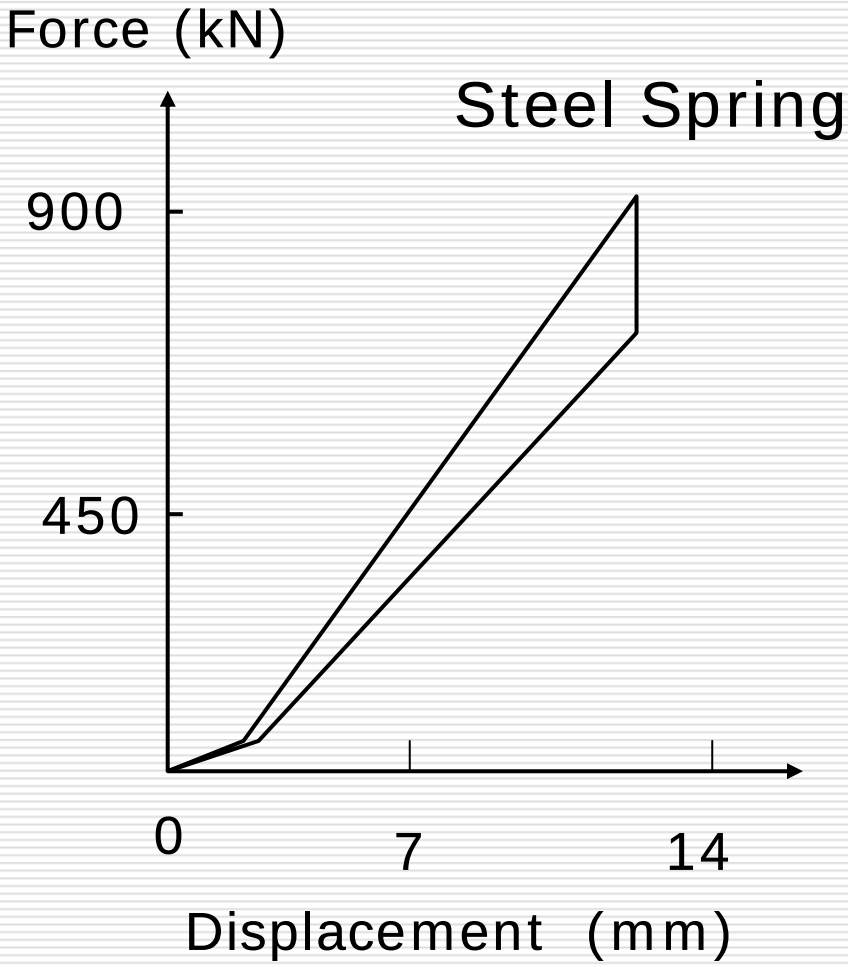
Yokohama Bay Bridge



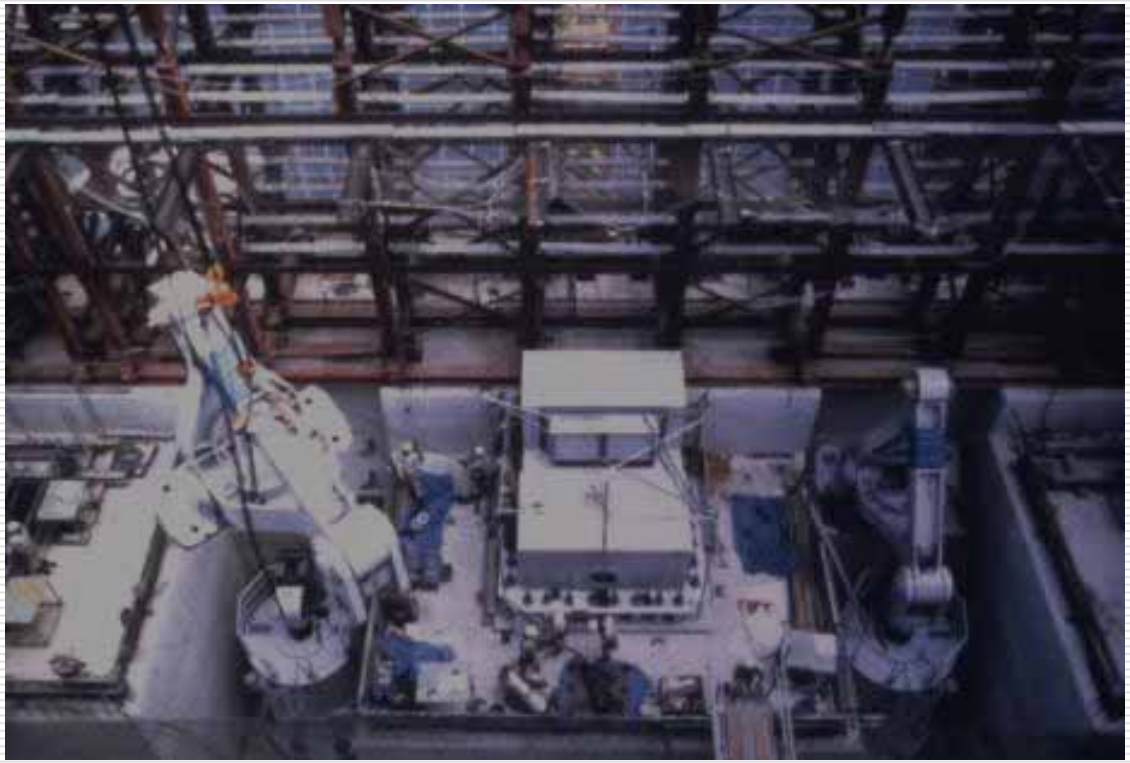
a) Period shift is well used in long-span bridges (contd.)

i) Hitsuishi-Iwaguro Bridge
Honshu-Shikoku Bridges

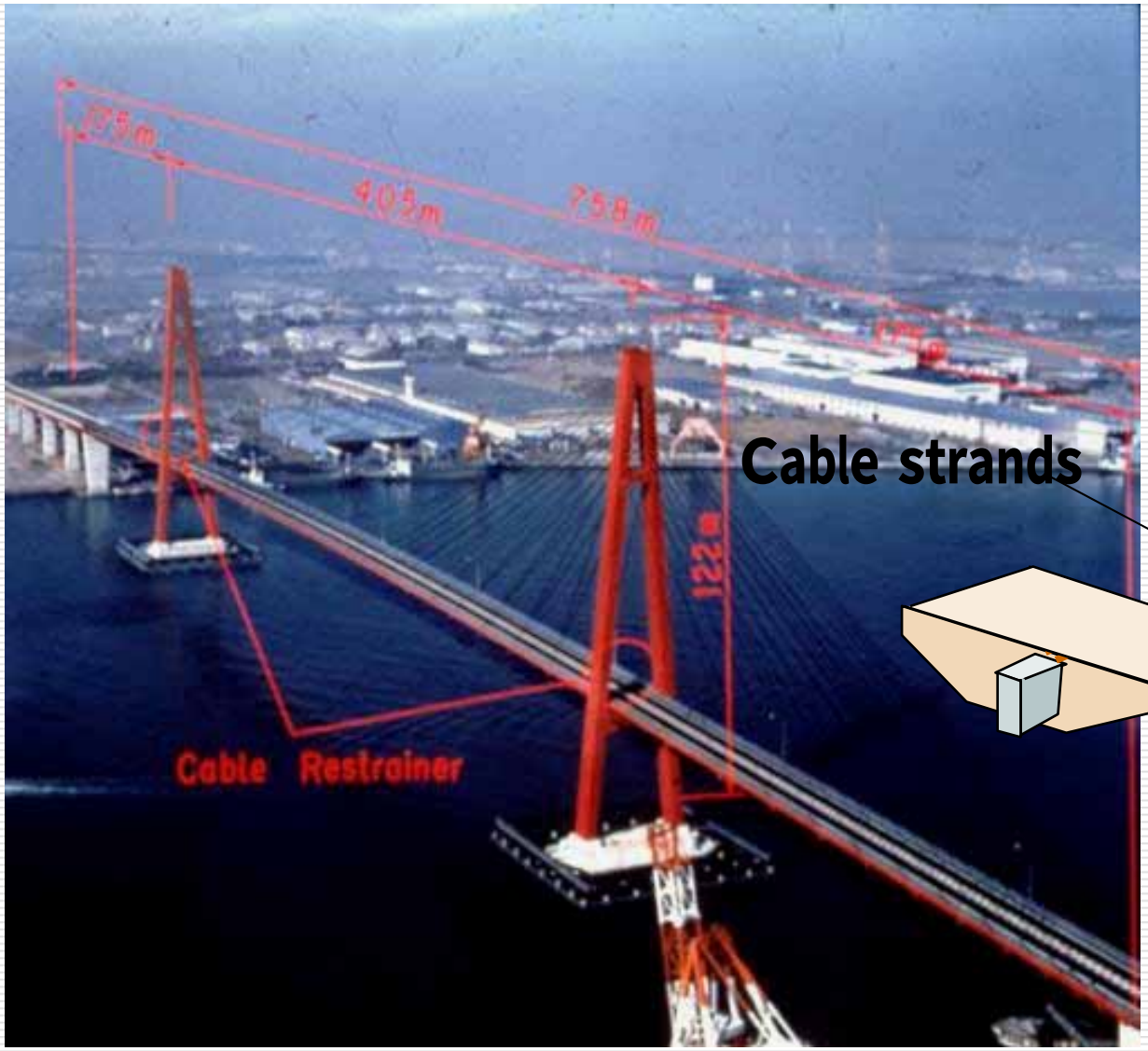


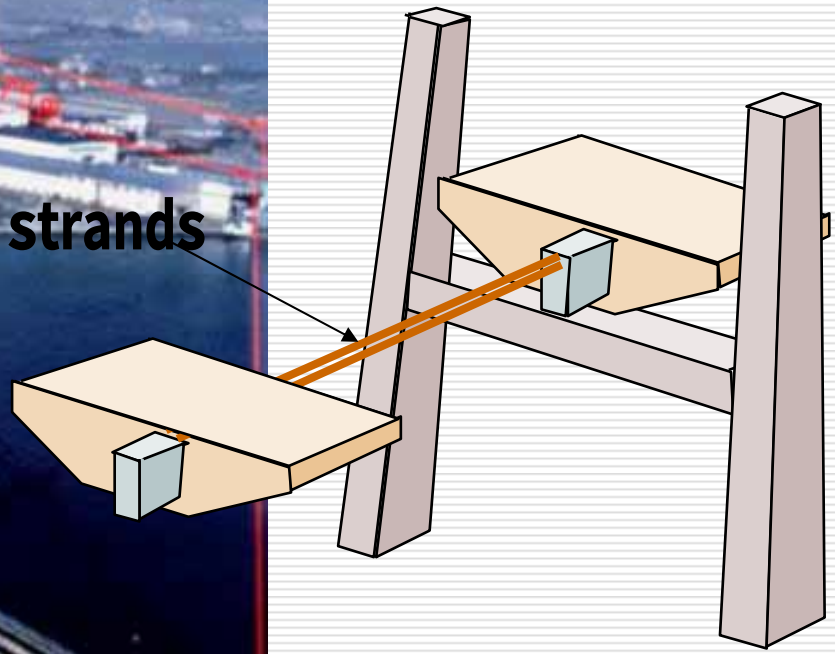


Hitsuishi-Iwaguro Bridge
Honshu-Shikoku Bridges



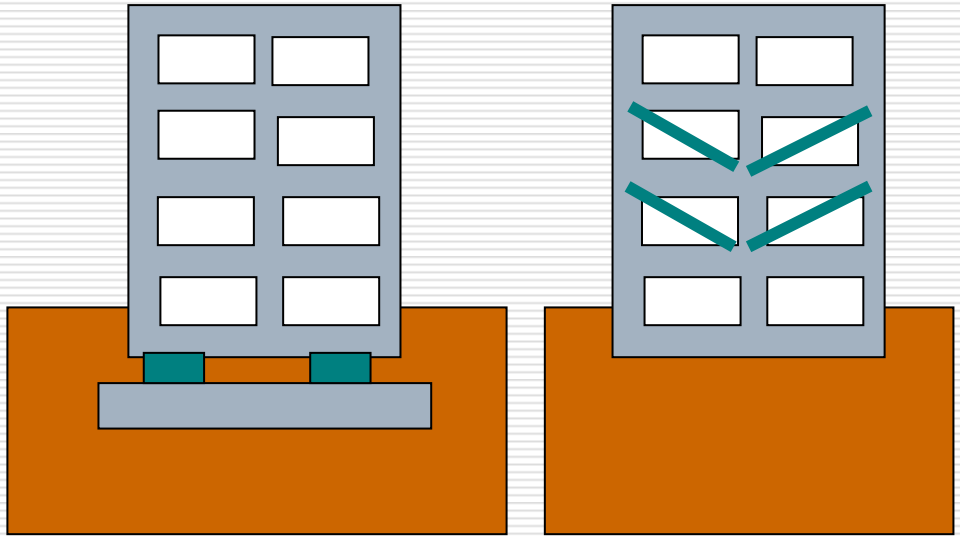
ii) Soliton Bridge

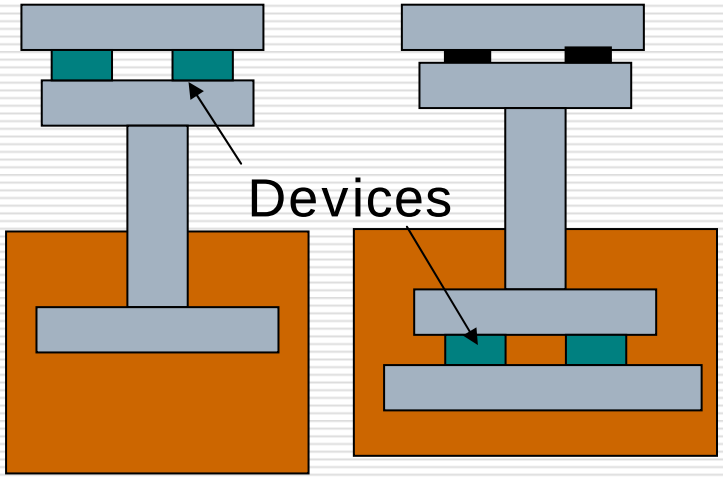


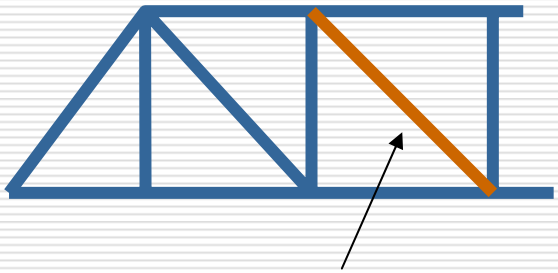


2) Location of devices

- Boundary between the ground and the base (B)
- In-structure (S)
- B+S





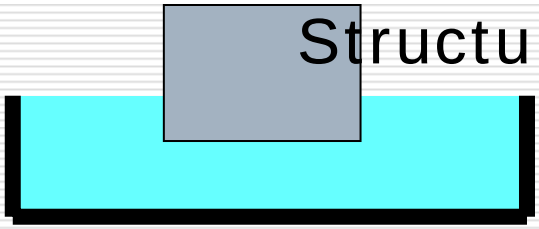


Unbond brace damper

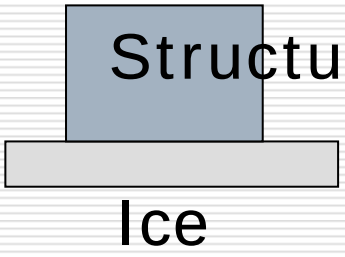
3) Types of device

(1) isolators: device for period shift

a)

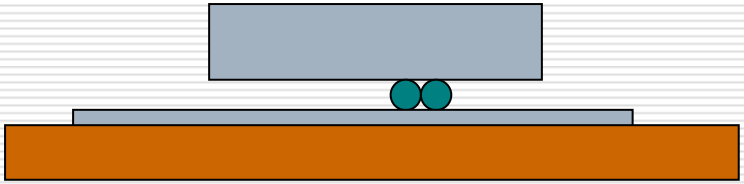


b)



Residual drift after an earthquake

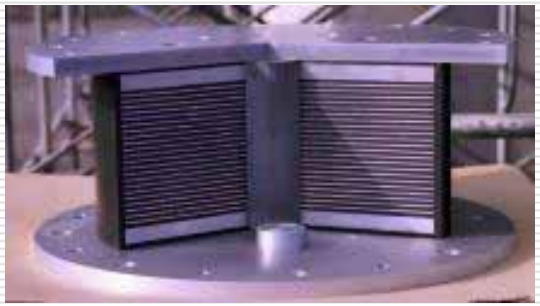
c) rollers



Restoring force has to be provided by setting another device

d) Rubber bearings

- Rubber pad (not used)
- Elastomeric bearing



(2) Energy dissipaters

- Plastic deformation of mild steels
- Plastic deformation of lead
- Viscous dampers
- friction
- Viscous materials
- Bituminous
- High damping rubbers
- Sand
- ……

4) Various terminologies

- Passive control
- Seismic response control
- Seismic isolation
- Seismic response modification
- Menshin design
- …..

In Japan, sometimes it is called

- **免震設計**(Menshin design): Period shift + Damper
- **制震設計**: Energy dissipation by dampers which are installed inside a structure

2.4 Summary

- Active control and semi-active control are still under investigation, and they are not yet used in practice. Thus passive control is widely used.
- Period shift is effective. Since “period shift” is used for long-span bridges and tall buildings, we have to watch the effect of long-duration and long-period ground motion.
- Installation of dampers is widely accepted technology for buildings at this moment. This technology is also used for superstructures of bridges.
- Combining the period shift and installation of dampers is widely accepted technology for bridges.