Response Modification of Urban Infrastructure
都市施設の免震設計

（7）第5章　長周期化とエネルギー吸収性能の増大に基づく免震設計(2)
(7) Chapter 5 Seismic Isolation of Bridges(2)

東京工業大学
川島一彦
Kazuhiko Kawashima
Tokyo Institute of Technology

5.3 How can we implement the seismic isolation? 具体的には、どうするのか？

1) Basic principle 基本要件

- Period shift (=Increase natural period) 長周期化
- Support a structure using elastomeric bearings 水平方向に柔らかい支承（一般には、積層ゴム支承）で支持する
- Set dampers ダンパーを取り付ける

2) Whole-in-one type dives are better for the implementation to bridges
一体型ディバイスの方が橋梁への適用では有利か？

Separate type device
別置き型ディバイス

Whole-in-one type devices **一体型ディバイス**

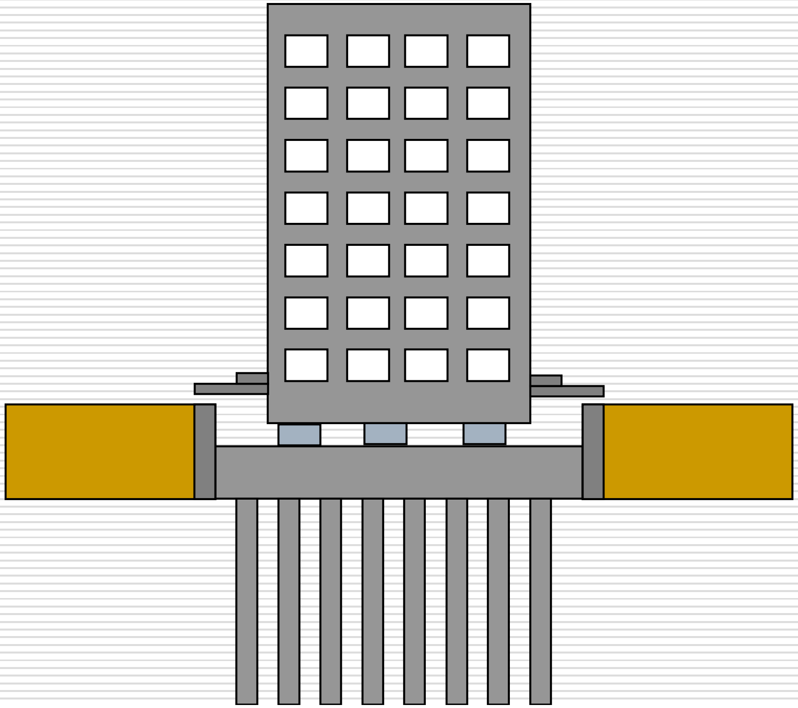
Set Isolators (Period Shifters)
アイソレーター (ペリオドシフター)

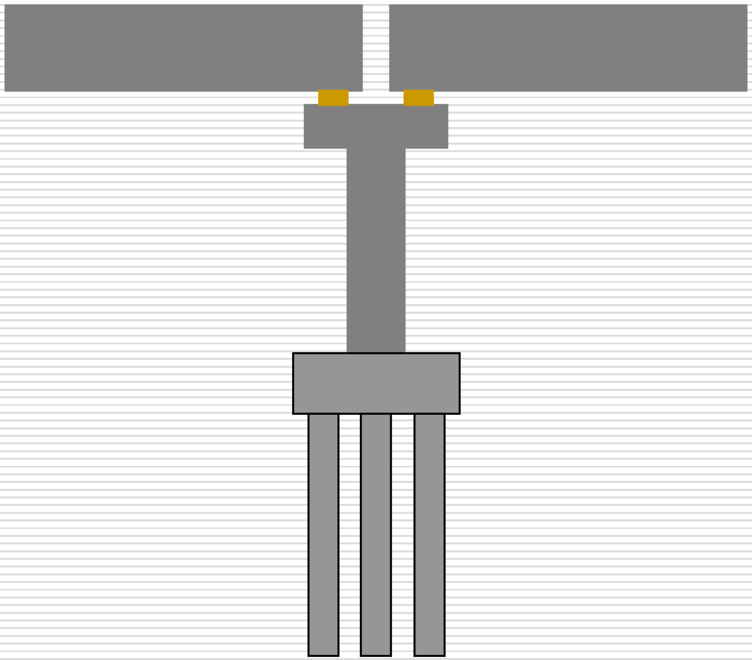
Set Dampers, or Energy Disspators **(ダンパー、あるいは、エネルギー吸収装置)**

Set a devices which have function of isolators and dampers.

3) Space for setting devices is limited in bridges
橋梁では、免震装置を設置するスペースの制約が大きい

- Space between substructures and girders is limited for setting devices in bridges, while the space is sufficient in buildings.
- Environmental condition for devices is more strict in bridges than buildings.





5.4 Implementation of Lead Rubber Bearings to Bridges　鉛プラグ入り積層ゴム支承の橋梁への適用

1) The World First Implementation of LRB to Bridges Toe Toe Bridge, New Zealand 世界最初の橋梁に対するＬＲＢの適用、トエトエ橋

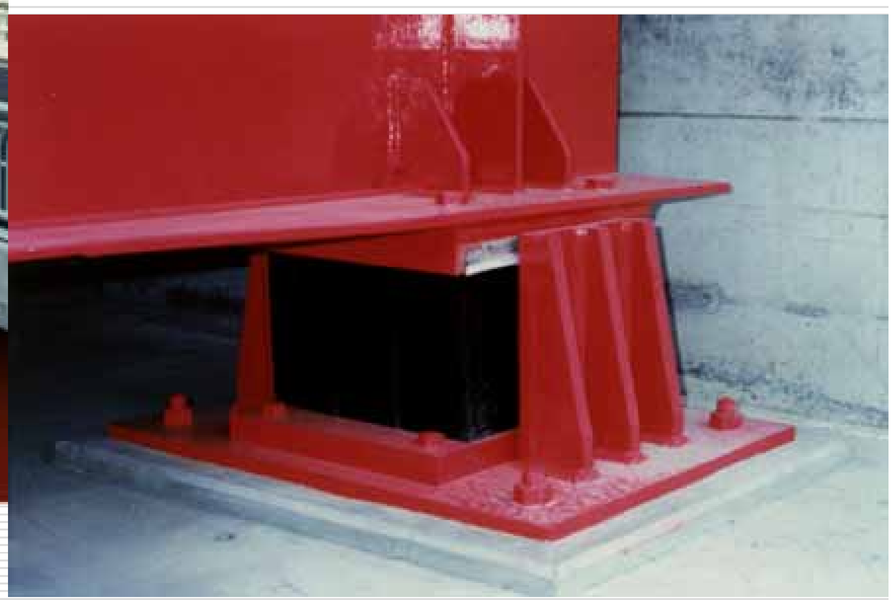
Lead Rubber Bearin

2) Moonshine Bridge, New Zealand

3) Grafton Bridge, Auckland

4) Miyagawa Bridge, The First Isolated Bridge in Japan　宮川橋、静岡県

Miyagawa Bridge, Shizuoka-ken, 1989

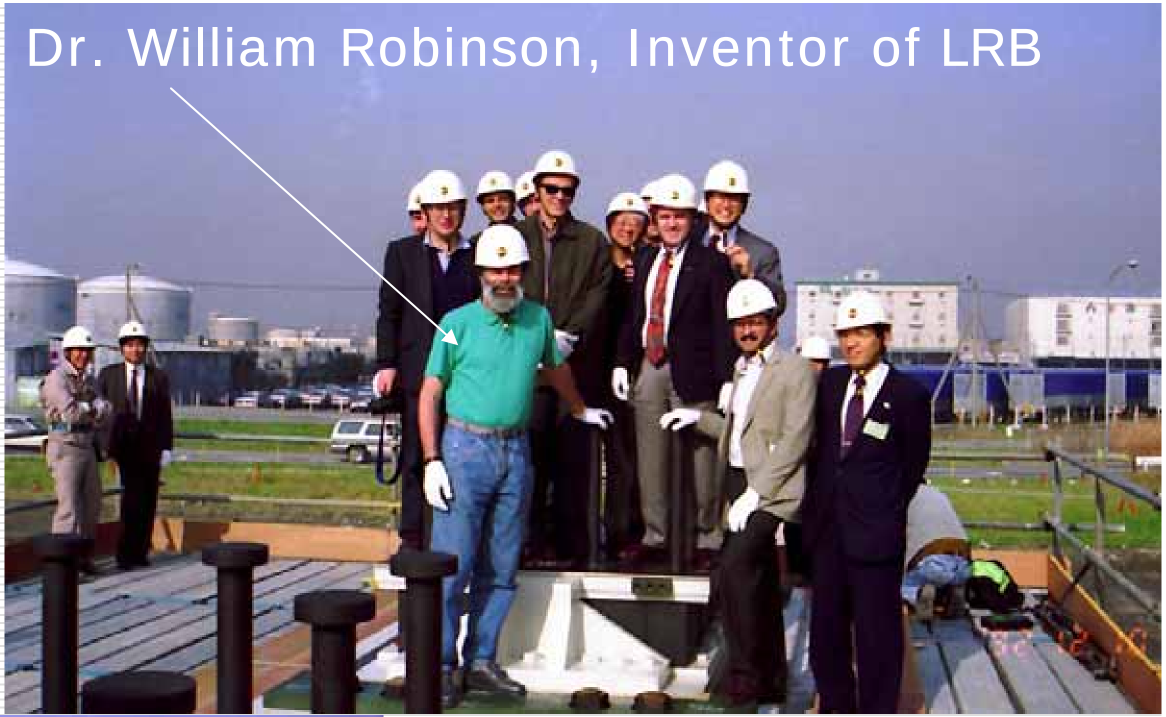


Symbolic “long-nose goblin” at the region was set at the hand-poles of Miyagawa Bridge.

Famous long-nose goblin at the site

Professor Okamoto, S. the 3rd from the left and Principal Engineer Hara in Shizuoka-ken at the right

5) O-Ghishima Viaduct, Metropolitan Expressway



東扇島橋
首都高速道路

5.5 Technical Challenges in the Implementation of Seismic Isolation to Bridges
5.5 橋梁の免震設計を適用する際の問題点

1) Resonance of Isolated Bridge resulting from Period Shift due to Long Period Ground Motions

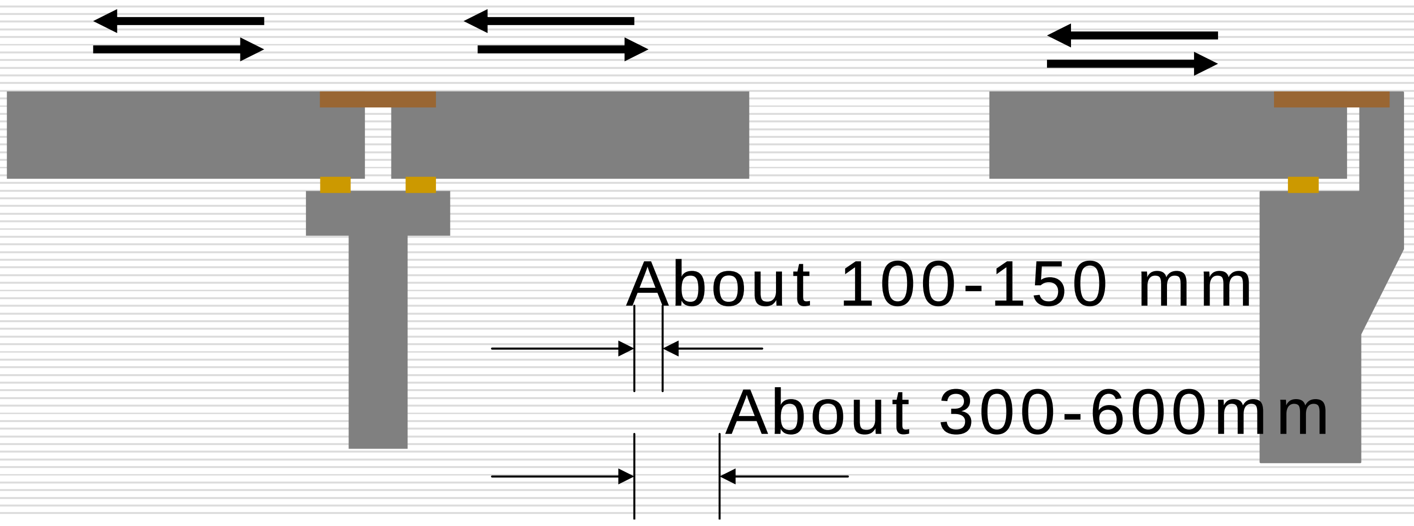
2) Difficulty of the Treatment for Increased Deck Displacement due to Increased Natural Period
長周期化することによる桁の応答変位の増大

●Deck displacement easily reaches +/- 0.5m even in a standard bridge under a near-field ground motion

✓Extreme ground motions

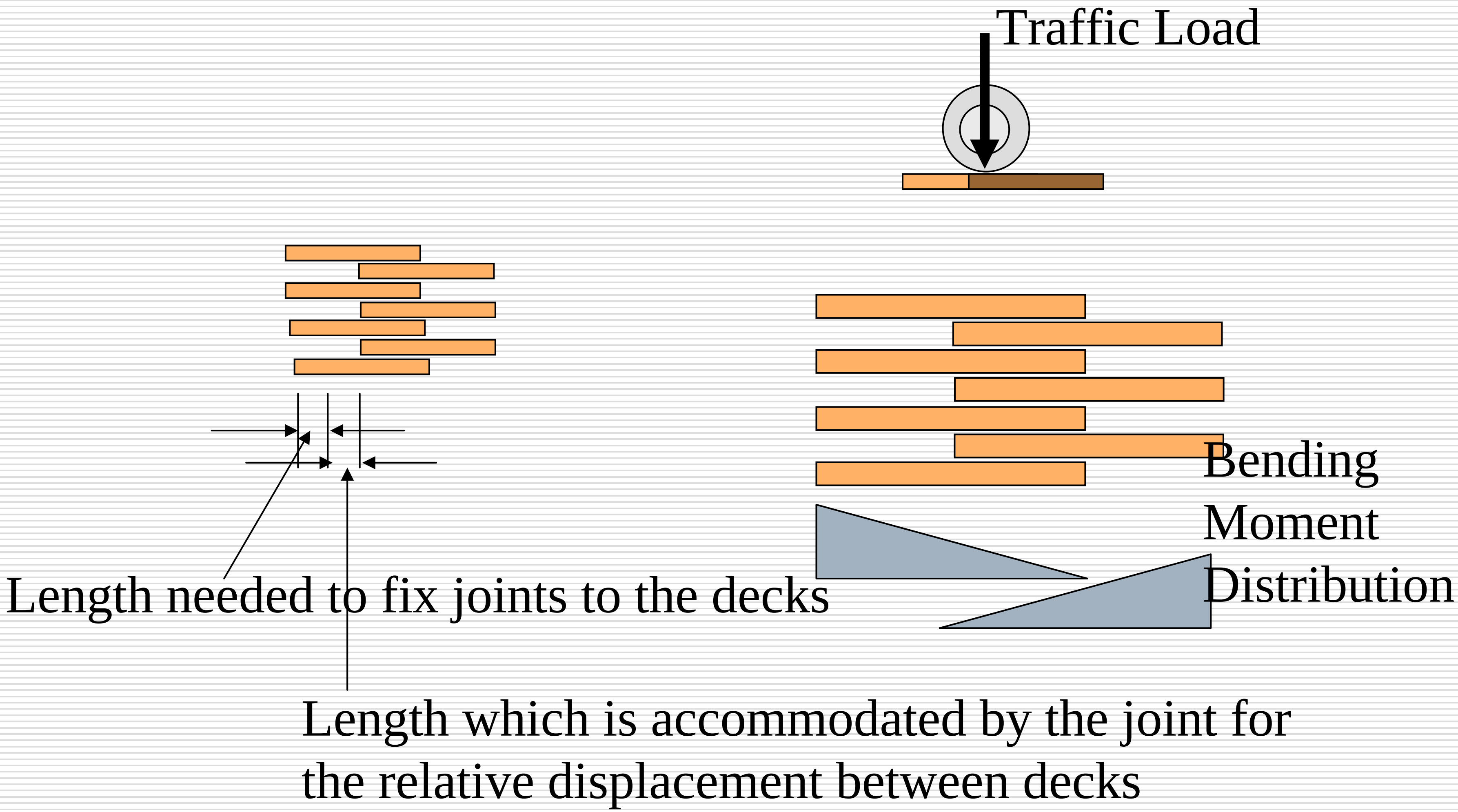
✓Soft soils

●Should we allow collisions between decks or not?

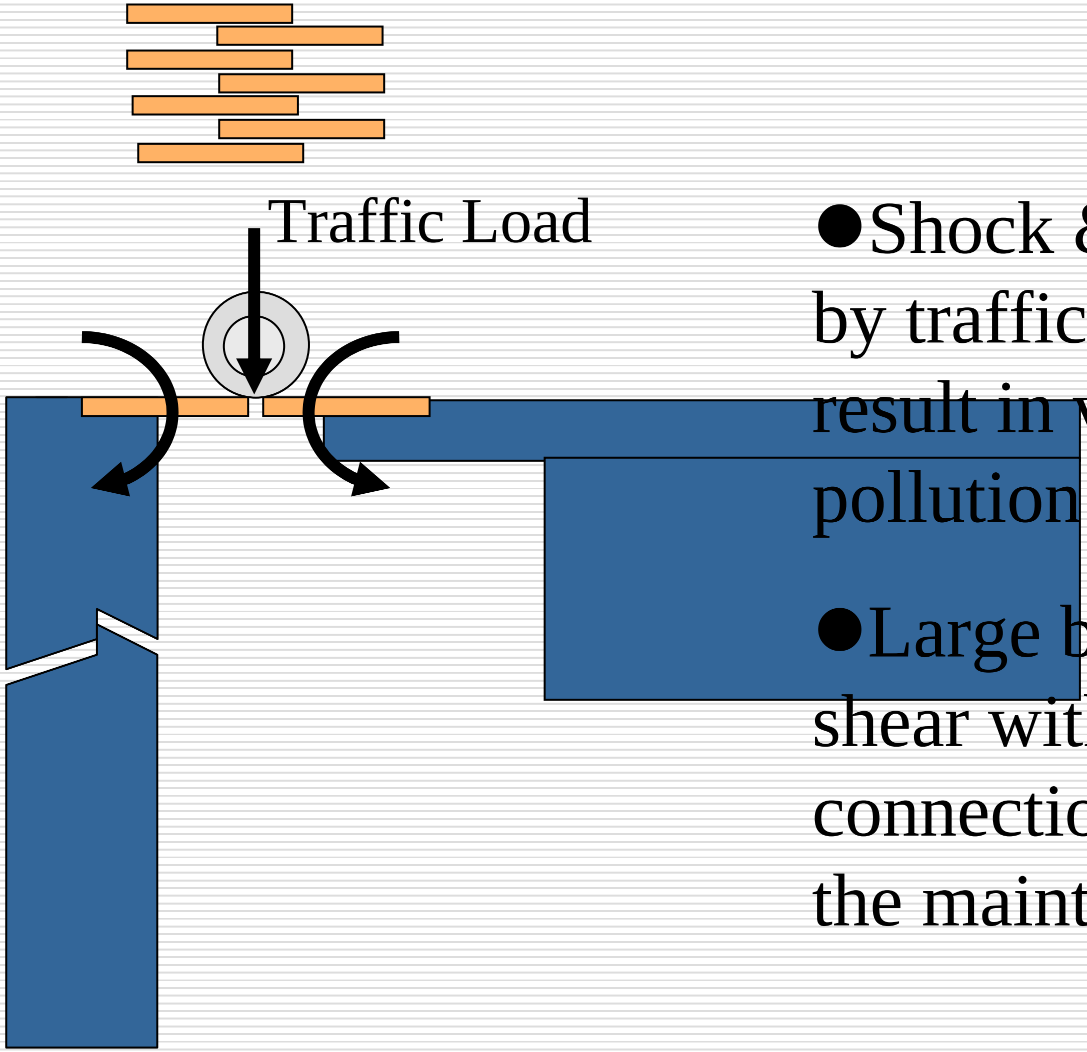


Problems associated with expansion joints which accommodate large relative displacement

大変位を吸収可能な伸縮継ぎ手の採用は可能であるが、問題もある

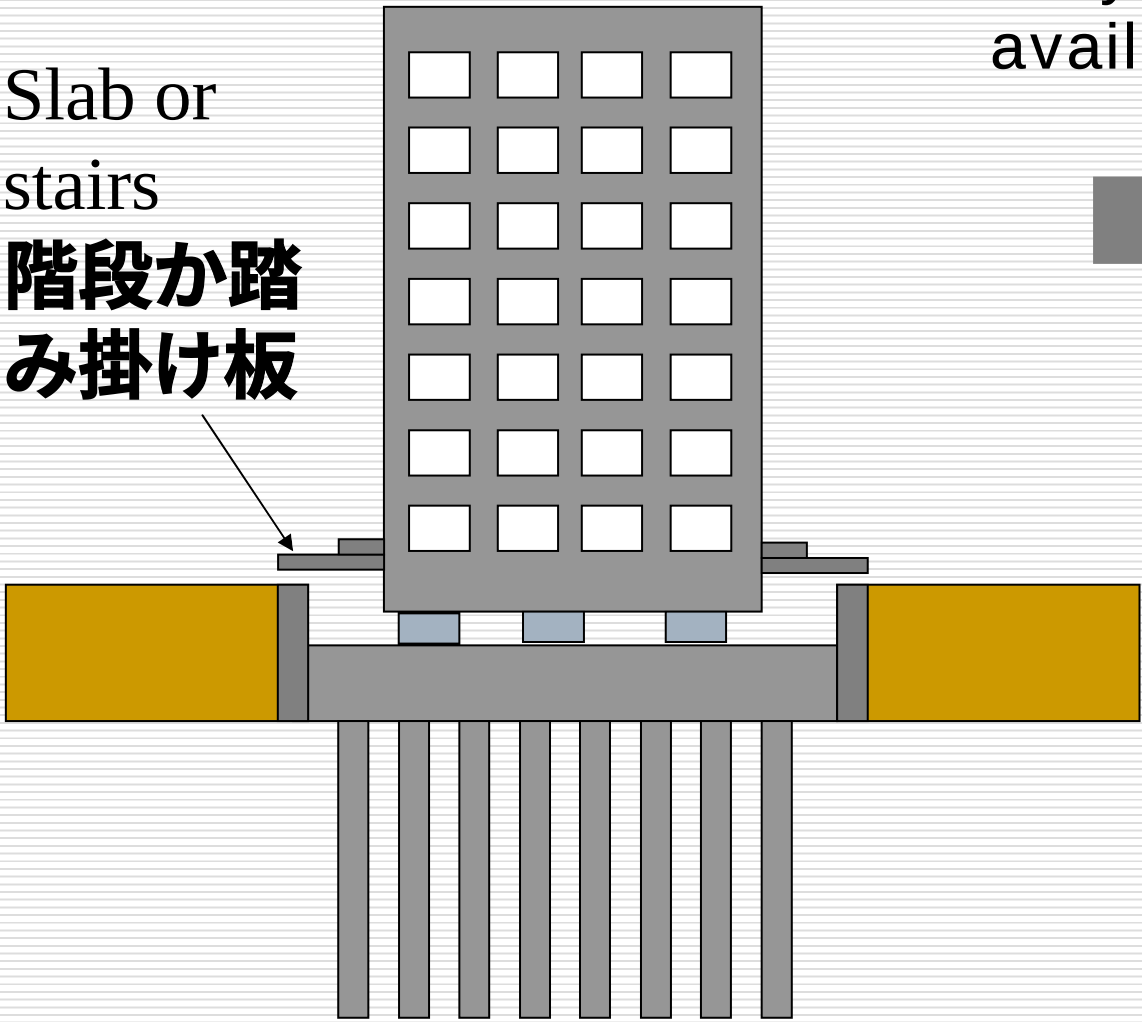


Problems of adopting an expansion joints which accommodate large relative displacement (2)

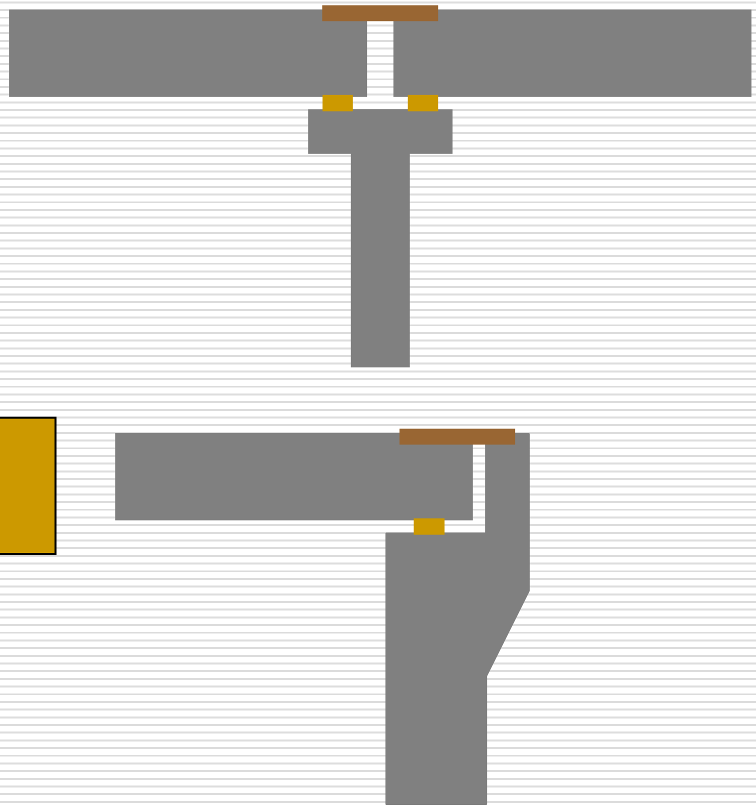


- Shock & noise induced by traffic loads are likely to result in vibration & noise pollution in city areas
- Large bending moment & shear with shock damage connections. This results in the maintenance problems.

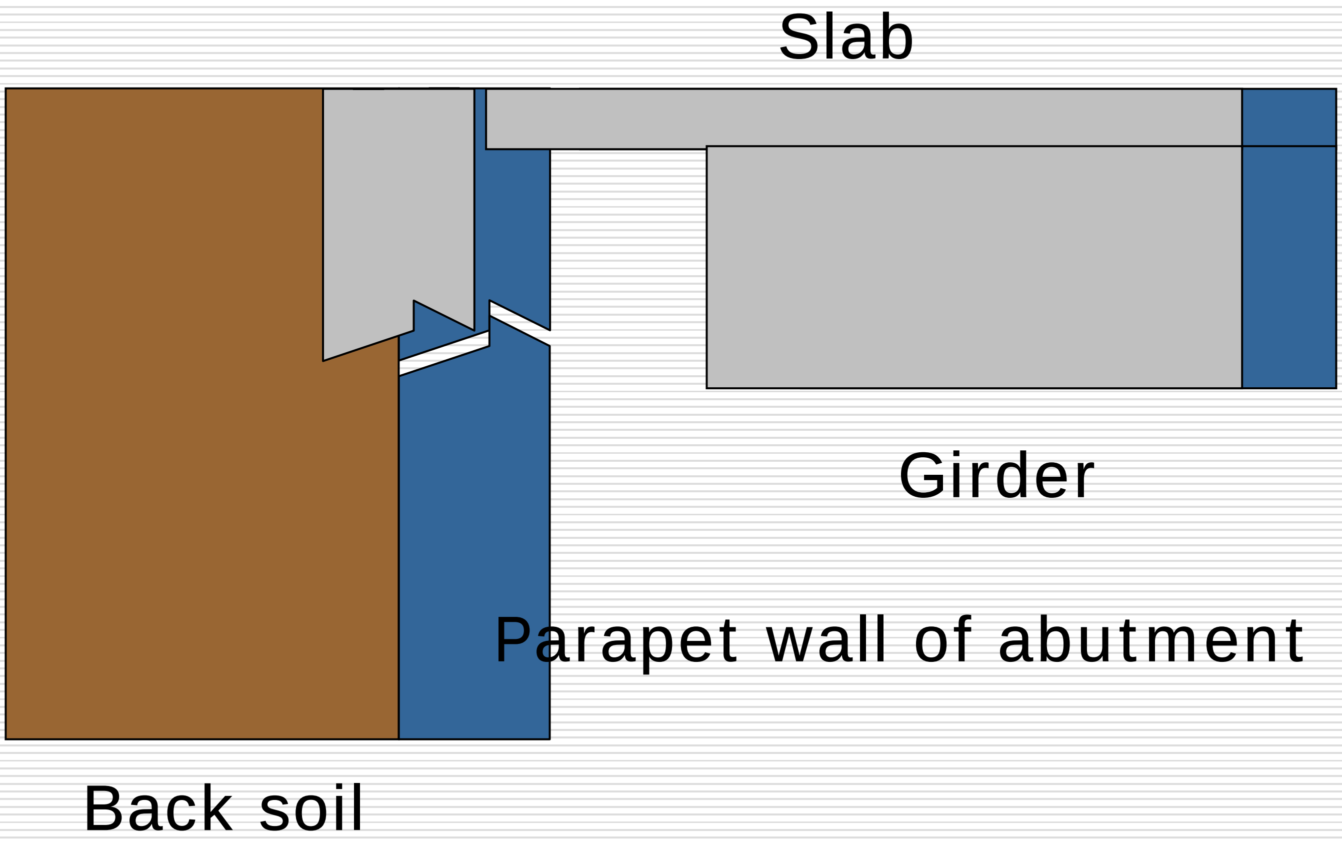
Gap is not generally problem in buildings
建物外周の遊間は建築物では一般に問題にならない



Only limited space is available on bridges



3) Knock off Abutment Developed in New Zealand
ノックオフ橋台 (ニュージーランド)



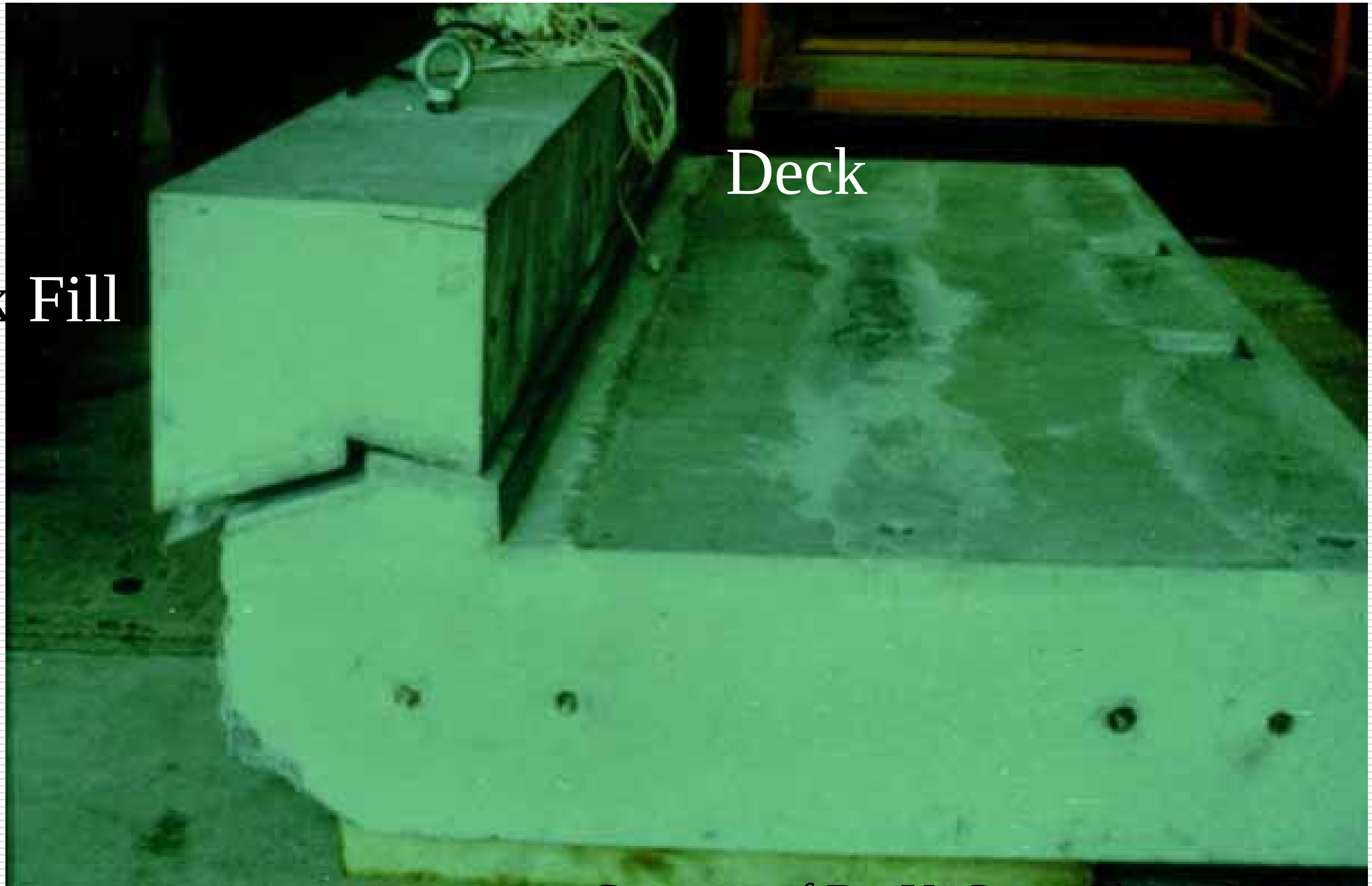
Knock-off Abutment

交通量が少ないため、ニュージーランドでは比較的簡単な伸縮継ぎ手が使用されている

Simple Expansion Joints used in New Zealand

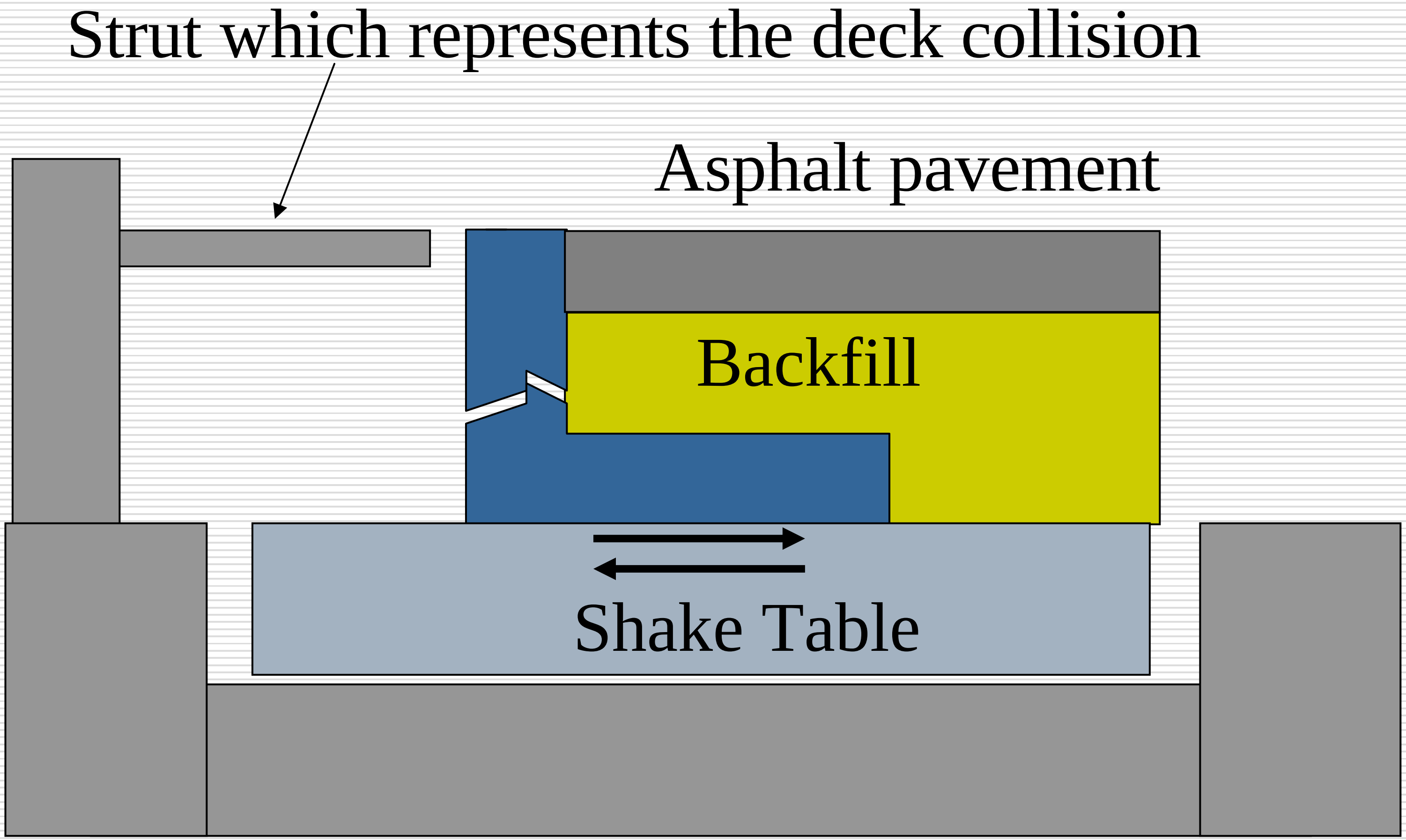
Is Knock-off Abutment effective in Japan?

Shake able experiments on Knock-off Abutment



Courtesy of Dr. Y. Goto, Obayashi Construction

Shake table experiments on Knock-off Abutment
ノックオフ橋台に対する振動台実験



Impact Load Test using a Shake Table for the Effectiveness of Knock-off Abutment

Knock-off Abutment

Courtesy of Dr. Y. Goto, Obayashi Construction

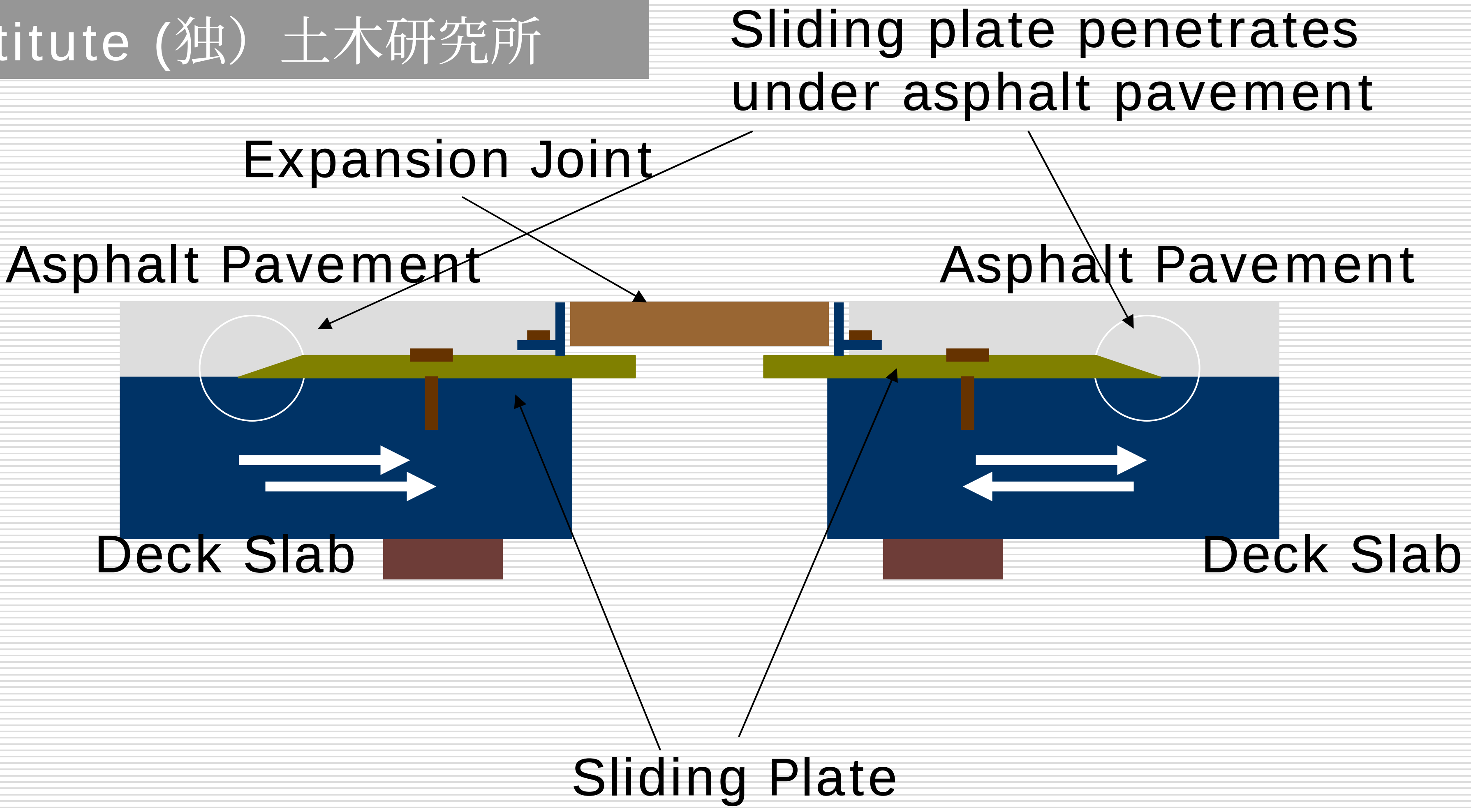
Buckling of asphalt pavement

Tilting of lower parapet wall underneath the asphalt pavement

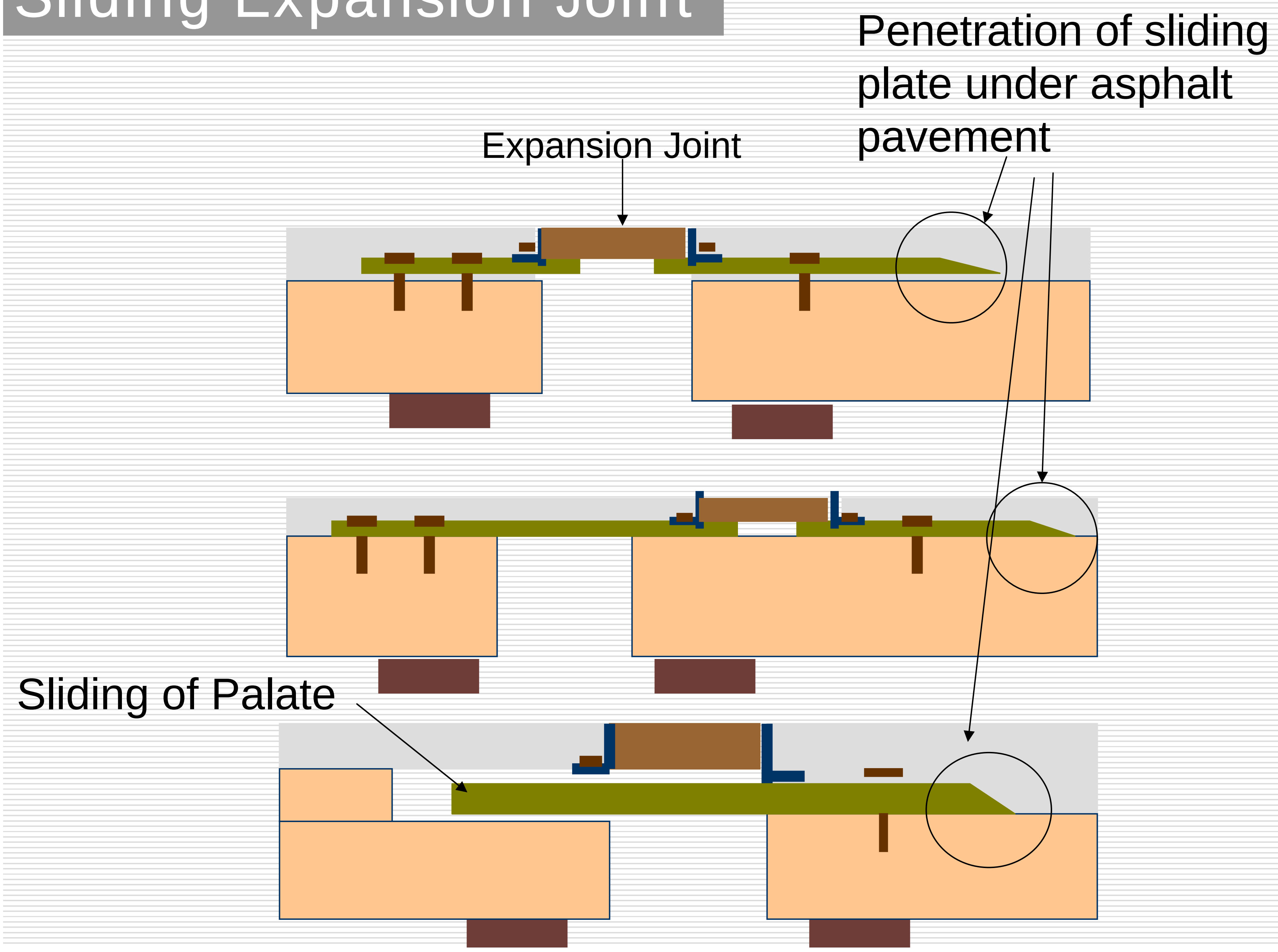
Courtesy of Dr. Y. Goto, Obayashi Construction

4) Development of Various Sliding Expansion Joints
いろいろな伸縮装置が開発されてきた

Public Work Research Institute (独）土木研究所

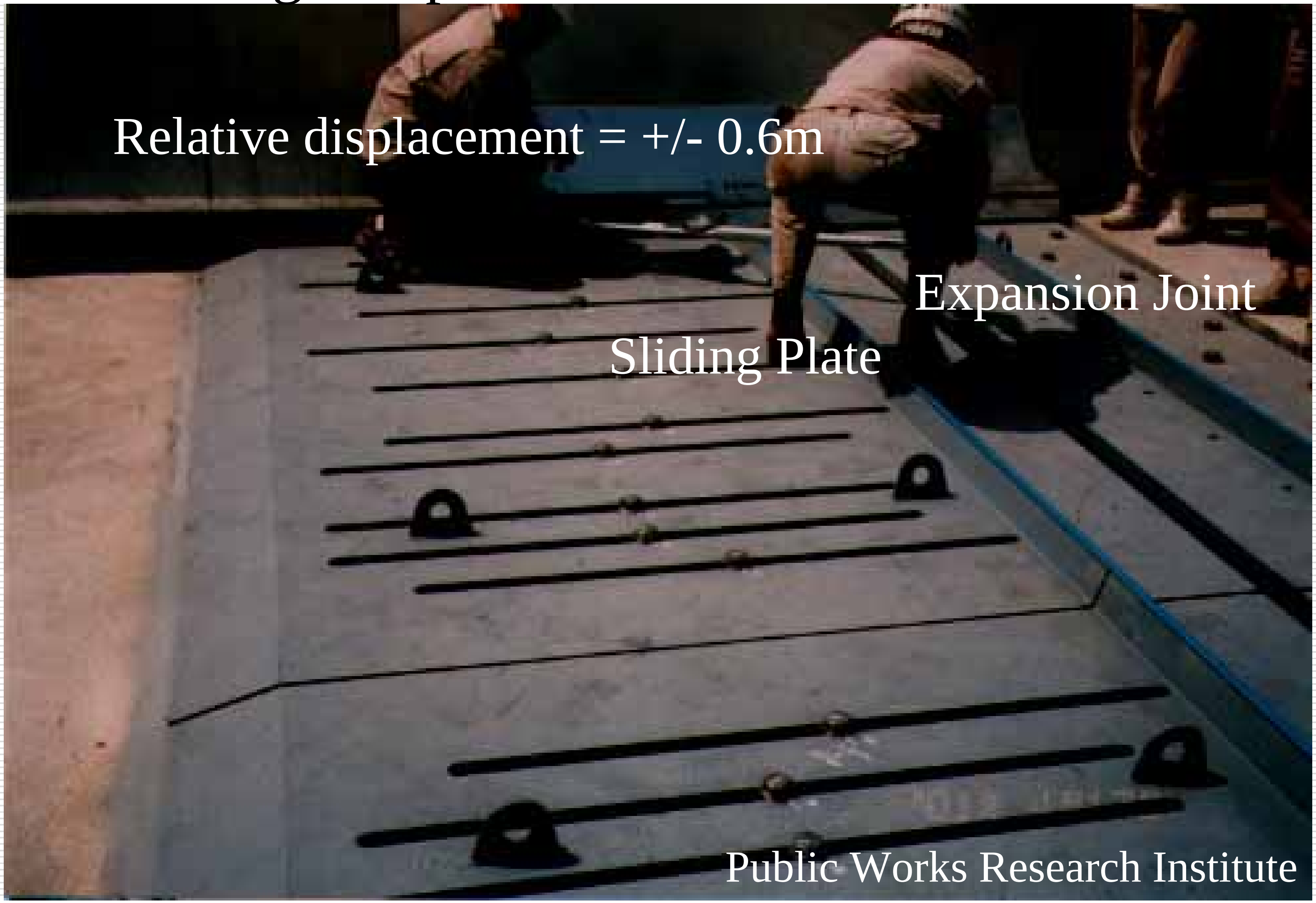


Sliding Expansion Joint



Implementation of a Set of Sliding Expansion Joint System to Amano Viaduct, Maibara

423m long 17-span continuous viaduct



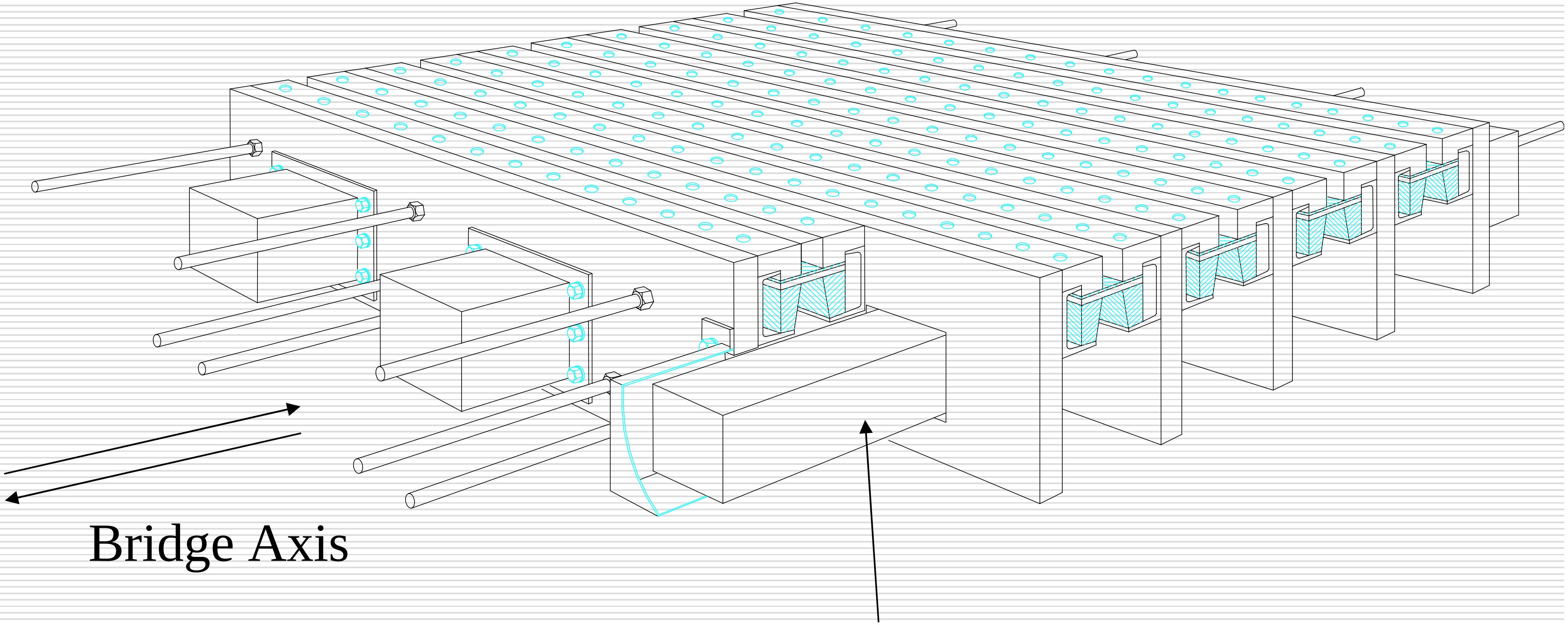
Sliding Expansion Joint

5) Development of 2 Directional Expansion Joint
2方向に相対変位を吸収可能な伸縮装置の開発

6) Big Joint 大変位を吸収可能な伸縮装置

An Expansion Joint with Function of a Restrainer

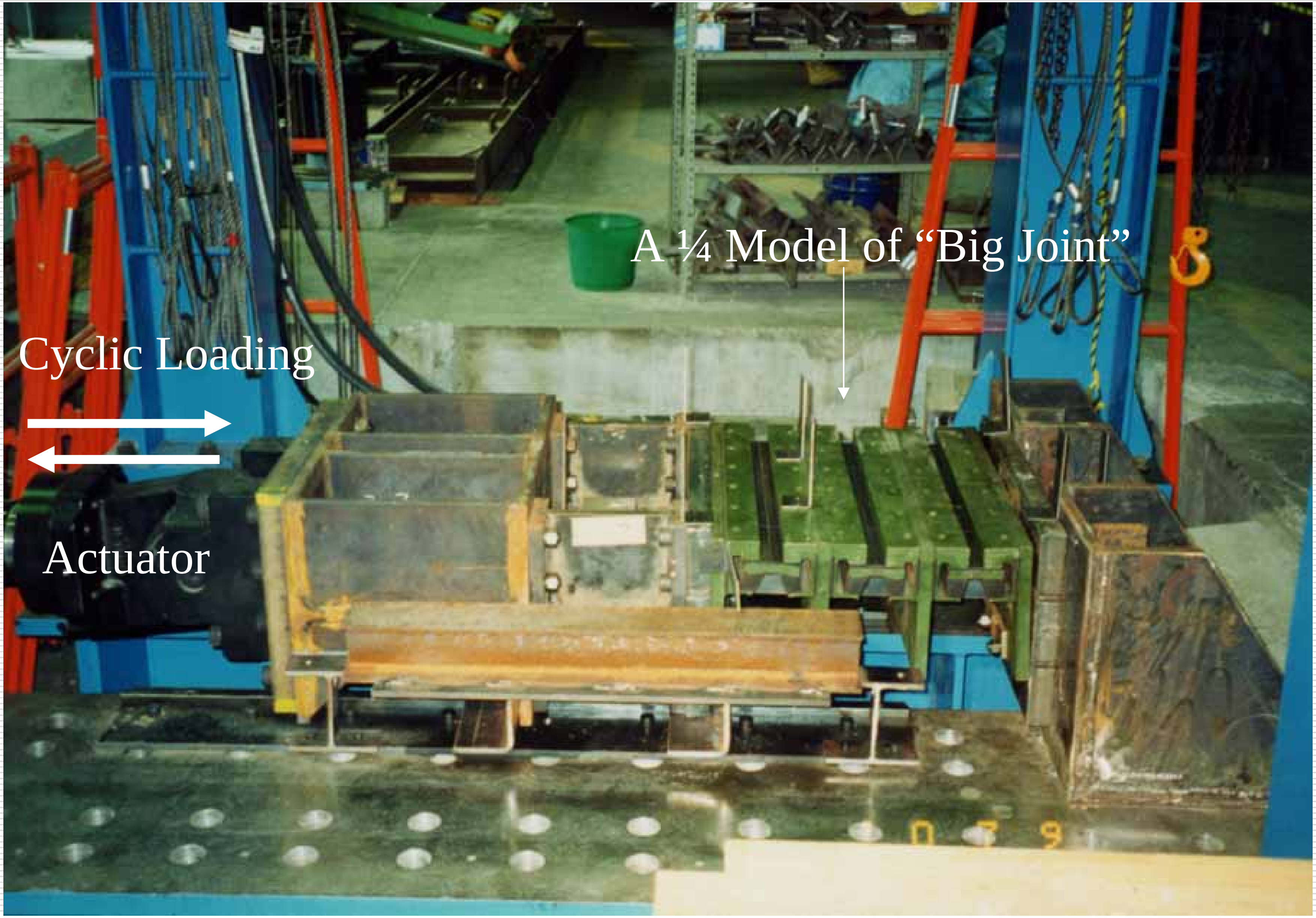
Yokohama Rubber Ltd.



Bridge Axis

Load Support Beam & Restrainer that limits Excessive Opening

Cyclic Loading Test for a Big Joint
“ビッグジョイント”に対する繰り返し載荷実験



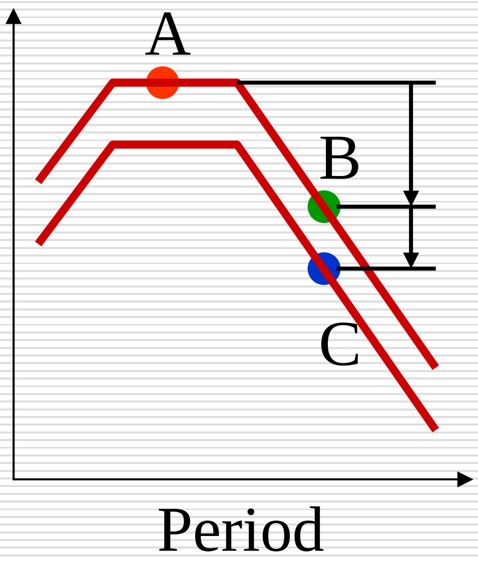
5.6 How Should the Natural Period of an Isolated Bridge be Set?
免震橋では固有周期をどの程度伸ばせばよいか？

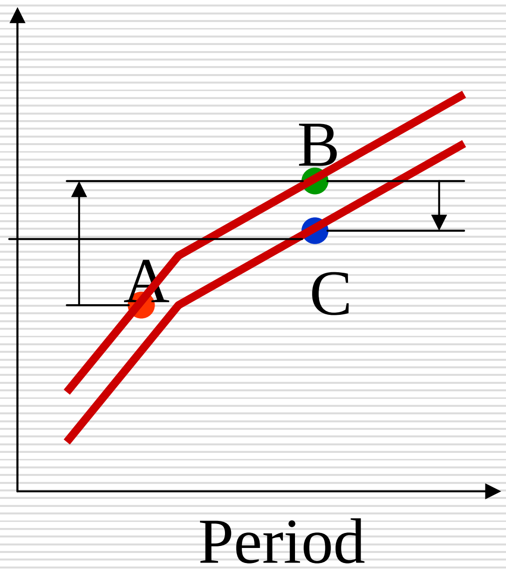
1) Expected Natural Period of Isolated Bridges

●Increase of natural period results in larger deck displacement having stronger impact force

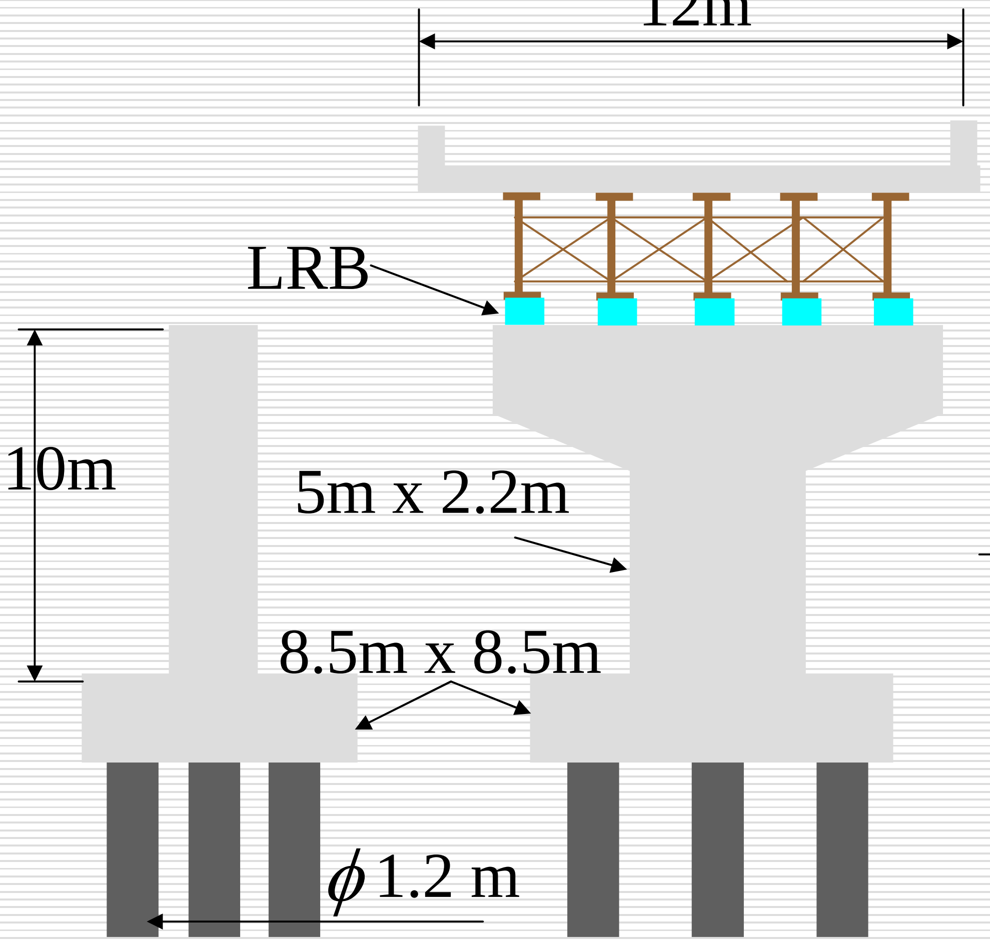
●What is the appropriate level of increase of natural period?

Response Acceleration Response Displacement

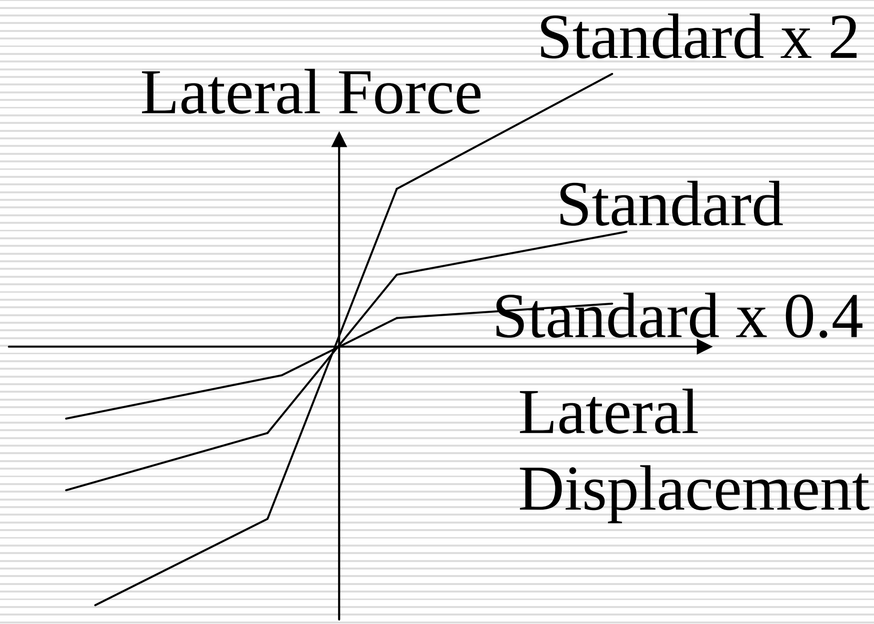




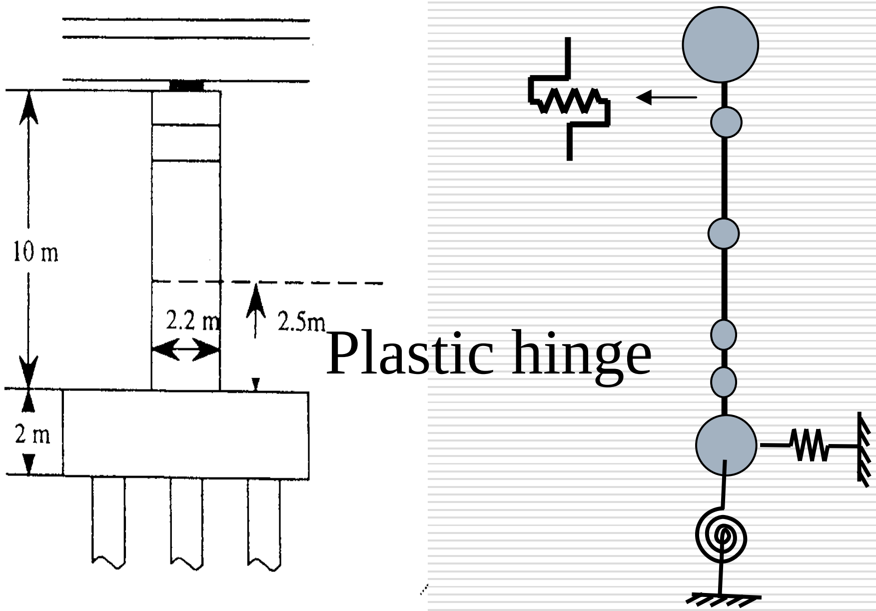
2) Analytical Example-Isolated Bridges Analyzed



Lateral Force vs. Lateral Displacement Relation of LRBs



3) Idealization of the Isolated Bridge



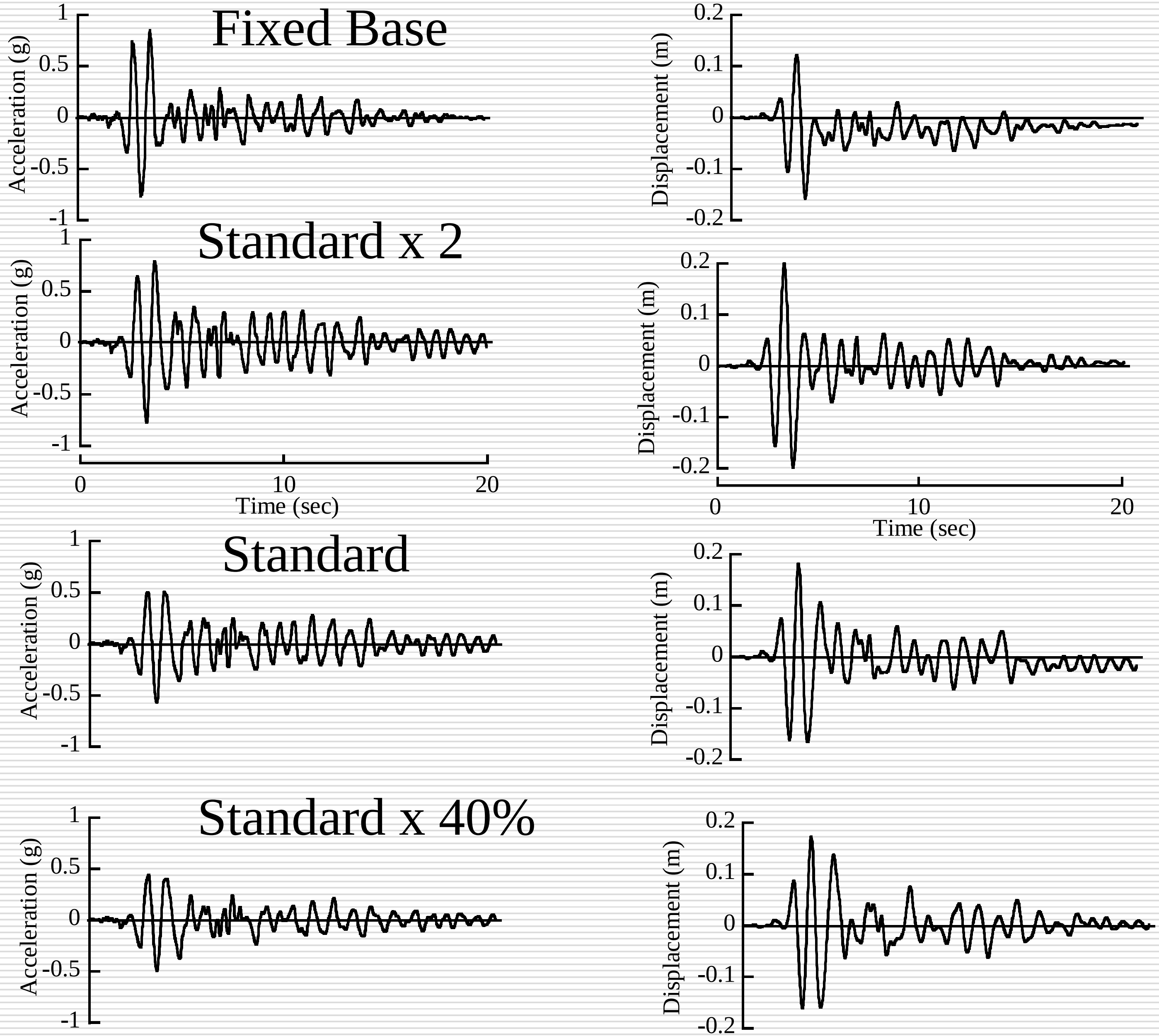
✓Lump the mass of a deck at the mass center of the deck

✓ Idealize the isolator by a lateral spring element with a bilinear hysteresis

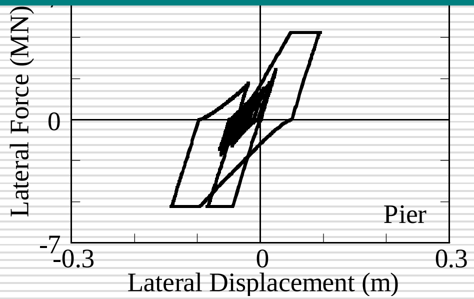
✓ Idealize the hysteretic behavior of the column at the plastic hinge by a rotational spring with Takeda degrading model

✓ Idealize the stiffness of a foundation and the soil-structure interaction by a set of translational and rotational linear spring elements

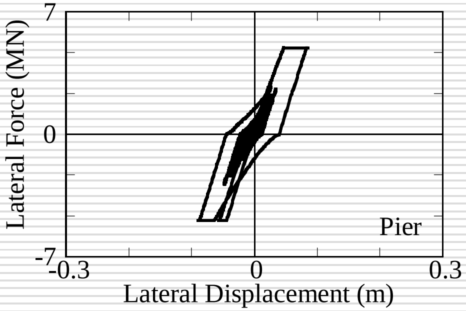
4) Deck Responses under JMA Kobe Observatory Record

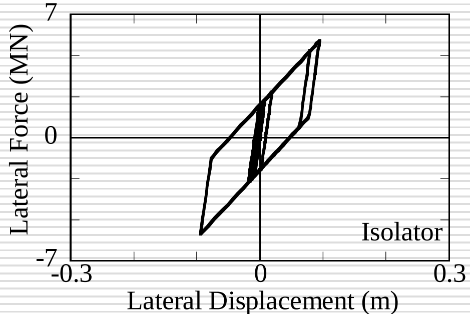


5) Column Hystereses under JMA Kobe Observatory Record

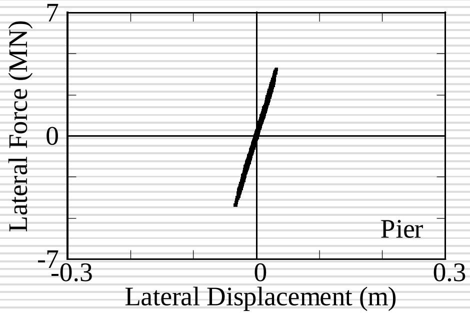


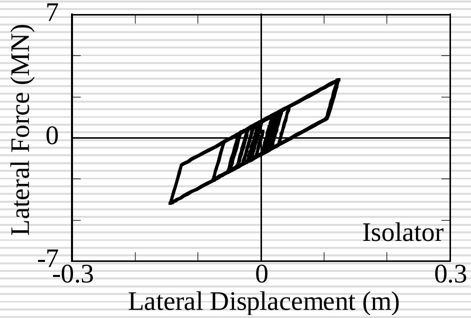
Fixed Base



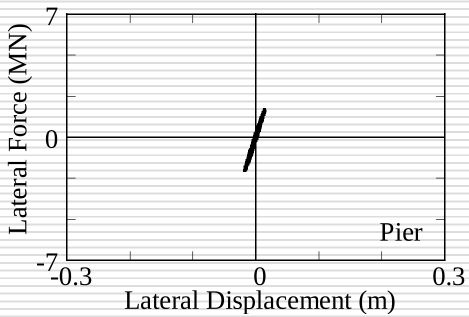


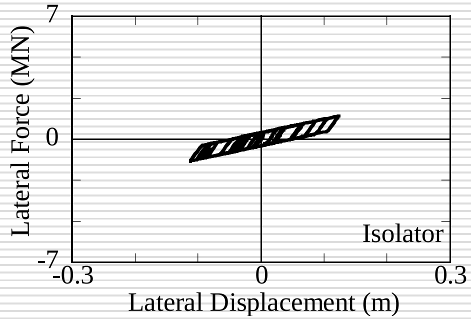
Standard x 2





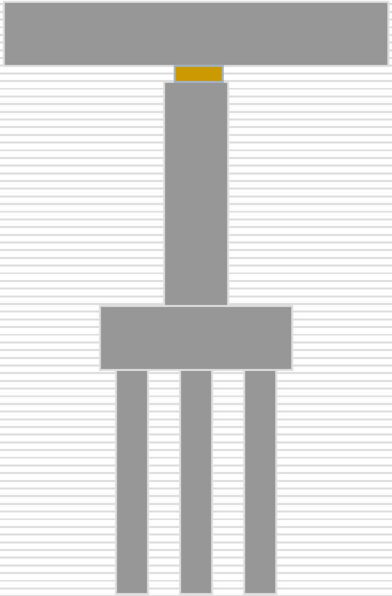
Standard





Standard x 0.4

6) Energy Dissipation of Isolators & Columns
免震装置と橋脚の塑性吸収エネルギー



Energy Dissipation of the Columns

✓ Isolated Bridge**免震橋**

$$U_C{}^I = \oint M_C{}^I d\theta_C{}^I$$

✓ Fixed Base Bridge**一般橋**

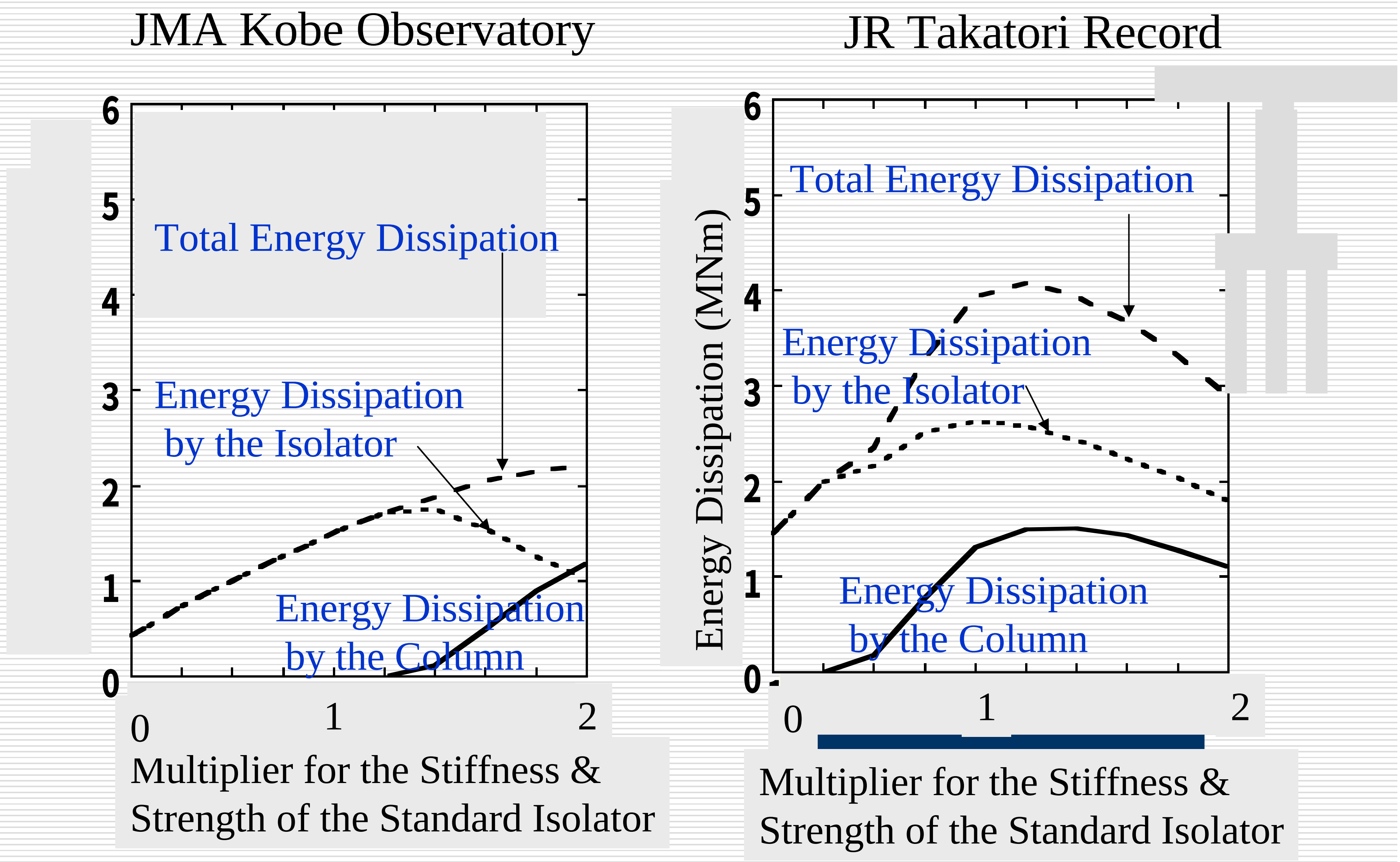
$$U_C{}^F = \oint M_C{}^F d\theta_C{}^F$$

Energy Dissipation Ratio of the Column

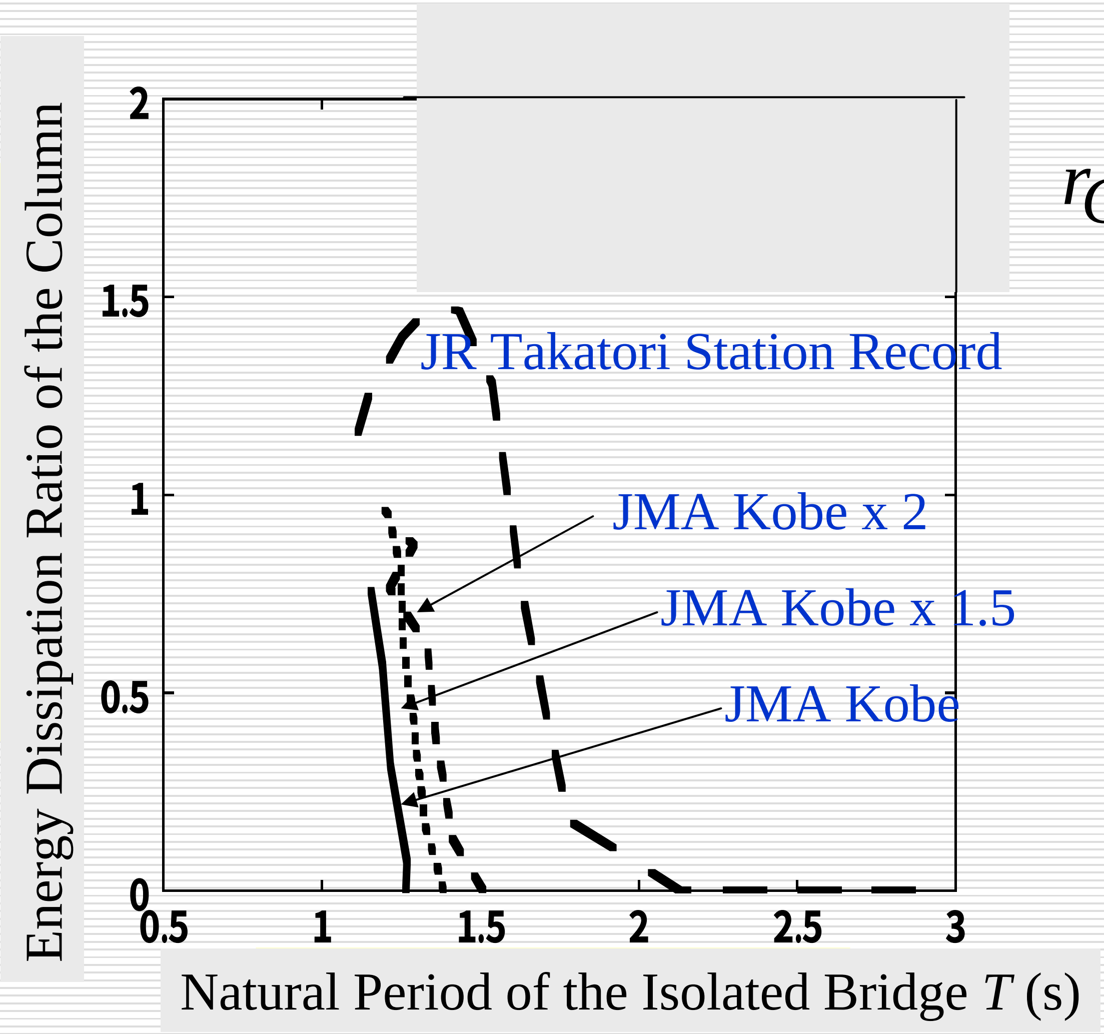
$$r_C = \frac{U_C{}^I}{U_C{}^F}$$

Seismic isolation is beneficial if $r_C < 1.0$

7) Energy Dissipation of Isolators & Columns

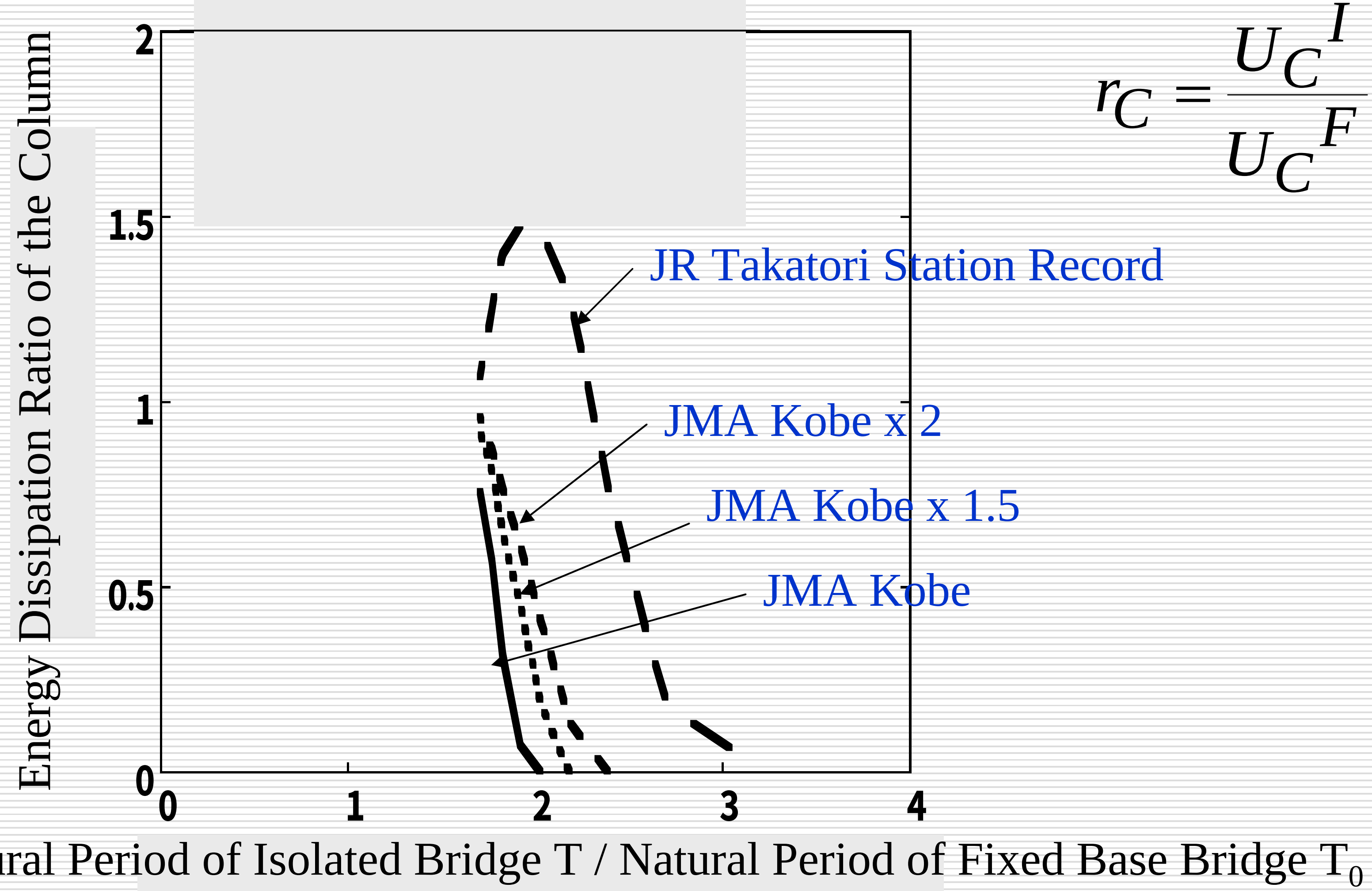


8) Energy Dissipation Ratio of the Column



$$r_C = \frac{U_C{}^I}{U_C{}^F}$$

Energy Dissipation Ratio of the Column



$$r_C = \frac{U_C{}^I}{U_C{}^F}$$

9) Summary-How should the Natural Period of an Isolated Bridge be Set?

Part V Seismic Design Specifications of Highway Bridge
Japan Road association, 2002, 2007道路橋示方書

$$\frac{T}{T_0} \approx 2$$

✓ T should not be extremely long so that the deck response displacement does not become excessively large = Menshin Design

✓ Careful evaluation on the site condition and site specific ground motions are required