Damages in the KOBE Earthquake & Japanese Seismic Design Guidelines of Drinking Water Supply Facilities

KOBE

KOREA

CHINA

JAPAN

Pacific Ocean

H. FUKUDA

Kobe Municipal Waterworks Bureau
Contents

1. General of JWWA's Guidelines for Seismic Design
2. Lessons and Planning for Earthquake Resistant Water System in KOBE

(Published by Japan Water Works Association in 1997)
### Damages of the KOBE Earthquake Damages in 1995

<table>
<thead>
<tr>
<th>Damages</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epicenter</td>
<td>far from 20km to the Kobe city hall</td>
</tr>
<tr>
<td>Scale</td>
<td>Mg 7.2</td>
</tr>
<tr>
<td>Fatality</td>
<td>6,430 persons</td>
</tr>
<tr>
<td>Injury</td>
<td>43,793 persons</td>
</tr>
<tr>
<td>Building</td>
<td>250 thousand buildings</td>
</tr>
<tr>
<td>Fire</td>
<td>198 cases</td>
</tr>
<tr>
<td>Facilities</td>
<td>Damages (damaged/total)</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Dams</strong></td>
<td>1/ 3 dams</td>
</tr>
<tr>
<td><strong>Purification Plant</strong></td>
<td>2/ 7 plants</td>
</tr>
<tr>
<td><strong>Raw water conduit</strong></td>
<td>2 lines/ 43 km</td>
</tr>
<tr>
<td><strong>Transmission Main</strong></td>
<td>6 lines/ 260 km</td>
</tr>
<tr>
<td><strong>Distribution Reservoir</strong></td>
<td>1/ 119 stations</td>
</tr>
<tr>
<td><strong>Distribution Pipe</strong></td>
<td>1,757 failures/ 4,002 km</td>
</tr>
<tr>
<td><strong>Service Pipe</strong></td>
<td>89,584 repairs/ 650,000 lines</td>
</tr>
<tr>
<td><strong>Others (inc. Building)</strong></td>
<td>Head office, one branch, etc</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>
Basic plans to be drawn beforehand for developing anti-seismic measures in water supply

1. Proper damage estimates & preventive measures.
2. Plans on emergency relief measures & effective emergency repair works.
3. Detailed plans on the organization of permanent restoration works.
1.2 Planning, Design & Implementation

To give sufficient consideration to earthquakes in accordance with various conditions.

To rationally design the structures with adequate consideration for important facilities.

To retain the water supply system as a whole as much capability to do water service.
1.3 Geo-technical Survey of the Foundation

- To be founded on the firm foundation and the stable landscape.

- To carry out a careful and detailed geo-technical survey.
1.4 The Employment of Highly Earthquake Resistant Materials & Joints

- To employ earthquake resistant materials.
- To provide watertight facilities and structures with earthquake resistant joints.
Damage of Cast Iron Pipe (800mm)
Damaged Rubber Gasket (800mm)
Pulling out of Mechanical Joints
Over-Slipped and Shrunken Ingot
Cut into Ingot together in the Collar
Damages Number and Rate (cases/km)

Steel Pipe
DIP(A,K,T)
CIP
PVC

Pipe Body
Joint

0  200  400  600  800
0  0.5  1  1.5
1.5 Anti-Seismic Design of System

1) To localize earthquake damage as much as possible.
2) To easily repair damages.
3) To provide measures to prevent secondary disasters as a result of an earthquake.

Looping and Interconnection systems.
Separation of a pipe network into blocks.
Installation of emergency shut-off valves.
Emergency Water Securing System

Emergency Shutoff Valve System Concept

- Okuhirano Control Center
  - Monitoring and control equipment
  - Seismometer

- Distribution reservoir at disaster prevention center
  - Reservoir equipped with emergency shutoff valves
  - Telemeter local station
  - Secured drinking water
  - Distribution pipes
  - Distribution
<table>
<thead>
<tr>
<th>Seismic Acceleration</th>
<th>Operation of Emergency Shutoff Valve System</th>
</tr>
</thead>
<tbody>
<tr>
<td>over than 250gal, or 250gal</td>
<td>Automatically Close all Valves of installed reservoirs</td>
</tr>
<tr>
<td>Less than 250gal over than 80gal, or 80gal</td>
<td>Automatically closed valves of reservoirs in flowing out abnormally</td>
</tr>
<tr>
<td>Less than 80gal</td>
<td>Non-operation</td>
</tr>
</tbody>
</table>
Water Tank connecting directly for securing Emergency Water

Hydrant
For Emergency Supply

Air Valve

Distribution Mains

Automatically Shut off Valve
Attention Points of Pipeline Network

• To adequately space-division valves in the pipeline network.
Collapsed Road and Damaged Pipes
Attention Points of Pipeline Network

- To adequately space-division valves in the pipeline network.
- To limit the depth of underground pipes.
- To set division valves both in back and in front of the pipeline to be considered occurring the secondary disaster.
1.6 Maintenance & Planned Improvements

• To undertake adequate inspection and maintenance.

• To conduct positive anti-seismic diagnostic inspections.

• To improve facilities with low anti-seismic ratings.
Seismic Pipe Replacement in the Coastal Area

March 1995

March 2002

Distribution Network Upgrade
Good Performance of Seismic Proof Joints.
Difference between Seismic Joint and Normal Joint

Seismic Joint (NS type)  Slip on Joint (T type)

Lock Ring  Spigot Projection
ロックリング

ゴム輪

ロックリング

挿し口突部
1.7 Assumption of Earthquake Damage

• To establish Plans for emergency water service and repair works.
• To facilitate such works:
  ) Information networks,
  emergency manpower mobilization,
  mutual cooperation system.
  stockpiling materials and equipments,
  complete sets of facility drawings,
  decentralization of their management.
1.8 Order of Restoration Works

- To start with up-stream preparations.
- To be sufficiently considered on relationship between emergency restoration works and subsequent permanent restoration works.
Kobe's Guidelines & Basic Plan for Anti-Seismic Water Supply
Long period of Service Recovery

It took 10 weeks!

Recovery Rate (%)

Weeks

1995 Kobe
# Inquires and Requests from Citizens after the Kobe Great Earthquake

<table>
<thead>
<tr>
<th>Customer’s Voice</th>
<th>1st week</th>
<th>2nd week</th>
<th>3,4th week</th>
<th>5th week</th>
</tr>
</thead>
<tbody>
<tr>
<td>水の見通しは？</td>
<td>いつ水が出るのか？</td>
<td>詳しい情報がない</td>
<td>我慢も限界だ</td>
<td></td>
</tr>
<tr>
<td>給水車はいつどこに来るのか</td>
<td>避難所に給水タンクを設置してほしい</td>
<td>水が十分給水されない</td>
<td>水汲みがつらい、疲れた</td>
<td></td>
</tr>
<tr>
<td>(場所、時間)</td>
<td>(量、回数をふやす)</td>
<td>(量、回数＋時間帯)</td>
<td>(近辺では出ているのに…)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Word</th>
<th>1st week</th>
<th>2nd week</th>
<th>3,4th week</th>
<th>5th week</th>
</tr>
</thead>
<tbody>
<tr>
<td>want to Know</td>
<td>Impatient</td>
<td>Frustrated</td>
<td>Angry</td>
<td></td>
</tr>
</tbody>
</table>

To complete temporary restoration within four weeks of the suspension of water supply, in the wake of a natural disaster.
Target in Emergency Water Supply

Unit: liter per capita/day

Days after earthquake

- Up to 3 days
- 10 days
- 21 days
- 28 days

- 30 l
- 20 l
- 100 l
- 250 l
## Target ration for emergency water supply

<table>
<thead>
<tr>
<th>Days after Earthquake</th>
<th>Target ration</th>
<th>Distance between Water Supply Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 3 days</td>
<td>3 L/capita•day</td>
<td>Less than 2 km</td>
</tr>
<tr>
<td>10 days</td>
<td>20 L/capita•day</td>
<td>Less than 250m</td>
</tr>
<tr>
<td>21 days</td>
<td>100 L/capita•day</td>
<td>Less than 100m</td>
</tr>
<tr>
<td>28 days</td>
<td>Pre-earthquake Level</td>
<td>Less than 10m</td>
</tr>
</tbody>
</table>
3 To secure water at the disaster prevention center

We aim to realize a permanent water supply station at an early date by constructing earthquake-resistant water tanks, establishing a water transport system using water wagons, and laying earthquake-resistant pipes to the disaster prevention center.
To implement geographically continuous and equitable restoration

We aim to implement geographically continuous restoration, so as not to arouse a sense of unfairness among residents.
5 To secure water for facilities essential to citizens' life, at early dates

We aim to secure water for use in fire fighting, hospitals, refuse incinerators and welfare facilities, etc. at early dates.
Monthly Fluctuation of Samples to inspect water quality after the disaster
Kobe Water’s Full Restoration Plan
Based on the lessons of the 1995 Kobe Earthquake

- Wide Area Service Interruption
  - Limit to tank wagon supply

- Reduced pipe breaks
  - Securing source water

- Extended recovery term

- Emergency Water Supply System

- Pipe Network Upgrade

- Large Capacity Transmission Main

- Reliable Emergency Water Supply

- Disaster Resistant Water System

- Easy to repair Water System
Emergency Water Securing System Covered Area

1995
Completed 21/Planned 33

2002
Completed 32/Planned 47
Change of Pipe Materials and Joint Types

Pipe Length (km)

- Level 3 (CIP, PVC)
- Level 2 (DIP)
- Level 1 (S-DIP, SP)

Year | Level 1 | Level 2 | Level 3 | Total
--- | --- | --- | --- | ---
1970 | 1276 | 296 | | 1572
1980 | | 1618.6 | 65.7 | 1684.3
1995 | 445 | 3198.2 | 358.8 | 3802.6
2000 | 395 | 3112 | 805.6 | 4002.6
2002 | 372.2 | 3056.1 | 981.6 | 4410
Large Capacity Transmission Main

Two existing tunnels

LCTM

Shaft and water supply
Large Capacity Transmission Main

Inspection, repair, renew (Existing Transmission) feasible

- Water transmission capacity
- To maintain two existing tunnels
- To reduce recovery period
- Back up for the other tunnels
- Emergency water supply in downtown area
Construction

Shield Tunnel

Shield Machine  3350

Shaft
Reduction of recovery period
--- By Large Capacity Transmission Main and Block divide

Improved recovery

1995 Kobe

Recovery Rate(%)

Weeks
Use of the shaft

Water supply to water wagons and fire trucks

Emergency water supply via temporary water taps

Connecting pipe
Wide Area Water Network system

Hyogo pref. Water

Hanshin Water

Kobe Water

Osaka Bay

LCTM

Osaka pref. Water
Others Countermeasures

- Collaboration Agreements with other Cities & Utilities
- Preparation of Anti-Disaster Manuals & Information Systems
- Private Well Registration
- Autonomous Disaster-prevention & Welfare Organization
Others Countermeasures

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Others Countermeasures

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Others Countermeasures

- Collaboration Agreements with other Cities & Utilities
- Preparation of Anti-Disaster Manuals & Information Systems
- Private Well Registration
- Autonomous Disaster-prevention & Welfare Organization
Drill to enable to practice Firefighting & Water Supplying
2.1 General

- To retain respective capacity even after an earthquake with the design intensity of seismic tremor.
- Suitable Method to the characteristics of respective facilities and the nature of founding and surrounding ground.
Classification of Water Works Facilities

- Rigid structures.

2. Pipeline structures.

3. Facilities which characteristically respond to an earthquake.

4. Structures to have different characteristics or special purposes.
2.2 Seismic Motion Level for Design

• To employ two different magnitudes of intensity for an anti-seismic design:

  **Level 1 (L1)** : To have a return probability of once or twice in the service life of the facility.

  **Level 2 (L2)** : To have a smaller probability than the former but is greater in magnitude.
2.3 Importance Ranking of Facilities

- To categorize facilities into two for planning anti-seismic design of water supply facilities.

  (1) Facilities at a high level of importance (Rank A)

  (2) Other facilities (Rank B)
Facilities Ranked A

(1) Facilities to generate serious secondary disasters.
(2) Facilities located up-stream.
(3) Main facilities not to have backup facilities.
(4) Pipelines for social important institutions and facilities.
(5) Main facilities to be difficult to restore.
(6) Facilities for gathering information.
### 2.4 Anti-Seismic Level to be maintained

<table>
<thead>
<tr>
<th>Rank of Significance</th>
<th>Seismic Motion Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
</tr>
<tr>
<td>A</td>
<td>No damage.</td>
</tr>
<tr>
<td>B</td>
<td>Individual facility may receive light damage and may be able to function.</td>
</tr>
</tbody>
</table>
2.5 Earthquake Effects on Anti-Seismic Designs

- For anti-seismic design, following effects of earthquake must be taken into consideration:
  - Displacement and distortion of the foundation.
  - Inertial force owing to the weight of structures.
  - Soil pressure during an earthquake.
  - Dynamic water pressure during an earthquake.
  - Water surface sloshing.
  - Lateral soil movements due to liquefaction.
  - Soil distortion on a slope of reclaimed land.
2.6 Sequence of Anti-Seismic Design Works

- Anti-seismic designs of water supply facilities must be carried out in the following order:
  1) **Selection of the construction site.**
  2) **Geo-technical survey at the site.**
  3) **Selection of the structural type and the study on geo-technical conditions of foundation.**
  4) **Anti-seismic calculation.**
  5) **Examination of anti-seismic level.**
Fig. Anti-seismic Structure Design Order

START

Selection of Construction Site

Design of Significant Ranking of Facility

Soil Survey

Structure Design and Framing

Stationary Load Calculation

Anti-Seismic Calculation for Seismic Motion Level 1

Anti-Seismic Standard Check

Yes

Significant Ranking

Necessity of Check for Seismic Motion Level 2

Yes

Anti-Seismic Calculations for Seismic Motion Level 2

No

Total System Response Capability Check

Yes

System Consolidation

END
3.1 Anti-Seismic Calculation Methods

- Standard anti-seismic design methods to be applied for water supply facilities.
- Their selection to be based on the structural nature of the objective structures and other factors.

1. Seismic intensity method
2. Response displacement method
3. Reference to the results by dynamic analysis
Factors of the vibration pattern and the force to a structure

- The characteristics of the ground supporting the structure.

2) The structure’s mass, natural oscillation period, damping characteristics and flexibility.

3) The strength of a seismic motion and vibration characteristics.
<table>
<thead>
<tr>
<th>Calculation Method</th>
<th>Water Supply Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.M: Level 1</td>
<td></td>
</tr>
<tr>
<td>Seismic Intensity Method (S.I.M)</td>
<td></td>
</tr>
<tr>
<td>S.I.M or R.D.M</td>
<td>Machinery &amp; electric, Building structure</td>
</tr>
<tr>
<td>S.I.M or R.D.M</td>
<td>Water intake</td>
</tr>
<tr>
<td>Shield tunnel and shaft Pond-type reservoir</td>
<td></td>
</tr>
<tr>
<td>R. D. M</td>
<td>Well, Pipeline and tunnel (cross direction)</td>
</tr>
<tr>
<td>R. D. M or S.I.M</td>
<td>Pipeline, tunnel (axis)</td>
</tr>
<tr>
<td>R. D.M or D.A.M</td>
<td></td>
</tr>
<tr>
<td>Water intake</td>
<td></td>
</tr>
<tr>
<td>Water service tower Elevated water tank</td>
<td></td>
</tr>
</tbody>
</table>

*If necessary: D.A.M check*