

Seismic Response Modification of Urban Infrastructure

都市施設の免震設計

(1) Damage Experience in the Past

(1) 地震被害の歴史

Kazuhiko Kawashima
Department of Civil Engineering
Tokyo Institute of Technology
東京工業大学大学院理工学研究科土木工学専攻
川島一彦

Does a Catfish Develop an Earthquake?



Old Japanese believed that an earthquake happens to take place when a large catfish in ground moves.



Kaname
(Key)
Stoke
Katori
Shrine

古語によればその昔、豊後・豊前の二つの大津は天神の命を受け、豊前の中津國を幸とし、各社・神社にまつた。しかし、この地をばらばらとふるえあがり、地震が頻りに人々をいたく苦しめていた。これは地中に大きな鯰が揺れ動き、震れまわっているからだと、大津は地中に潜る鯰をさし込み、鯰の腹を押しつぶして地震を鎮めたといわれている。豊前・豊後の二社、豊前神社は四社で地上に「ただけ」をあらわし、震え鎮めたとされている。あまの年（一六四二）年、豊前・豊後二社が合併して豊前神社とされ、これを鎮めた鯰をあらわすことが出来なくなったといわれる。

Knowing what damage we had in the past is the best way to mitigate the similar damage in the future.

We need a good insight to avoid damage which we have not yet experienced.

Kazuhiko Kawashima, 1995

1. What Types of Damage of Urban Infrastructures Did We Have in Past?

- 1.1 Damage resulting from ground vibration
- 1.2 Damage resulting from ground deformation and failure of soils
 - 1.2.1 ground deformation
 - 1.2.2 Slope failure and rock falls
 - 1.2.3 Effect of soil liquefaction & lateral spreading
 - 1.2.4 Insufficient bearing capacity of loose clay
- 1.3 Damage resulting from fault displacement
- 1.4 Damage resulting from tsunami
- 1.5 Damage resulting from fire

1.1 Damage Resulting from Ground Vibration

- Damage resulting from the direct effect of inertia force
- Most common type of damage due to an earthquake
- Extensive research has been conducted to mitigate this type of damage.

(1) 1923 Kanto Earthquake, Japan



Toyokuni Bridge



(2) 1947 Fukui Earthquake, Japan



(3) 1971 San Fernando, Earthquake, USA

Collapse of 5/14 Overcrossing



(4) 1988 Armenia Earthquake



(5) 1989 Loma Prieta Earthquake, USA



1989 Loma Priest, USA, Earthquake



(6) 1992 Cairo, Egypt Earthquake (M5.4)



Adobe Construction
which always
resulted in extensive
damage worldwide



(7) 1994 Northridge Earthquake, USA



(8) 1995 Kobe Earthquake, Japan



(9) 2008 Wenchuan Earthquake, China



(10) 2009 L'Aquila Earthquake, Italy

Collapse of a Student
Dormitory

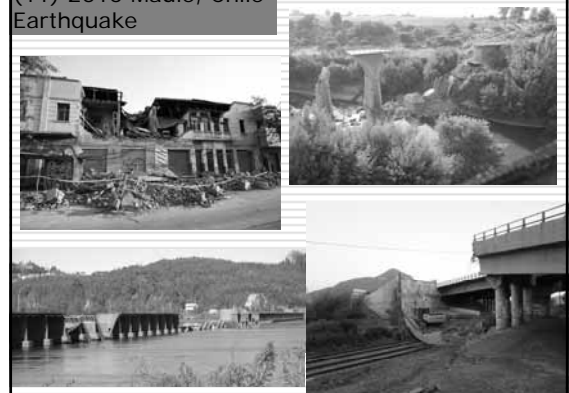
Bricks



Failure of RC columns
with poor concrete



(11) 2010 Maule, Chile Earthquake

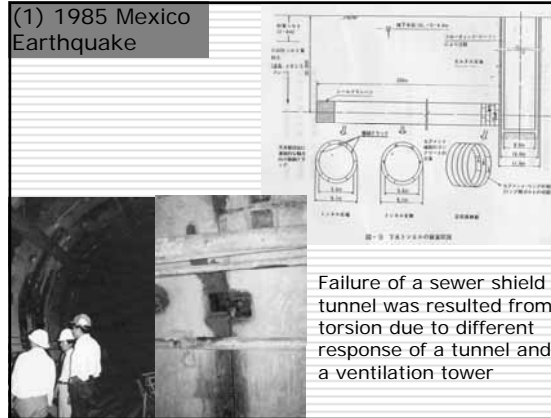


1.2 Damage Resulting from Deformation and Failure of Soils 地盤の変形や破壊によって生じる被害

1.2.1 Damage Resulting from Ground Deformation 地盤の変形によって生じる被害

- Ground deformation in this section implies the deformation due to seismic response of ground. Ground deformation due to surface ruptures of ground is treated separately.
- Since foundations and underground structures are subjected to earthquake ground deformation, this effect is important for foundations and underground structures.

(1) 1985 Mexico Earthquake



Failure of a sewer shield tunnel was resulted from torsion due to different response of a tunnel and a ventilation tower

(2) 1994 Northridge Earthquake, USA

Failure of Water Pipes Resulting from Ground Motion Effects



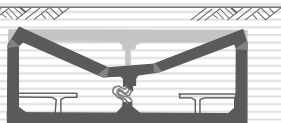
(3) 1995 Kobe Earthquake, Japan

Collapse of Daikai Subway Station



Subsidence of Road Surface

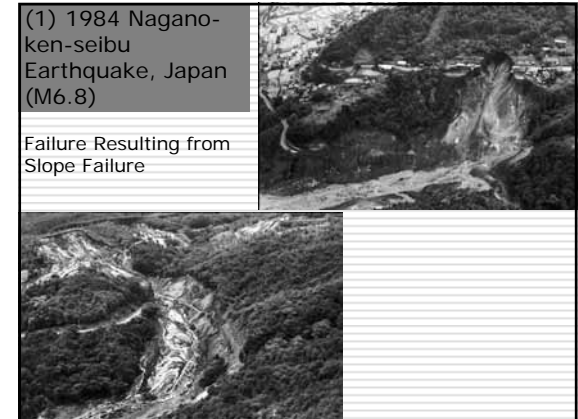
Failure Mechanism

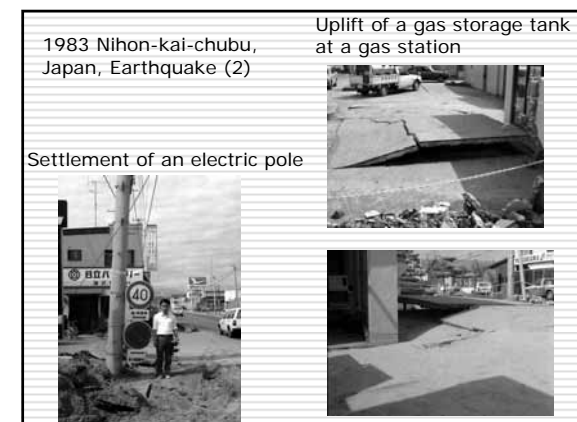
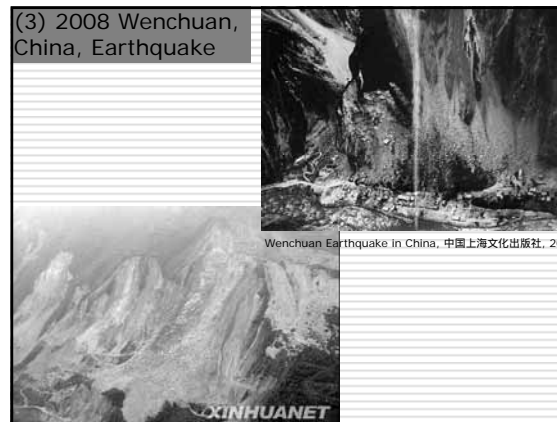
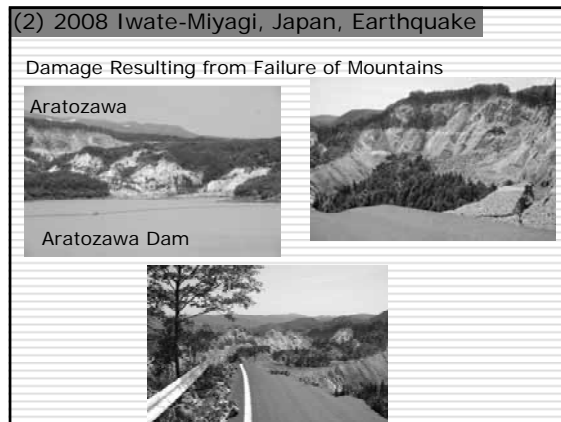


1.2.2 Damage resulting from Slope Failure and Rock Falls

(1) 1984 Nagano-ken-seibu Earthquake, Japan (M6.8)

Failure Resulting from Slope Failure





Failure of road pavement resulting from lateral spreading
1983 Nihon-kai-chubu, Japan, Earthquake



(3) 1992 Cairo, Egypt, Earthquake

A large sand bulb developed at Nile River Delta



1.3 Damage Resulting from Fault Displacement

(1) 1888 Nobi, Japan Earthquake

Midori Fault

2002



(2) 1906 San Francisco Earthquake, USA



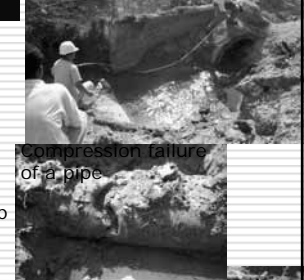
(3) 1999 Düzce, Turkey Earthquake



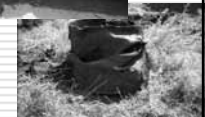
Nearly 6 m right lateral slip

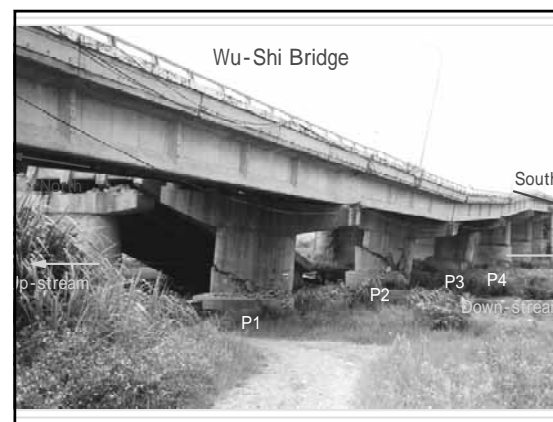
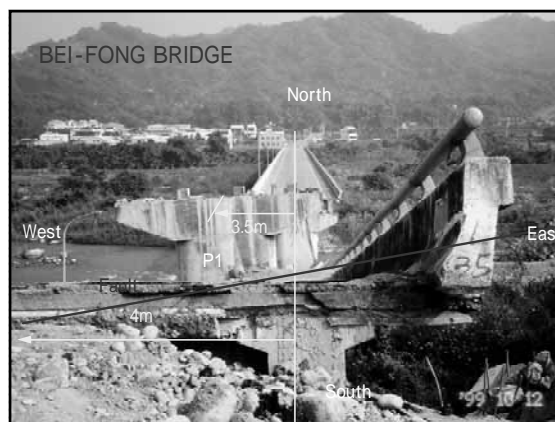
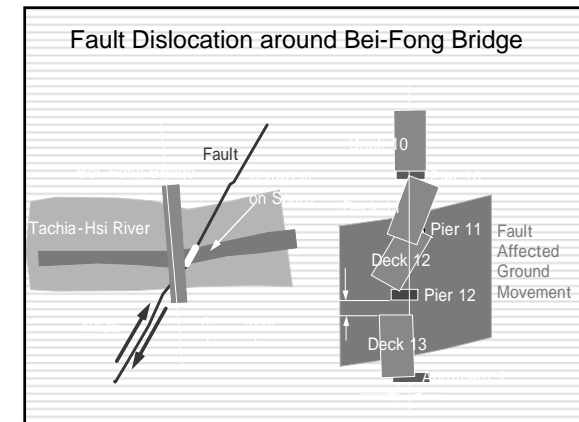
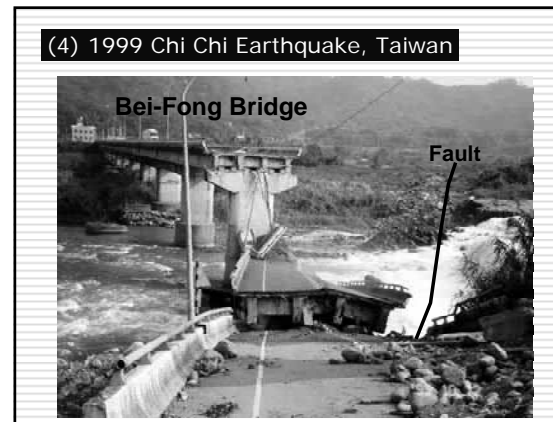
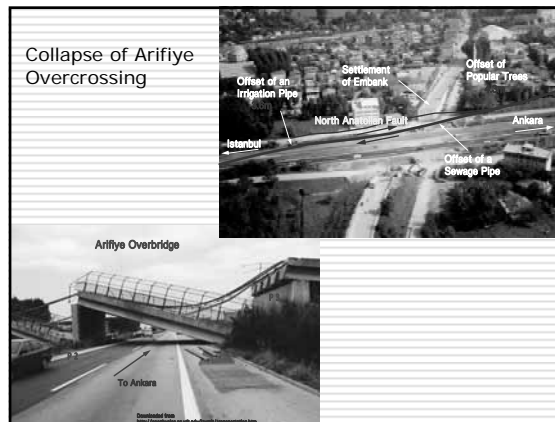


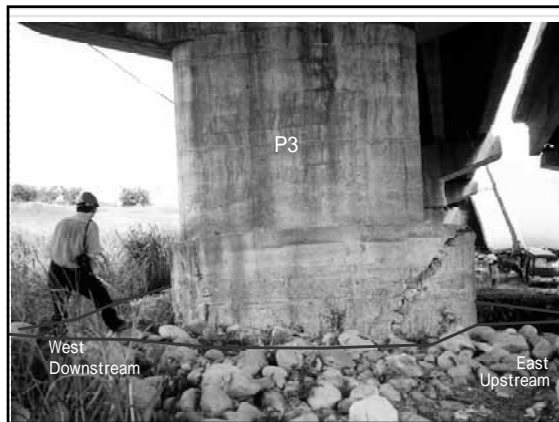
Failure of a water pipe



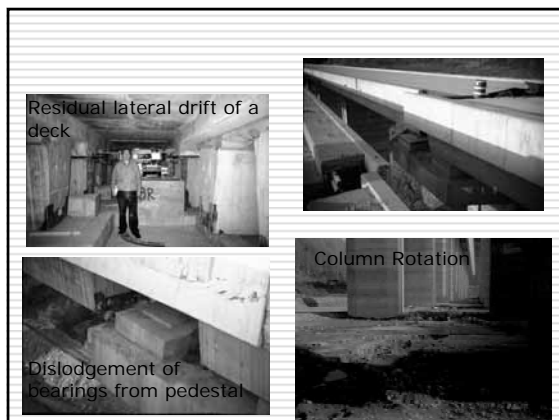
Compression failure of a pipe







Shikang Dam
1999 Chi Chi, Taiwan, Earthquake



Damage of a tunnel
1999 Bolu, Turkey earthquake



1.4 Damage Resulted from Tsunami

(1) 1992 East Flores Island Earthquake, Indonesia



(2) 2010 Maule, Chile Earthquake



1.5 Damage Resulted from Fire After an Earthquake

(1) 1906 San Francisco, USA, Earthquake



(2) 1923 Kanto Earthquake, Japan



(3) 1994 Northridge, USA, Earthquake



(4) 1995 Kobe,
Japan, Earthquake



Summary of Chapter 1

1. Seismic effects include at least 1) ground vibration, 2) ground deformation, 3) fault displacement (断層変位), 4) tsunami and 5) fire.
2. In addition to the above five effects, there are many other effects, such as 1) generation and propagation of functional damage, economical effects, and mental damage. 機能喪失とこの連鎖、経済的損失、精神的ダメージ
3. Because the five effects in 1. results in various damage in 2. it is essential to mitigate damage in 1.
4. Seismic isolation and response modification technology aim of mitigating damage due to ground vibration.