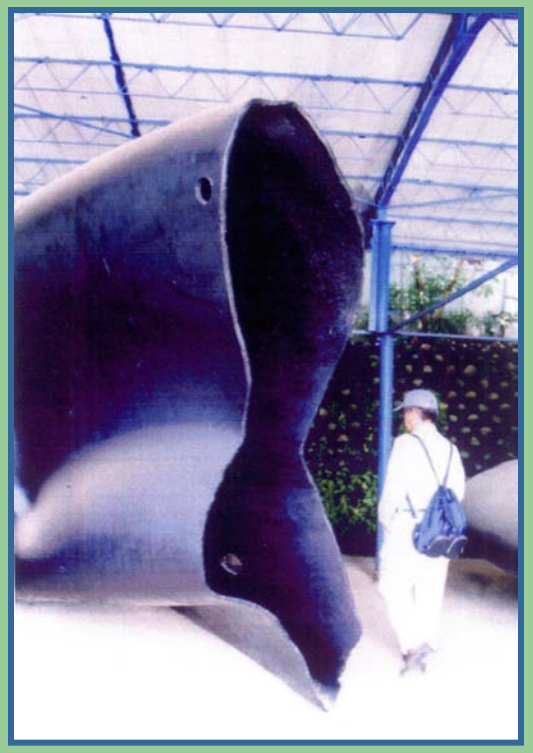
WATER SUPPLY FACILITIES DAMAGES BY THE 1999 CHI-CHI EARTHQUAKE AND THE AFTERSHOCK RESTORATION WORKS



Dr. LIAO, Tsung-Shen

Chairman

Chinese Taiwan Water Work Association

中華民國自來水協會 CTWWA

ABOUT TAIWAN

- Area: 35,980 km^2
  - 394 km (245 mi) long
  - 144 km (89 mi) wide
- Population: 22,974,347 (2009)
- Capital: Taipei
- Other Major Cities:
  - Kao-hsiung
  - Tai-chung

Water Service Organization of Taiwan Area

- Taipei water Department (TWD)
- Taiwan water Corporation (TWC)

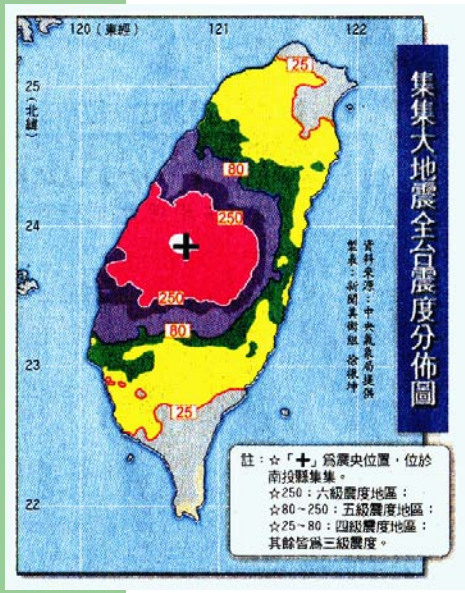
INTRODUCTION OF TAIPEI WATER DEPARTMENT

- Established in 1907
- Offering 2.6 million CMD water
- More than 1.6 million connections
- Servicing about 3.85 million people
- 99.51 percent connection
- More than 3,635 kilometers of water lines ($\geqq$ 75 mm)
- Service Area : Taipei Metropolitan

INTRODUCTION OF TAIWAN WATER CORPORATION

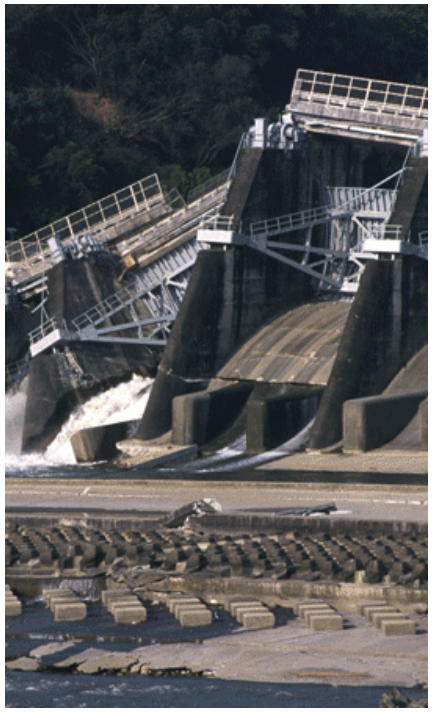
- Established in 1974
- Offering 8.6 million CMD water
- More than 6.1 million connections
- Servicing about 18 million people
- 91 percent connection
- More than 55,000 kilometers of water lines ($\geqq$ 50 mm)
- Service Area : Besides Taipei Metropolitan

STATISTICS OF THE CHI-CHI EARTHQUAKE



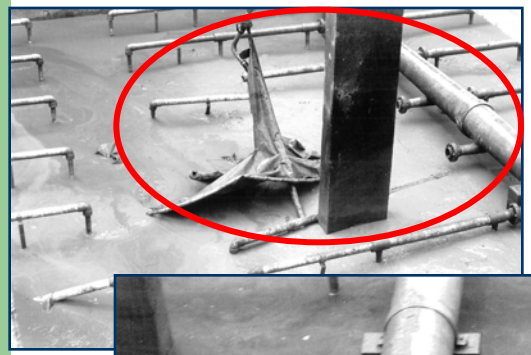
- Magnitude: MW = 7.3 (**Richter magnitude scale**)
  - Sichuan Earthquake, 2008: MW = 7.9
- Death Toll: 2,505
  - Hanshin-Awaji, 1995: 5,470
  - South Asia Tsunami, 2004: > 200,000
  - Hurricane Katrina, 2005: > 1,836
  - Sichuan Earthquake, 2008: > 88,000
- Direct Property Loss: 10.7 billion USD

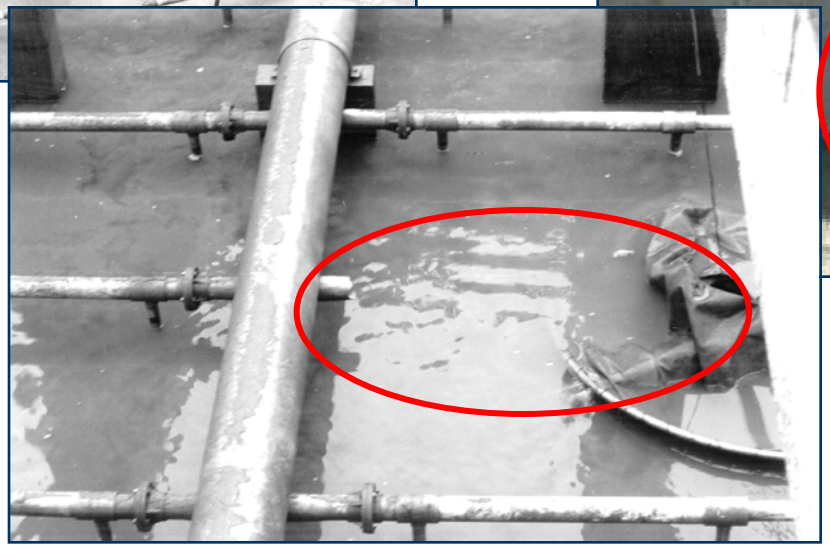
DAMAGE TO THE SHIGARNG DAM IN THE CHI-CHI EARTHQUAKE



9.8 m offset fault in vertical direction

DAMAGE TO THE FONGYUAN PURIFICATION PLANT IN THE CHI-CHI EARTHQUAKE -1





Flocculation and Sedimentation Basin

Flocculation Basin

DAMAGE TO THE FONGYUAN PURIFICATION PLANT IN THE CHI-CHI EARTHQUAKE – 2

Finished Water Reservoir

Collapse of the Finished Water Reservoir

DAMAGE TO THE WATER PIPELINES

- In the Chi-Chi earthquake, the area of the subsurface damage to water pipelines is much larger in size than the area of above-surface structural damage.
- The site investigations approximate a total length of damaged water pipelines of around 16,000 km, including 12,000 km of primary water supply lines (≧300 mm).

EFFECTS OF PIPELINE MATERIALS AND JOINTS

- SP, CIP, DIP, PE and PVC, are used for the pipelines of the TWC water supply system.
- The steel pipes (SP) and the polyethylene (PE) pipes were both received only small damage in the Chi-Chi earthquake.
- The joint of the PVC pipe seems very vulnerable in the earthquake. For other types of pipe, such as the DIP pipes, the damage to segmented pipes most often occurs at the joint too.

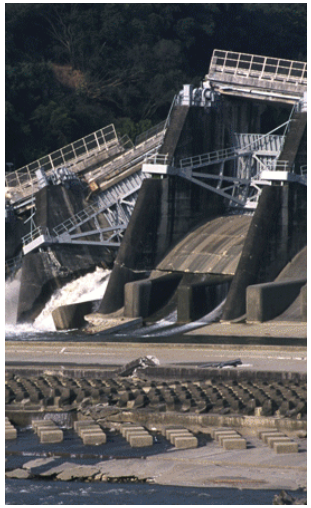
Damage to 600 mm Pipe in the Fongyuan Purification Plant

SUMMARY - 1

- Immediately after the earthquake, herculean efforts from TWC mostly invested to the repairing works.
- Continuing for weeks, all the efforts were organized on a round-the-clock basis.
- Before damage recovery, TWC devised the emergency water supply using portable reservoirs served by tank trucks.

SUMMARY - 2

- Serious damage to water supply pipelines in the Chi-Chi earthquake can be attributed to many factors involving at least:
  - the irresistible faulting movement along the fault zones.
  - the intensive ground shaking near the epicenter.
  - the site amplification of ground shaking induced by varying local geology.
  - the liquefaction due to poor ground condition.
- Damage modes of the buried water pipelines can be categorized in accordance with different materials of the pipelines
- The damage to the pipeline was effected by the soil-pipeline interaction, which depended mainly upon the pipeline diameter. (The smaller, the worse.)
- The pipe fitting connections are apt to suffer damage.
- The joint of the pipe is the key point of earthquake resistance.



SUMMARY - 3

- High performance of pipeline burying work is essential.
- Better selection of pipeline materials is important.
- More underground distribution reservoirs should be built.
- Regional water supply backup systems should be established.
- Design ground acceleration coefficient has been increased from 0.23G to 0.33G.

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Thanks for Your Patience