A Reasonable Approach to the Seismic Assessment of Water Supply Facilities

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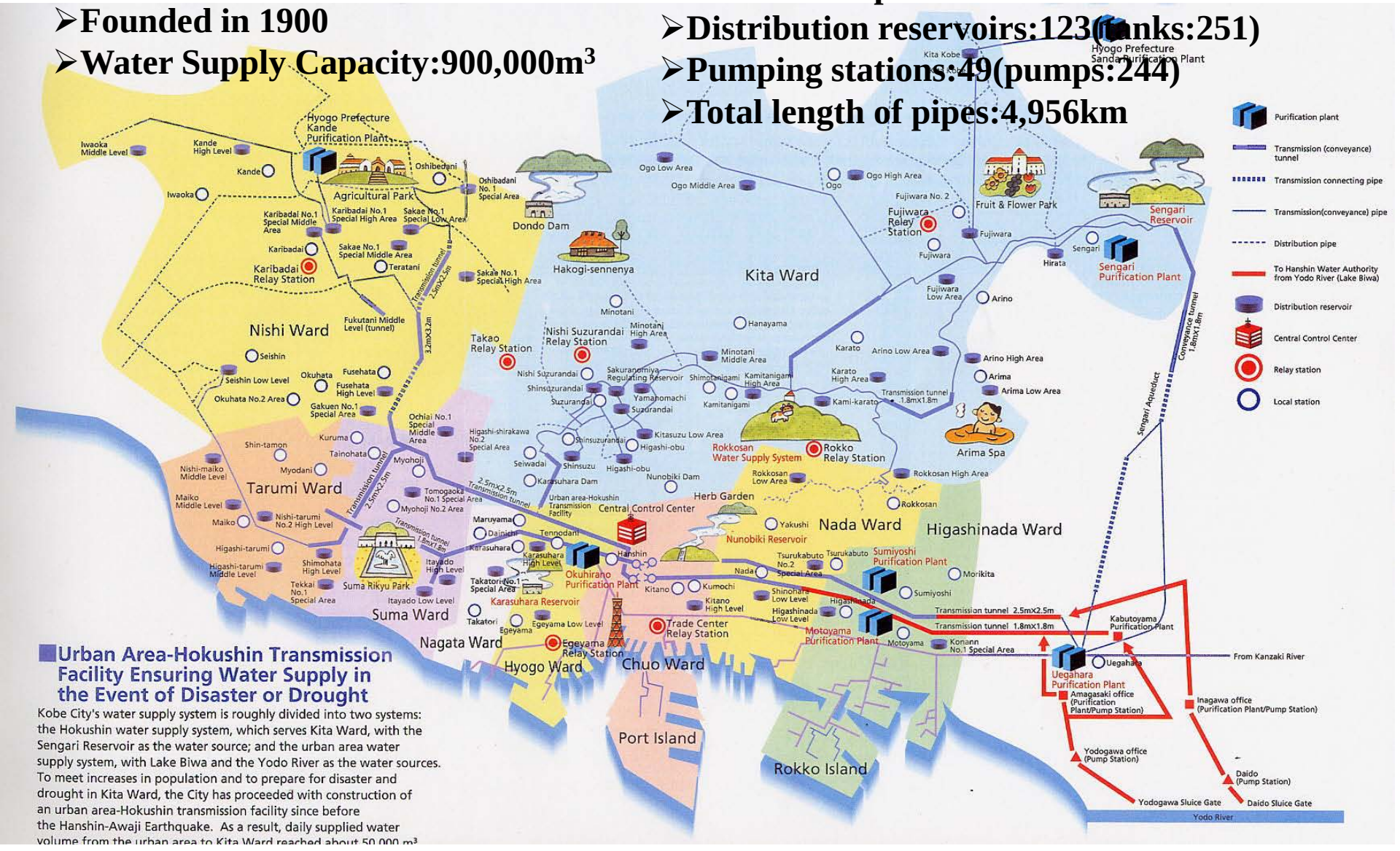
Contents

Location of Kobe City

Kobe Water System

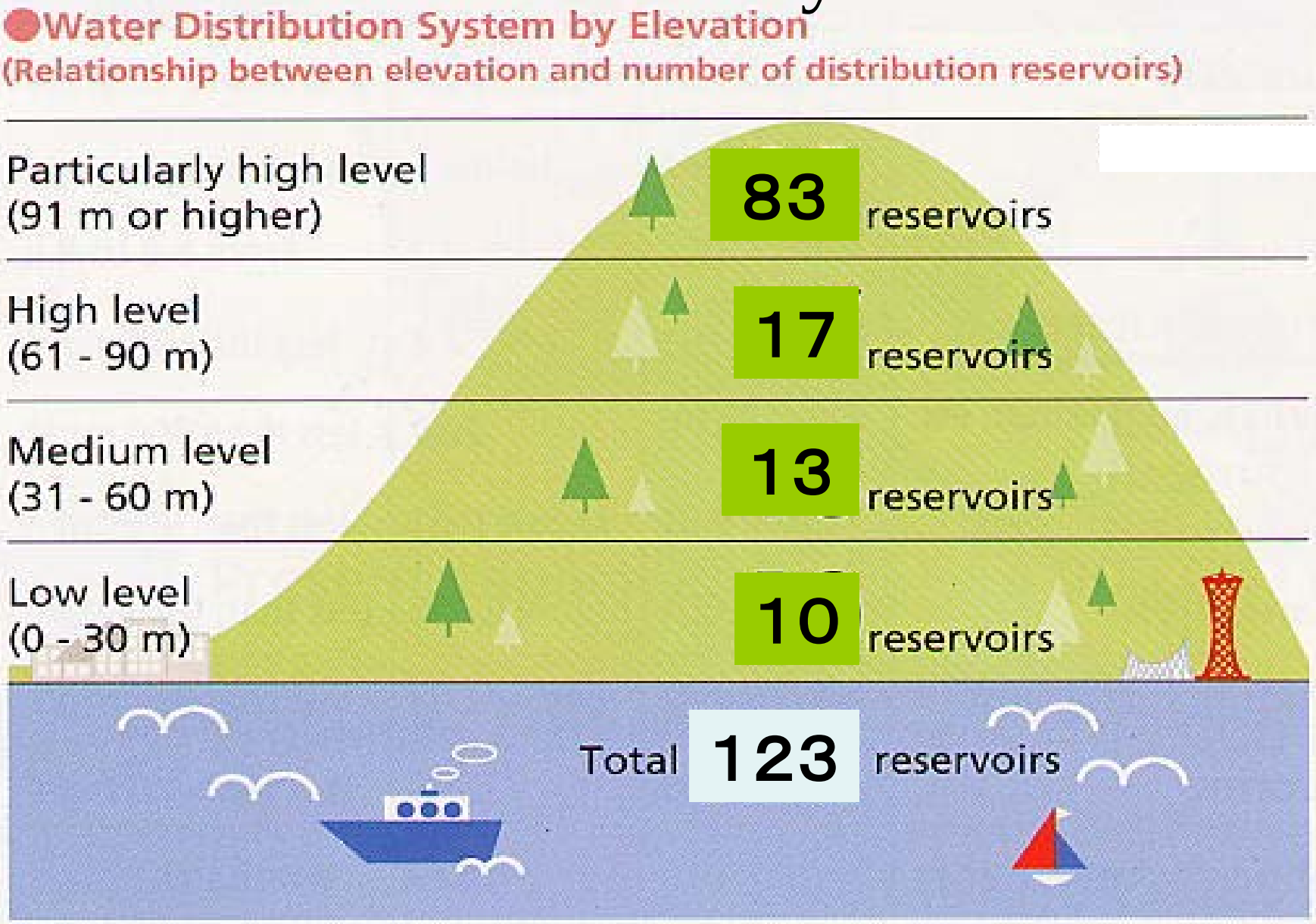
- **Serving Area:550km^2**
- **Population:1,530,000**
- **Founded in 1900**
- **Water Supply Capacity:900,000m^3**
- **Water storage:3**
- **Purification plants:6**
- **Distribution reservoirs:123(tanks:251)**
- **Pumping stations:49(pumps:244)**
- **Total length of pipes:4,956km**



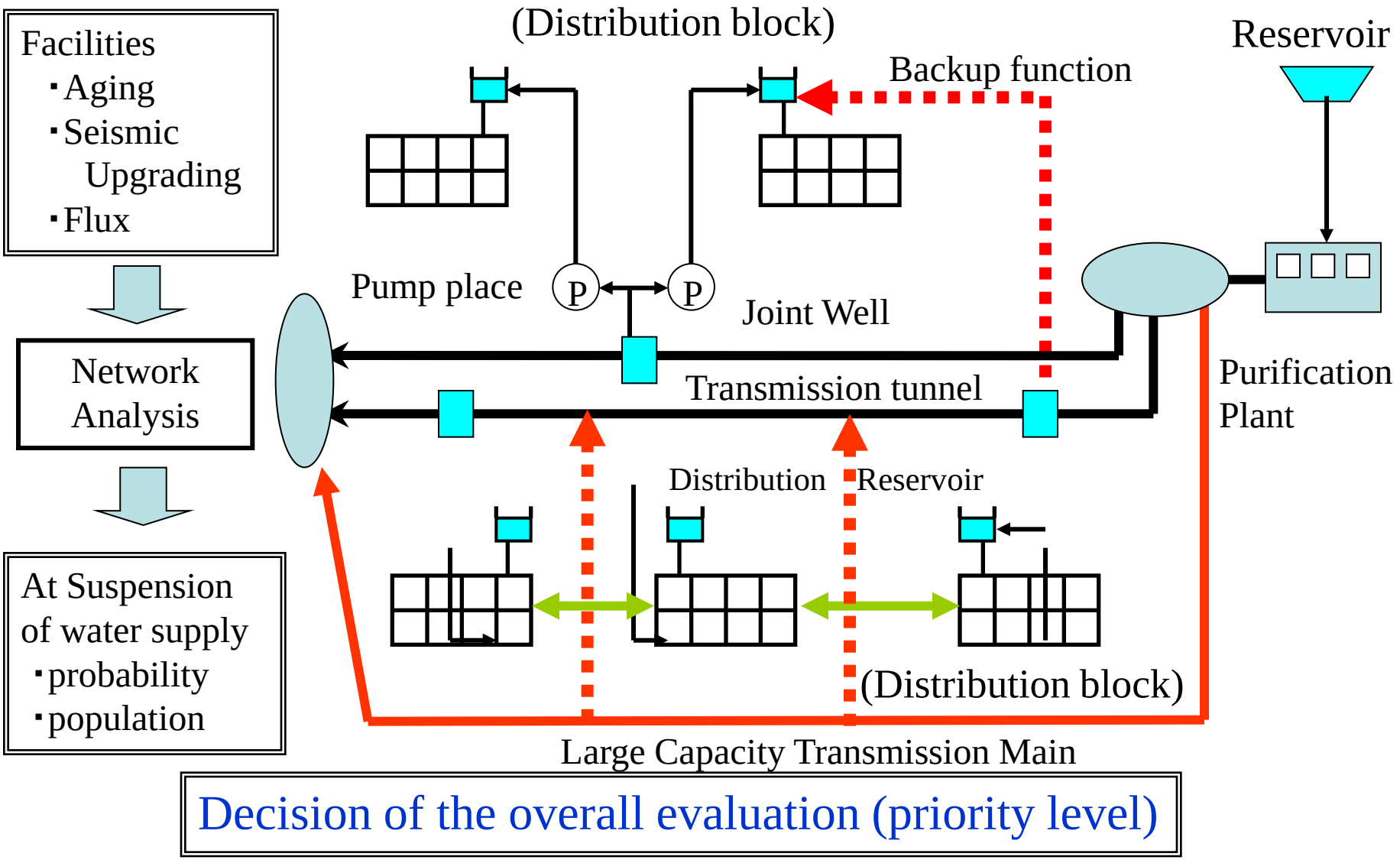
Urban Area-Hokushin Transmission Facility Ensuring Water Supply in the Event of Disaster or Drought

Kobe City's water supply system is roughly divided into two systems: the Hokushin water supply system, which serves Kita Ward, with the Sengari Reservoir as the water source; and the urban area water supply system, with Lake Biwa and the Yodo River as the water sources. To meet increases in population and to prepare for disaster and drought in Kita Ward, the City has proceeded with construction of an urban area-Hokushin transmission facility since before the Hanshin-Awaji Earthquake. As a result, daily supplied water volume from the urban area to Kita Ward reached about 50,000 m^3

Kobe Water System



Water Supply System Reliability Evaluation Program



Decision of the overall evaluation (priority level)

Efficient update and seismic reinforcement
(Improvement of system reliability)

SEISMIC ASSESSMENT PROCEDURES

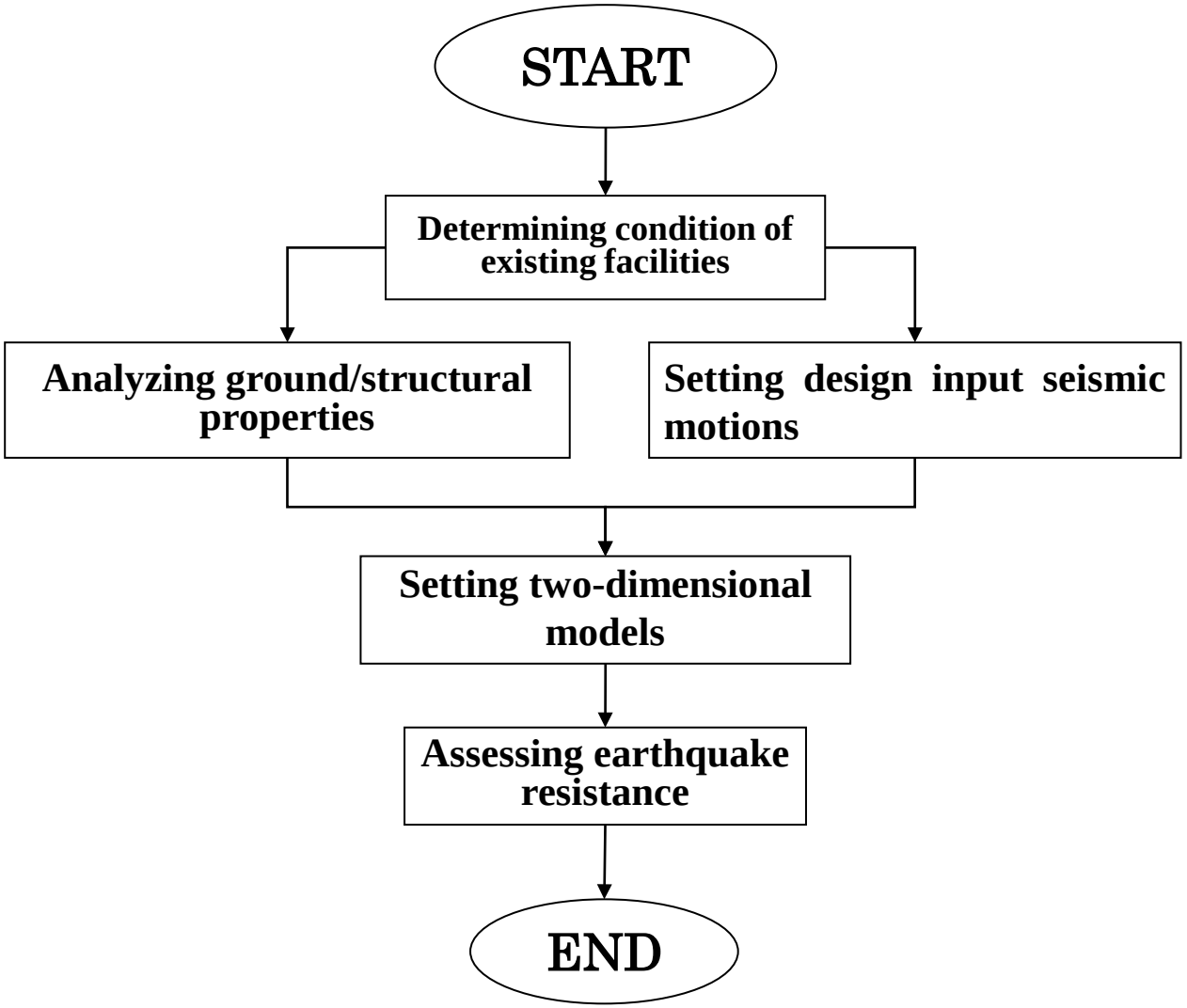


Figure 2-1

DETERMINING THE CONDITION OF EXISTING FACILITIES

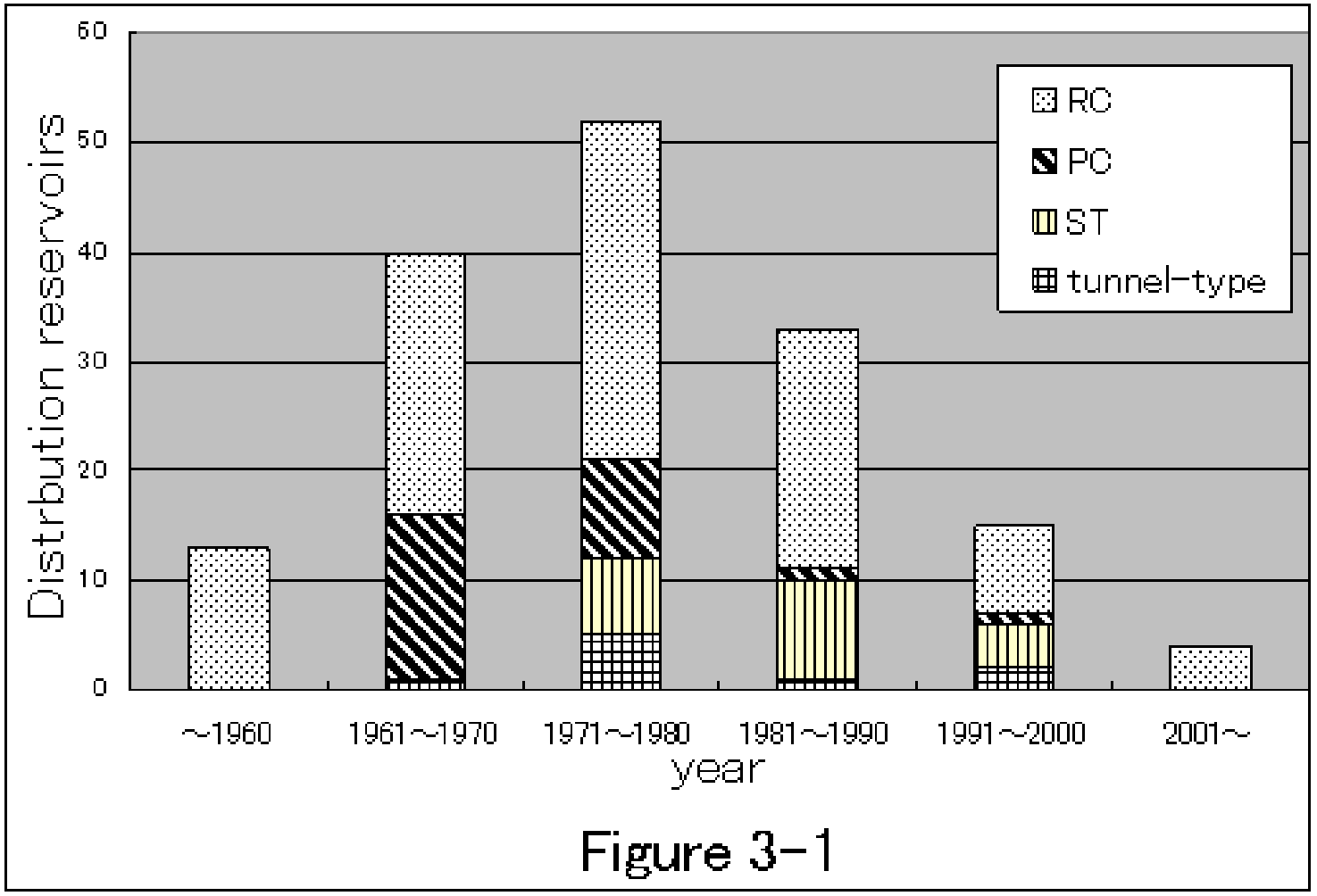
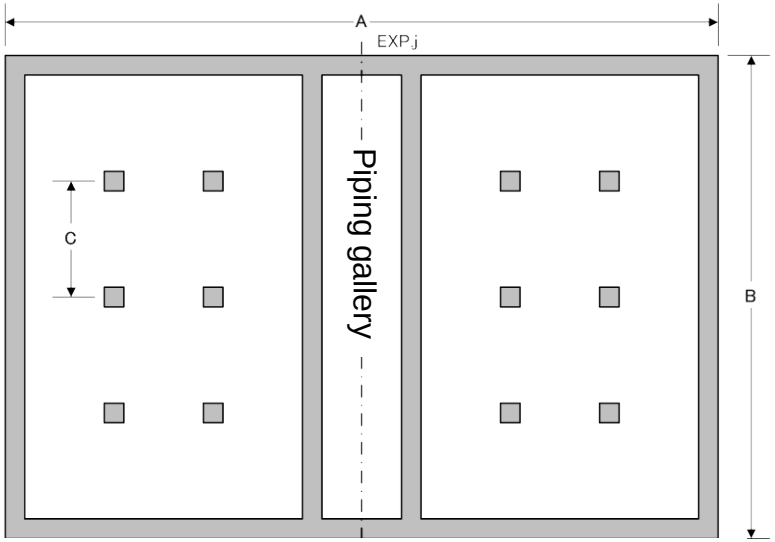


Figure 3-1

SETTING OF DESIGN INPUT SEISMIC MOTIONS



- Flat slab with two tanks
- A≒B (near square)
- No EXP.j inside
- Half subsurface

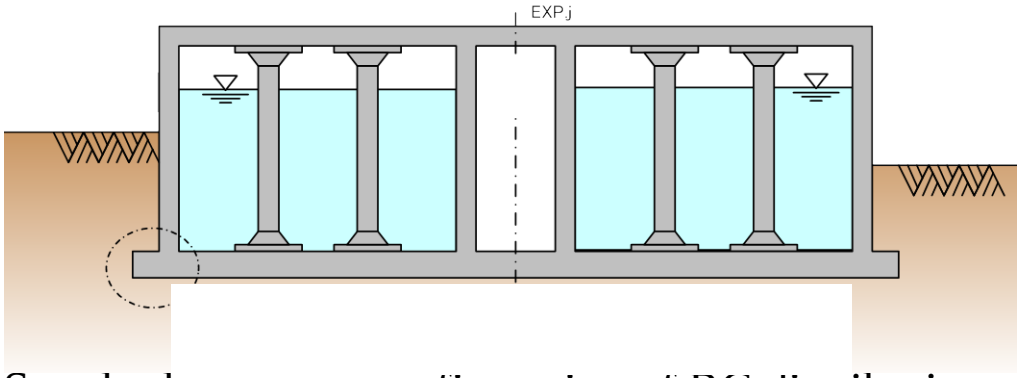


Figure Standard structure configuration of RC distribution reservoir

SETTING OF DESIGN INPUT SEISMIC MOTIONS

（1）Preparation of Base Ground Surface Input Waveforms

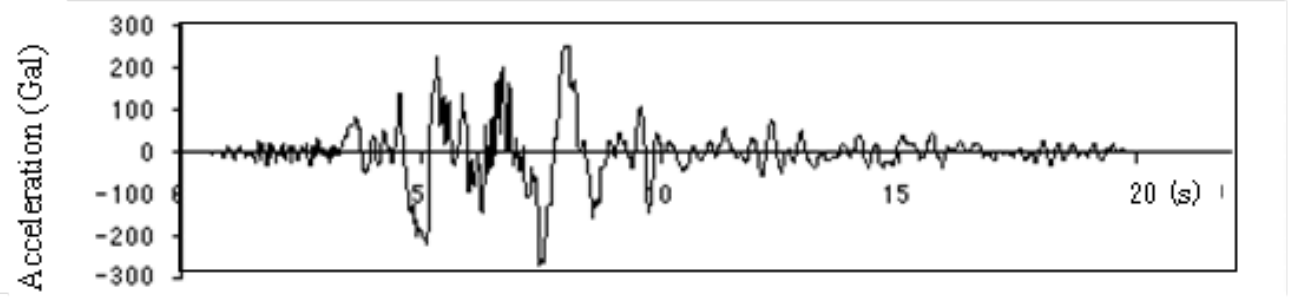


Figure 4-1　NS component records at Kobe University

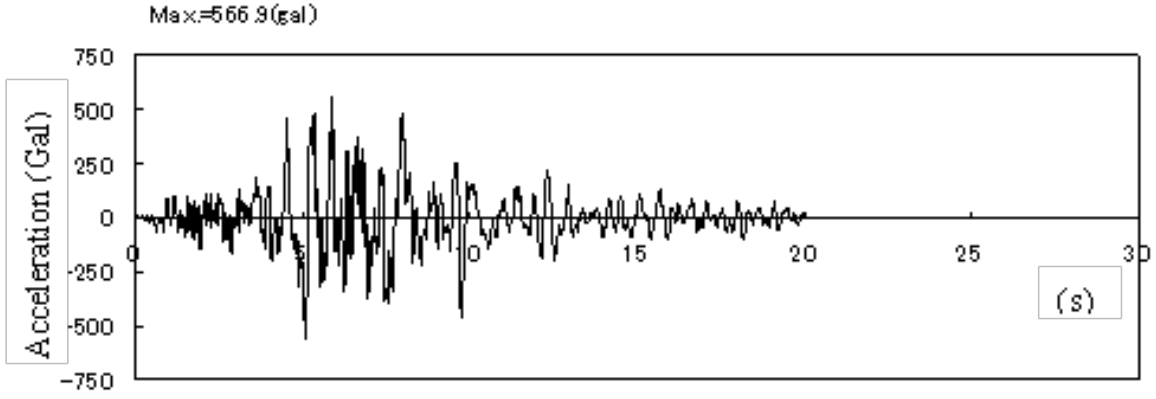


Figure 4-2　Base ground surface input acceleration wave for dynamic analysis

（2）Dynamic Characteristics of Structures

[Analysis conditions]
- Foundation structure: Spread foundation
- Foundation ground: N value; 50
- Relaid soil: N value; 10 (sandy soil)
- Inside water level: High water level
- Elements: See figure at right

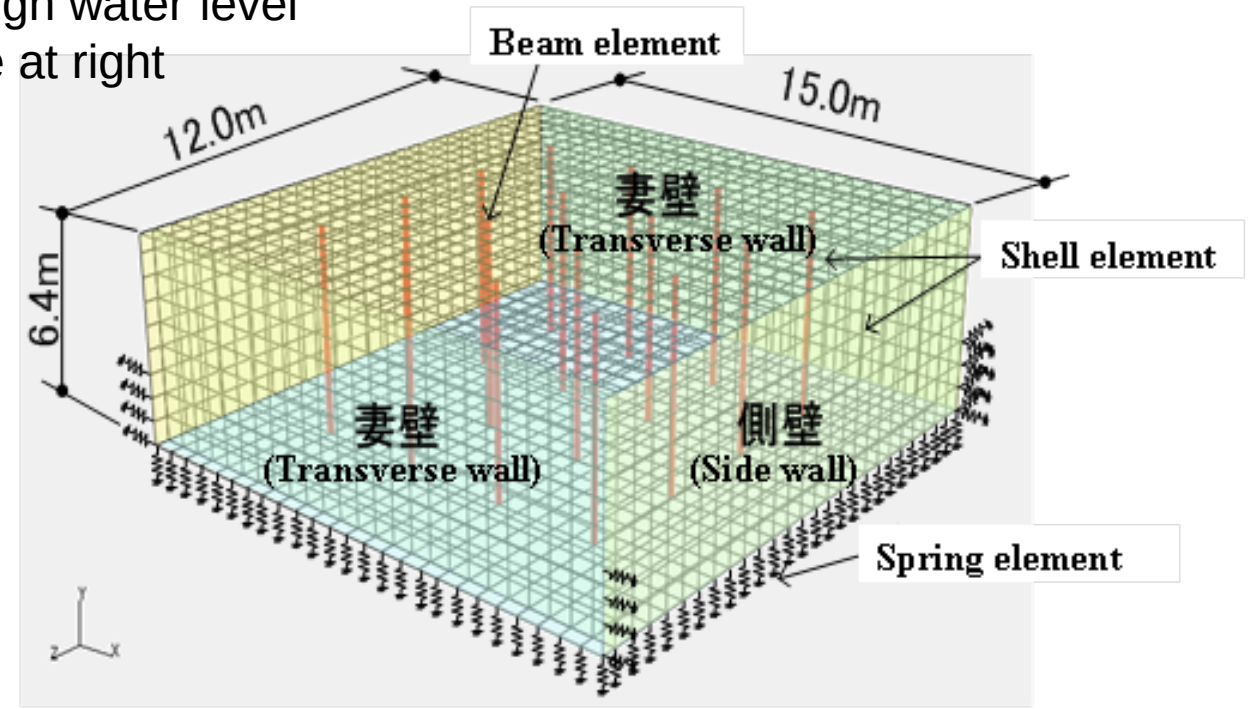


Figure 4-3

（2）Dynamic Characteristics of Structures

Table 4-1 Input physical properties of the building (shell element)

	Deck slab	Upper slab	Side wall	Transverse wall
Plate thickness t (mm)	550	300	550	550
Young's modulus E (kN/m^2)	2.500E+07	2.500E+07	2.500E+07	2.500E+07
Poisson's ratio ν	0.2	0.2	0.2	0.2

Table 4-2 Input physical properties of the center pillar (beam element)

Young's modulus E (kN/m^2)	2.500E+07
Cross section A (m^2)	0.25
Torsional constant J (m^4)	8.788E-03
Geometrical moment of inertia Iy = Iz (m^4)	5.208E-03

Table 4-3 Input physical properties of the ground (spring element)

		Deck slab	Side wall	Transverse wall (end side)
Coefficient of subgrade reaction[*2] (kN/m^3)	X direction	29404	17713	5111
	Y direction	102912	5061	5111
	Z direction	29404	5061	17888

（2）Dynamic Characteristics of Structures

Table 4-4

		Natural period (s)	
		With fill soil	Without fill soil
Vibration direction	X direction	0.1398	0.1272
	Y direction	0.1576	0.1394

Table 4-5

		Damping coefficient (%)	
		With fill soil	Without fill soil
Vibration direction	X direction	15.4	14.8
	Y direction	14.8	14.5

（3）Earthquake Response Analysis

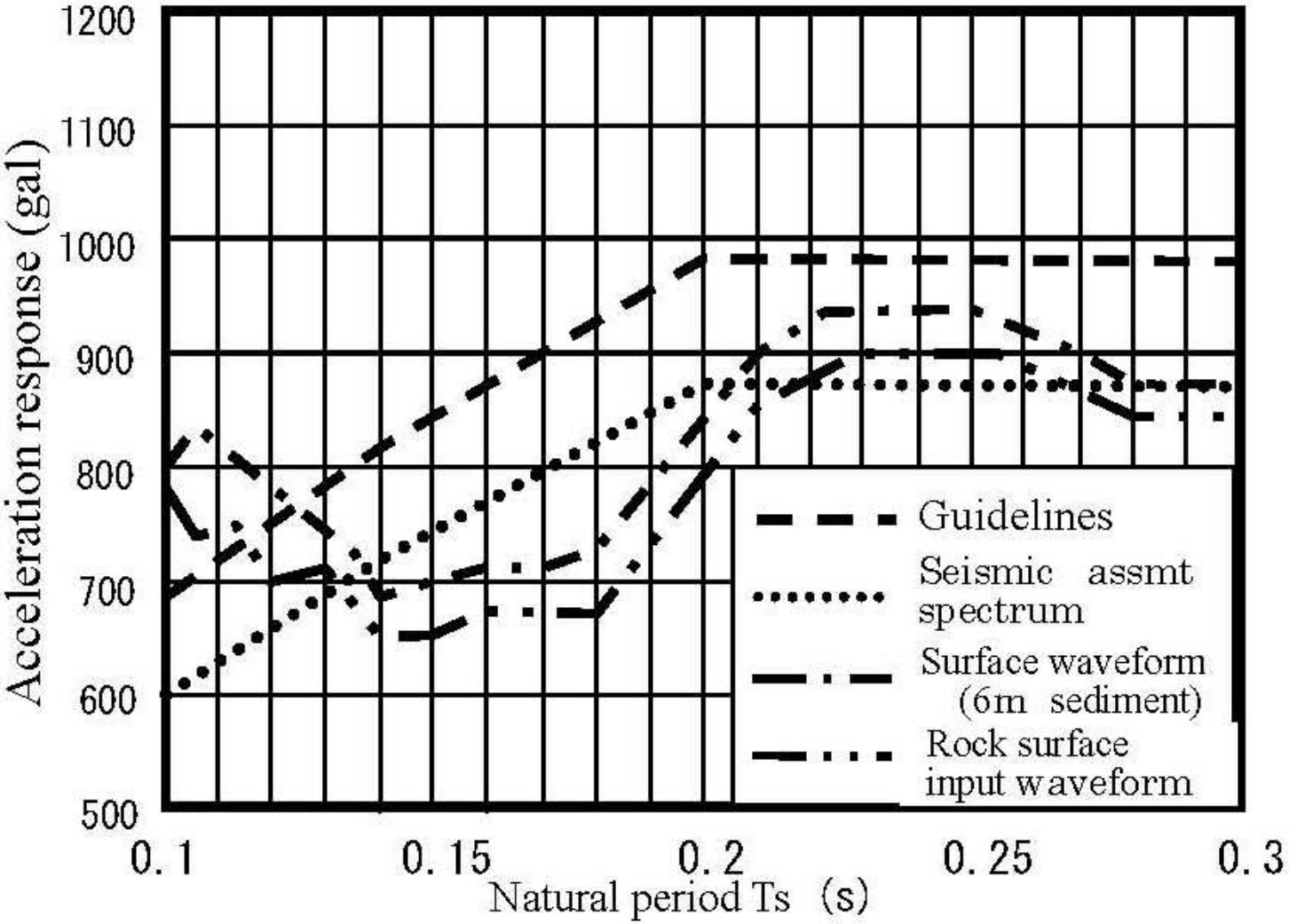


Figure 4-4

ANALYSIS OF GROUND/STRUCTURAL PROPERTIES

Table 5-1

Analysis cases	Parameters	
Case 1	Water level	Design water level
Case 2		Operational water level
Case 3	N value of bottom ground	N=10
Case 4		N=30
Case 5	Fill soil	Yes / No
Case 6	Unsymmetrical earth pressure	Yes / No
Case 7	Embedment	Yes / No
Case 8	Dimensions in planning ※Ratio of the space between transverse (gable) walls (L) to the width of transverse(gable) walls (B)	L/B=1.4
Case 9		L/B=2.2
Case 10		L/B=3.0

SETTING A TWO-DIMENSIONAL MODEL

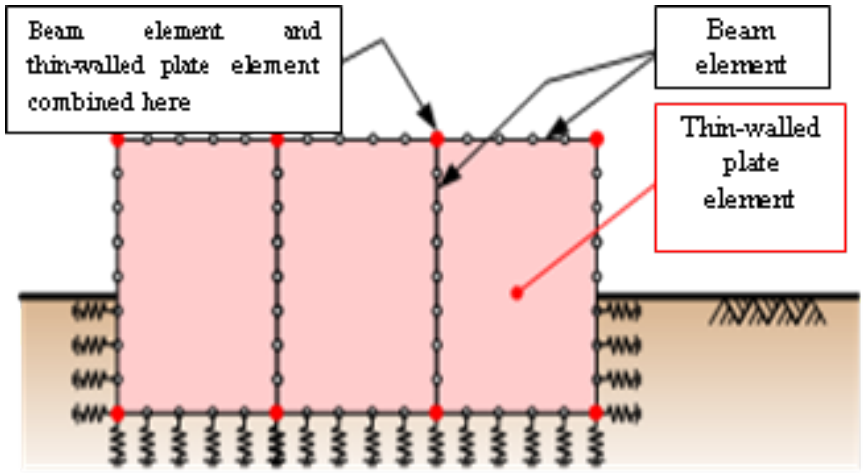


Figure 6-1

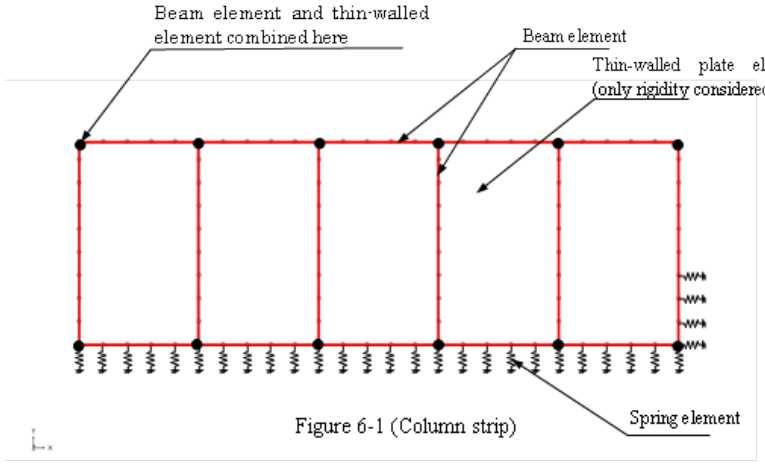


Figure 6-1 (Column strip)

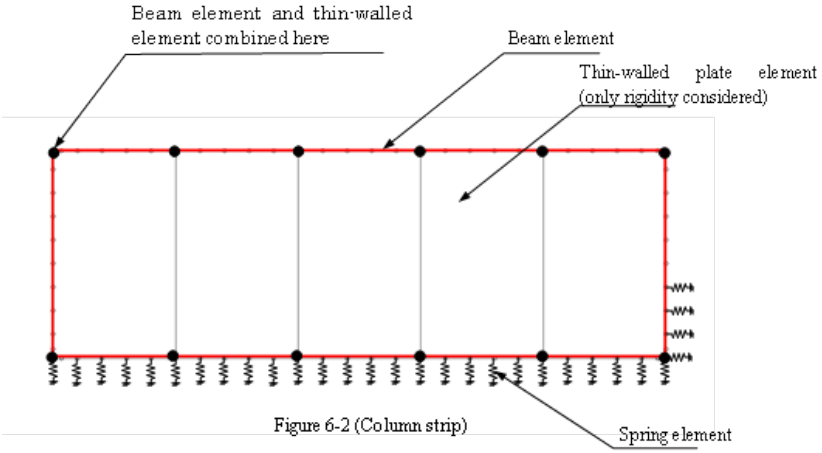


Figure 6-2 (Column strip)

SETTING A TWO-DIMENSIONAL MODEL

Table 6-1 Cases for analysis

No.	Physical properties of thin-walled plate elements		Remarks
	Young's modulus E_2	Plate thickness	
1	E_c^*	t_{eq}^{**}	
2	$0.5 \cdot E_c$	t_{eq}	
3	$0.2 \cdot E_c$	t_{eq}	
4	$0.1 \cdot E_c$	t_{eq}	
5	$0.05 \cdot E_c$	t_{eq}	
6	$0.02 \cdot E_c$	t_{eq}	
7	0	0	No thin-walled plate element

Here, Ec (Young's modulus for the building's concrete) = 2.5×107kN/m2, and
(equivalent plate thickness of the transverse wall) is calculated using the following equation:

$$t_{eq} = \frac{2 \times t_w}{B} = \frac{2 \times 0.55}{18.8} = 0.0585 \quad \text{(m)}$$

where (thickness of the transverse wall) = 0.55 (m), and
(space between transverse walls, or depth of the structure) = 18.8 (m).

SETTING A TWO-DIMENSIONAL MODEL

Table 6-2 Conditions of the structures

	Deck slab	Upper slab	Sidewall	Transverse wall	Center pillar
Geometrics (mm)	Plate thickness t = 550	Plate thickness t = 300	Plate thickness t = 550	Plate thickness t = 550	500 × 500 ctc3650
Young's modulus E (kN/m^2)	2.500E+07	2.500E+07	2.500E+07	2.500E+07	2.500E+07
Unit weight γ (kN/m^3)	24.5	24.5	24.5	24.5	24.5
Poisson's ratio ν	0.2	0.2	0.2	0.2	0.2

Table 6-3 Coefficient of subgrade reaction (kN/m^3)

		Lower part of deck slab	Sidewall	Transverse wall (end side)
Under stationary load	X direction	5758	——	——
	Y direction	20153	——	——
	Z direction	5758	——	——
Under incremental load during earthquake	X direction	11516	17957	5181
	Y direction	40307	5131	5181
	Z direction	11516	5131	18135

SETTING A TWO-DIMENSIONAL MODEL

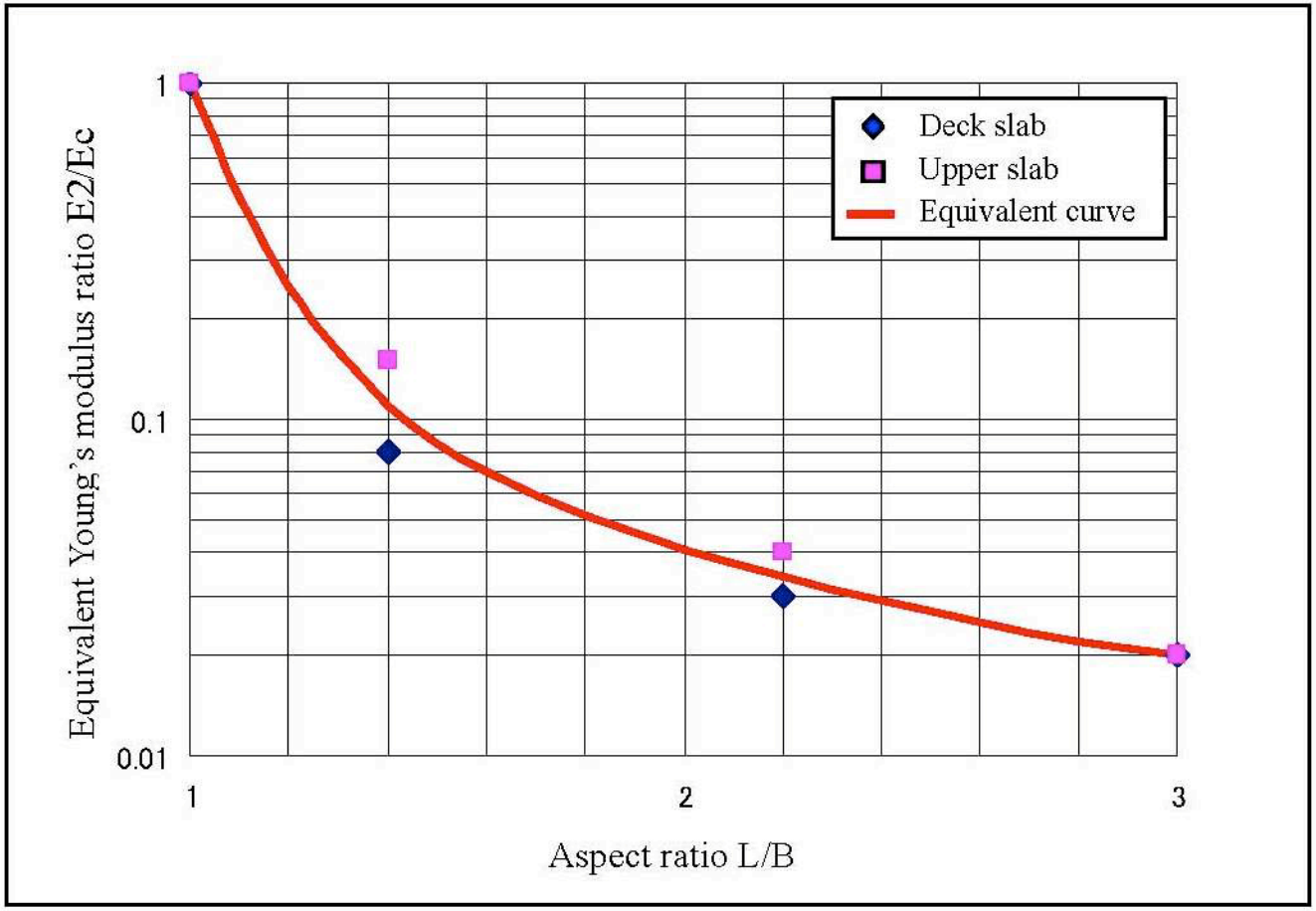


Figure 6-3

SEISMIC ASSESSMENT

Table Seismic assessment of RC distribution reservoir according to group(1)

Group		Evaluation method	Reason for grouping
Standard flat slab (above ground type) (pillar of two rows or more)	A-1-1-1(on the base ground surface, hard ground) (17) A-1-1-2(on the surface ground, hard ground) (19)	Comparative assessment based on result of analyzing representative facilities	Almost the same structural characteristic
	A-1-1-3(usual ground)	Detailed analysis of each facilities	Different seismic force condition in each facilities.
Standard flat slab (underground type)	A-1-2 (10)	Comparative assessment based on result of analyzing representative facilities	Almost the same structural characteristic
Standard flat slab (Small scale) (Pillar of one row or less)	A-2 (16)	Comparative assessment based on result of analyzing representative facilities	Almost the same structural characteristic
Wall construction without pillar and the similar	A-3-1 (wall-type) (4)	Comparative assessment based on result of analyzing representative facilities	Almost the same structural characteristic
	A-3-2 (similar to wall-type)	Technological evaluation of each facilities	Various structure characteristics & Data shortage

SEISMIC ASSESSMENT

Table Seismic assessment of RC distribution reservoir according to group(2)

Group		Evaluation method	Reason for grouping
Pillar foundation structure with deck slab jointed	A-4	Technological evaluation of each facilities	Various structure characteristics & Data shortage
Similar structure to flat slab	A-5-1(Structure reinforced edge of deck or upper slab) A-5-2(Excluding the above-mentioned) A-8-1(Special condition)		
Composite structure	A-6	Undiagnosis	Special structure
Level 2 design structure	A-7	Undiagnosis	The latest design standard

SEISMIC ASSESSMENT

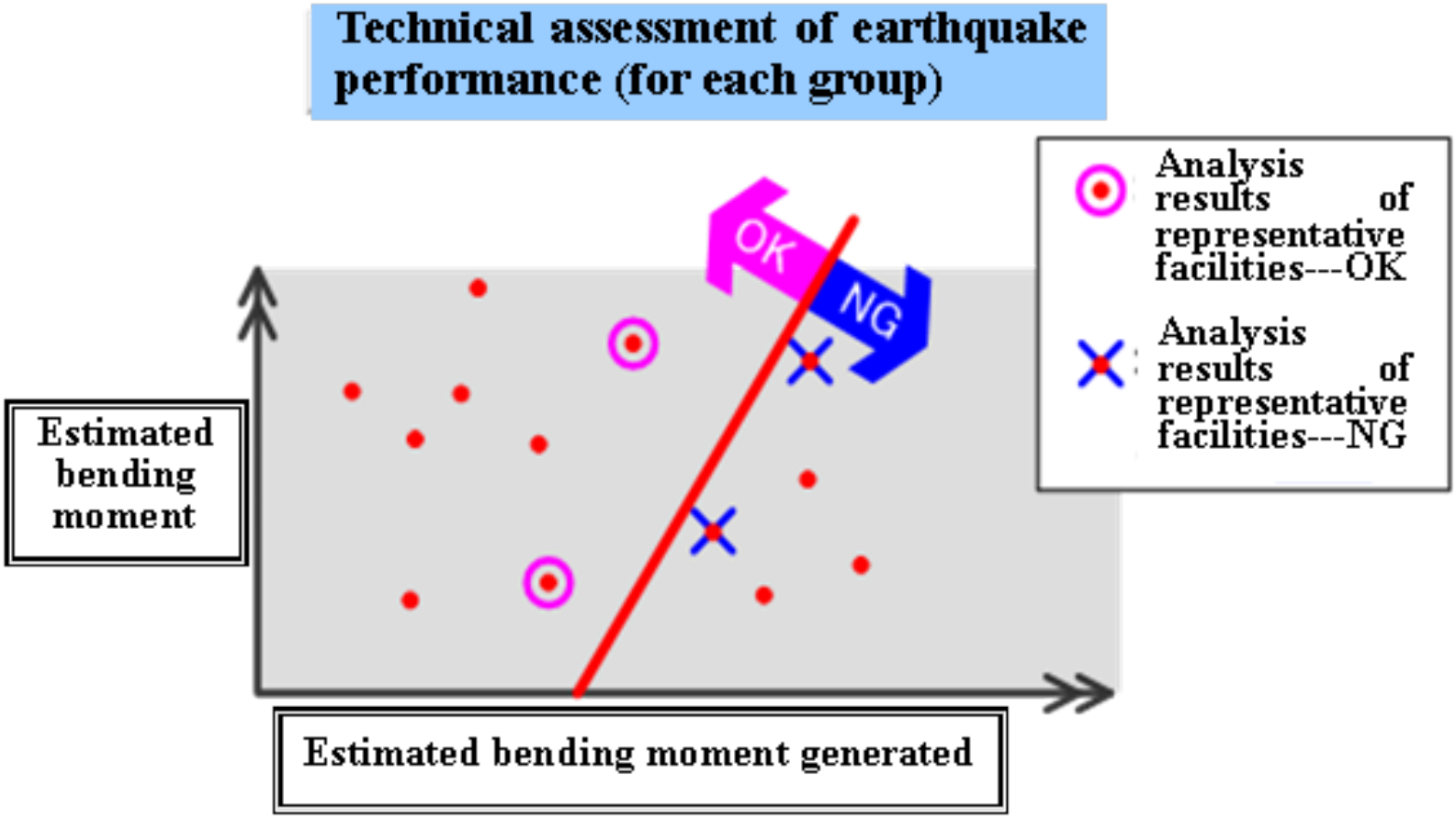


Figure7-1

SEISMIC ASSESSMENT

Table Seismic Assessment Result

	Total	NG	OK	Undiagnosis
RC	184	65(36%)	109(59%)	10(5%)
PC	29	21(72%)	8(28%)	0
ST	26	0	26(100%)	0
Tunnel-type	12	2(17%)	10(83%)	0
Total	251	88(35%)	153(61%)	10(4%)

Sunset with AKASHI Strait Bridge
from Kobe Airport

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