EARTHQUAKE RESISTANT DESIGN
FOR
A WATER SUPPLY SYSTEM

EDITORS

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1. GENERAL REMARKS

Earthquake Resistant Design Criteria for a Water Supply System was published by Japan Water Works Association in 1979. Main articles of this Criteria are introduced here.

1.1. BASIC IDEA FOR SEISMIC STABILITY OF WATER SUPPLY FACILITIES

1. Planning, designing and construction of water supply facilities must be carried out with paying adequate considerations of the seismic conditions of the area.

2. Water supply facilities must be rationally designed against earthquake force.

3. Water supply facilities must be planned to maintain their supplying capability as much as possible in an entire system even under a considerable damage due to the disastrous earthquake.

4. Water supply facilities are desired to be constructed on a good, stable ground as much as possible. In reality, however, there are many cases, where the facilities have to be built on such a ground, which is weak or on a site of sudden topographical change, thus adequate measures proper to each site must be adopted in order to ensure their seismic slability.

In particular, in the case of important structure, designing and construction must be conducted on the basis of the results of the geotechnical investigation.

5. High quality materials against earthquake must be used for water supply facilities.

When water tighteness is required, structures must be carefully designed and constructed lest the water tightness should be broken by the earthquake.

6. Such devices like expansion flexible joint which is able to absorb the deformation or to soften the excess stress, must be used in a place where is supposed to appear relative displacement due to ground motion.

7. Since perfect earthquake resistant facilities are difficult to build both economically and technically, the following considerations must be made:

(1) to restrict the scope of earthquake damages to the least possible degree.

(2) to make the repair works as easy as possible if damaged.

(3) to provide counter measures against spreading of secondary damages due to earthquakes.

8. The level of seismic slability for key facilities must be increased according to their importance.

9. In case the facilities are particularly important, subject to damages and their recovery is difficult or time-consuming, or the damaged portions are hard to discover, they should either be divided into two way systems or more or spare facilities be provided.

10. As regards conduit, transmission, or distribution pipelines, mutual connections should be provided between different networks to the most possible degree; this kind of connections should be provided between neighboring communities.

11. In the designing and construction of water supply facilities, when the matters are prescribed by rules and regulation of the National and/or Local Government, these must be observed.

As for matters regarding technical criteria & standards published by engineering society and associations, these must be followed if need be.

12. As for maintenance and control of the facilities, trustworthy inspection is indispensable for keeping up earthquake resistability and, by conducting checks of earthquake resistant reliability of the existing facilities, positive steps towards improvement of the facilities of low earthquake resistability must be taken.

At the same time, thourogh investigations must be made about the watershed upstream the intake, and if necessary, adequate measures must be adopted for the safety of water supply.

13. As it is inevitable for water facilities to suffer more or less damages at the time of a great earthquake, the following preparations are absolutely needed.

i prediction of earthquake damages.
ii emergency water supply program based on the earthquake damage prediction.
iii emergency restoration program based on the earthquake damage prediction.
iv establishment of mobilization and mutual aid system.
v storage of tools and materials needed for the restoration works.
vi provision of facilities' drawings and maps.

1.2. BASIC POLICY OF EARTHQUAKE RESISTANT DESIGNING

1.2.1 General Principle

In designing of earthquake resistant water supply facilities, in consideration of their structural features and environmental ground conditions, designing must be in accordance with these features in order to confirm these facilities safety against earthquakes.

1.2.2 Influence of earthquake to be considered in design

1. Ground displacement or deformation during earthquake.
2. Inertia force due to dead load of the structure or to surcharged load.
3. Earth pressure during earthquakes.
4. Hydrodynamic pressure during earthquakes.
5. Water surface sloshing.

1.2.3 The order of earthquake resistant designing

1. Selection of the construction site.
2. Investigation of geology and grounds at the construction site.
3. Selection of structure type and examination of the ground condition.
4. Decision of dimension of structures.
5. Calculation regarding earthquake resistance of structure.
6. Evaluation of safety.

1.3 GEOTECHNICAL INVESTIGATION

1.3.1. Basic items in geotechnical investigation

In earthquake resistance designing for water supply facilities, according to their importance, necessary geotechnical investigation of the sites for facilities must be conducted.

1.3.2. Methods of soil surveys

1. Geotechnical investigation including laboratory tests should be conducted according to the Japan Industrial Standards (JIS) or Standard by the Japanese Society of Soil Mechanics and Foundation (JSSMFE) when prescribed.

2. Measurements of dynamic soil property and dynamic nature of the foundation should be conducted directly in principle. In case such measurements are not possible, these may be estimated indirectly by means of the results of other sort of investigations.

1.3.3. Liquefaction of sandy soil

When the soil liquefaction of the ground takes place, the ground bearing strength suddenly drops and endangers the service ability of the facilities, therefore, susceptibility of the soil liquefaction is needed to be carefully assessed.

1.4. EARTHQUAKE RESISTANT DESIGN AND INPUT MOTION FOR DESIGNING

1.4.1. Methods of calculations

Methods of calculations used for waterworks earthquake-resistant design are classified as follows; the choice has to be decided in consideration of the features of the structure concerned. When more detailed analysis of the structural behavior at the time of an earthquake is necessary, the results of **1.**~**3.** are checked by **4.**

1. Seismic coefficient method.

2. Modified seismic coefficient method.

3. Seismic deformation methods.

4. Dynamic analysis.

1.4.2. Seismic coefficient method

1. Earthquake resistant calculation for a structure of which the natural period is 0.5 sec. or shorter, should resort to the seismic coefficient method; the inertia force of the structure during earthquake can be obtained by multiplying the dead weight and loaded weight, by the designed seismic coefficient (k_n)

2. Horizontal seismic coefficient (k_h) used for structures, on the ground is as follows:

$$k_h = \Delta_1 \cdot \Delta_2 \cdot \Delta_3 \cdot k_0$$

(1) Standard horizontal seismic coefficient (k_0) should be 0.2 (included) or over.

(2) Corrective coef. Δ_1 is a regional coef. determined by the data obtained from earthquakes and seismic intensity in the past.

(3) Corrective coef. Δ_2 is coef. determined in consideration of the ground condition of the site for planned structure.

(4) Correction coef. Δ_3 should be 1 as a general principle. However, considering kind, use, material quality of the structure, and construction method of the structure and the behavior of the simular kind at the time of the past earthquakes, Δ_3 can be reduced to 0.5

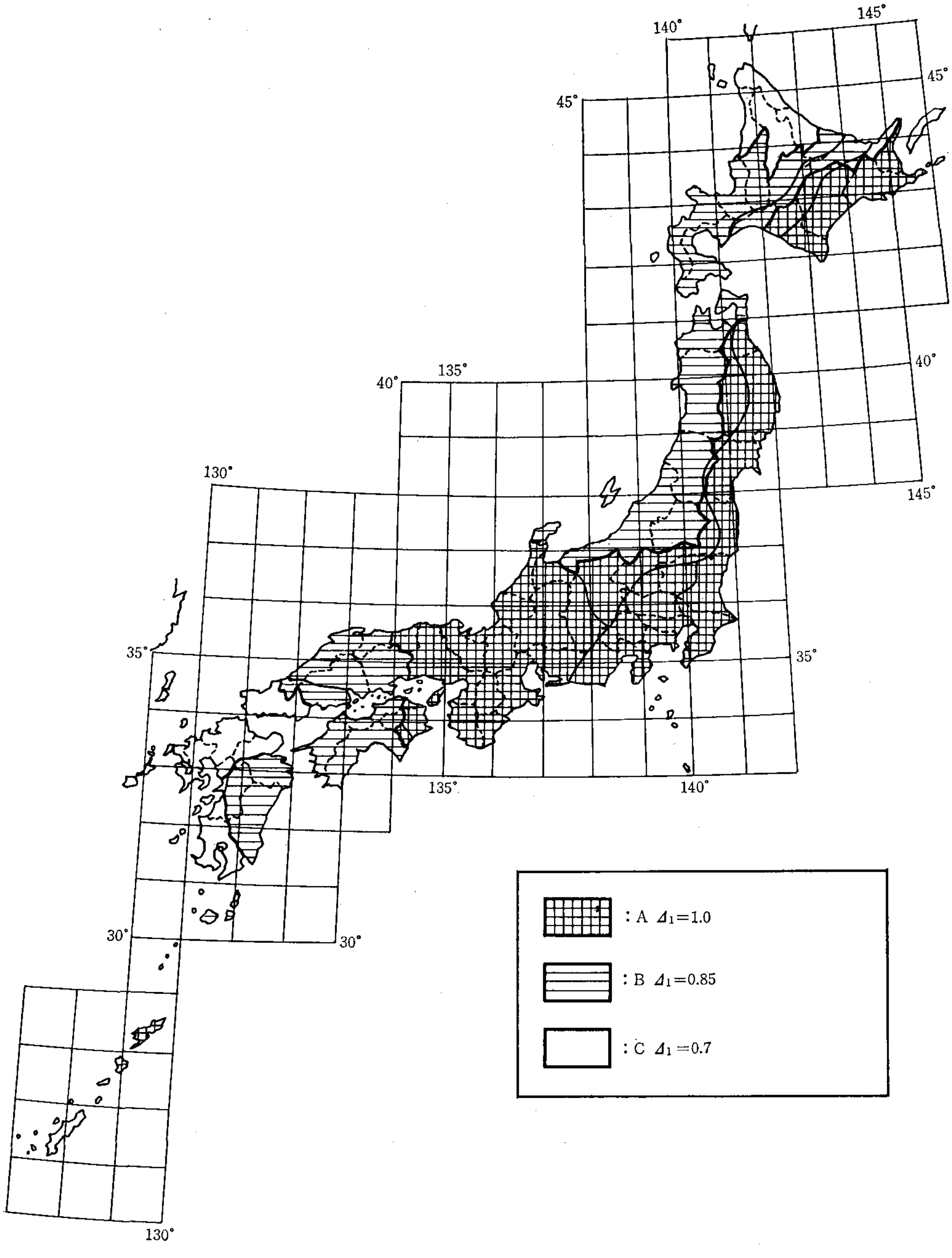

Fig. 1 Corrective Coefficient Δ_1

Table 1. Corrective Coefficient Δ_2

Classification	Ground Condition	Coefficient
1st	(1) Ground before the Tertiary period (2) Depth of diluvial deposit up to rock bed is 10 m below	0.9
2nd	(1) Depth of diluvial deposit up to rock bed is 10 m above (2) Depth of alluvial deposit up to rock bed is 10 m below	1.0
3rd	Depth of alluvial deposit is 25 m below and depth of soft deposit is 5 m below	1.1
4th	Others	1.2

on condition that the horizontal seismic coefficient (k_h) falls not below 0.1.

3. In calculation of the earth-pressure during earthquake used in earthquake resistant calculation for underground structure, horizontal seismic coefficient (k_h') at the design ground surface should be obtained by the following formula; the horizontal seismic coefficient (k_h) obtained by **2**. can be considered the value at the surface of the ground, and the value for depth between those surfaces can be interpolated by a straight line.

$$k_h' = \frac{3}{4}\Delta_1 \cdot k_0$$

Δ_1 and k_0 have been defined in **2**.

4. In considering vertical seismic coefficient (k_v). $k_v = k_h/2$; the value should be used for both above-or under-ground.

1.4.3. Modified seismic coefficient method

1. Seismic resistant calculation in such relatively flexible structure as its natural period is 0.5 per sec. or longer should be made under modified seismic coefficient method i.e. the inertia force at the time of earthquake is sought by multiplying the self weight and load by horizontal seismic coefficient (k_{hm}).

2. The horizontal seismic coefficient (k_{hm}) employed in modified seismic coefficient method is as following formula:

$$k_{hm} = \Delta_1 \cdot \Delta_2 \cdot \Delta_4 \cdot \Delta_5 \cdot k_0$$

(1) Standard horizontal seismic coefficient (k_0) and corrective coefficient Δ_1, Δ_2 is referred to in **1.4.2.**

(2) Corrective coef. Δ_4 is to be decided in consideration of the class of the ground condition for planned site and the natural period of the structure.

(3) Corrective coef. Δ_5 is, in principle, to be 1. However, in case earthquake resistability is to be checked as to the ultimate strength and ductility of structures, it should be determined according to the engineering upper limit of the earthquake acceleration and the ductility of the structure.

3. When designed vertical seismic coefficient (k_v) is considered.

$$k_v = k_{hm}/2$$

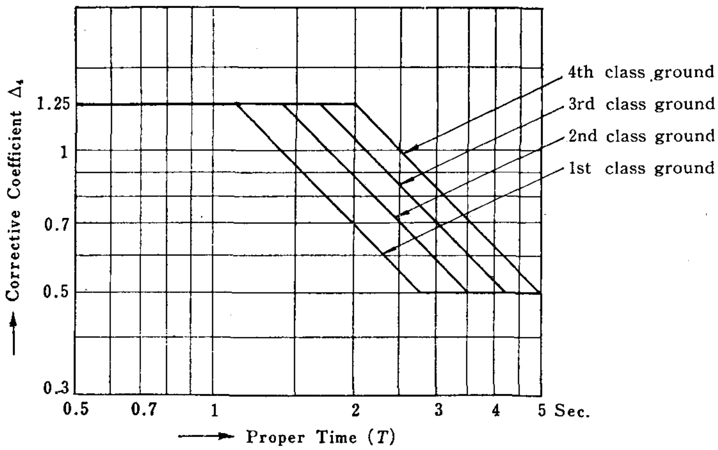

Fig. 2 Corrective Coefficient Δ_4

1.4.4. Seismic deformation method

1. Seismic resistant calculation when the behavior during earthquake is principally governed by the surrounding ground motion like buried pipes should be conducted, in principle, by use of seismic deformation method; by displacement and/or deformation of the ground, the cross-sectional force and stress are calculated.

2. Ground displacement amplitude employed in seismic deformation method should be applied at the depth x (m) from the ground surface:

$$U_h(x)=\frac{2}{\pi^2}S_V T_G k_h' \cos\frac{\pi x}{2H}$$

in here horizontal displacement amplitude (cm) at $U_h(x)$: x (m) depth below surface

S_V: normalized response velocity (cm/sec) per unit seismic coefficient

T_G: natural period of subsurface ground (sec)

k_h': hirizontal seismic coefficient, at the design ground surface (based on **3** of **1.4.2.**)

H: thickness of subsurface

(1) Normarized response velocity (S_V) per unit seismic coefficient is to be determined according to the natural period of subsurface ground. (T_G).

(2) The natural period (T_G) is to be determined by complehensive checking of the ground tremor, surveyed results of shear wave velocity, ground conditions, etc.

3. When the vertical ground displacement amplitude should be considered.

$$U_v=U_h/2$$

1.4.5. Dynamic analysis

1. Method or the dynamic analysis is either of the following.

(1) Response spectral analysis.

(2) Time history response analysis.

2. Characteristics of earthquake ground motion used in dynamic analysis should be in principle, presumed from ground conditions of the construction site, after considerations of the characteristics of earthquake activities over a comparatively large area including the construction site, as well as the characteristics of ground motion gained by strong motion records.

3. Response spectra used for analysis should have the earthquake ground motion features presumed by above **2**, or generally approved averaged response spectra.

4. The earthquake waves used in dynamic analysis should be the past strong earthquake records or quasi earthquake waves so adequately made as have the above-stated characteristics.

1.5. EARTH PRESSURE DURING EARTHQUAKE

1.5.1. General principle

1. The horizontal earth pressure during earthquakes is ruled by Mononobe, Okane formula.

2. The vertical earth pressure during earthquake should be considered the value consisting of the weight of loaded earth multiplied by $(1 \pm kv)$.

1.5.2. Calculation of horizontal earth pressure

Horizontal earth pressure during earthquake should be calculated of soil adhesion.

1.5.3. Calculation of overburden pressure

Overburden pressure to underground pipe should be calculated in consideration of the influence of lateral friction.

1.6. HYDRODYNAMIC PRESSURE AND SLOSHING

1.6.1. Hydrodynamic pressure during earthquake

In earthquake resistant designing for structures touched water, hydrodynamic pressures during earthquakes should be considered.

1.6.2. Surface sloshing

In earthquake resistant designing for water basin, the influence of surface sloshing should be considered.

1.7. ALLOWABLE STRESS & SAFETY FACTOR

1.7.1. Combination of Load

The safety factor of structure in rearthquake resistant calculation should be examined for such conditions as dead load (=self weight plus normal loaded weight) combined with earthquake influence.

1.7.2. Allowable stress for steel material and concrete & prestressed concrete (PC)

This should be in principle, 1.5 times of that of usual times, as shown in the following related criteria.

Standard Specification for Highway Bridges (Part of Steel Bridges; Japan Road Ass.

Standard Specification for Highway Bridges (Part of Concrete Bridges; Japanese Road Ass.)

Standard Specification of Concrete (Japan Society of Civil Engineers)
Standard Specification of Prestressed Concrete (Japan Society of Civil Engineers).
Water Gate & Iron Pipe Technical Standards (Sluice & Steel Pipe Ass.)

1.7.3. Checking of safety in earthquake resistant design in pipelines

Safety during earthquake in pipelines should be, in principle, examined in consideration of the strength and flexibility of the pipeline.

1.7.4. Allowable bearing power of the foundation ground

Allowable bearing power of the ground in earthquake resistant calculation should, in principle, observe **1.8.3.** (Supporting ground and allowable bearing power).

1.7.5. Safety factor of earth structure & retaining wall as viewed from earthquake-resistant calculation

The safety factor in foundation, earth structure & retaining walls should follow, in principle, **1.8** (Earthquake resistant calculations of foundation) & **1.9** (Earth structure and retaining wall calculations).

1.7.6. Safety factor in calculations considered from ultimate strength

1. In case supported by adequate analytical or experimental results, earthquake resistant quality of the structure can be studied on the basis of such ultimate conditions.

2. In a design where the ultimate conditions are considered, care must be taken so that the structure member might have no need to break as brittle fracture until it exceed its ultimate strength and tenacity break its fragility.

3. In earthquake resistant calculations based on the ultimate conditions, adequate factor of safety must be considered for final displacement.

This Criteria prescribes EARTHQUAKE-RESISTANT CALCULATIONS FOR FOUNDATION in Article **1.8**, and EARTHQUAKE-RESISTANT CALCULATION FOR SOIL STRUCTURE & RETAINING WALL in Article **1.9**, however, these Articles are omitted here.

1.10. THE EARTHQUAKE RESISTANT CALCULATION FOR UNDERGROUND PIPELINES, CULVERT, PIPE UTILITY CONDUIT AND SHAFT

1.10.1. General principle

Stress calculations of earthquake resistant design for under ground pipelines and those for axial relative expansion and contraction, transverse relative displacement and relative rotation of pipe joints are to be calculated generally by means of seismic deformation method. Earthquake resistant design of culvert, utility conduit and tunnel shaft are to be calculated by means of seismic deformation method and/or seismic coefficient method. Further, as for such parts as complicated behavior is expected like the ground conditional sudden changes, or special parts as the connection part with subordinate structures, etc. earthquake resistant calculations should be subject to, as needs be, dynamic analysis for checking safety of the structure.

1.10.2. Calculations by seismic deformation method for underground-laid pipeline

1. When the pipeline is continuous (without flexible and expansion joint):

When the laid pipe is of continuous form stresses calculations are to be performed according to beh following:

$$\sigma_L=\alpha_1\cdot\frac{\pi U_h}{L}E$$

$$\sigma_B=\alpha_2\cdot\frac{2\pi^2 D U_h}{L^2}E$$

$$\sigma_x=\sqrt{\gamma\sigma_L{}^2+\sigma_B{}^2}$$

where

σ_L, σ_B: Axial stress and bending stress, respectively laid pipe (kg/cm^2)

α_1, α_2: Reduction factors: calculation is as follows:

$$\alpha_1=\frac{1}{1+(2\pi/\lambda_1 L')^2}, \qquad \alpha_2=\frac{1}{1+(2\pi/\lambda_2 L)^4}$$

$$\lambda_1=\sqrt{\frac{K_{g1}}{EA}}\ (1/cm), \qquad \lambda_2=\sqrt[4]{\frac{K_{g2}}{EI}}\ (1/cm)$$

where,

π: The circular constant

L': Apparent wave length ($=\sqrt{2}L$) (cm)

L: Wave length (cm)

K_{g1}, K_{g2}: Longitudinal and transverse stiffness properties of elastic foundation per unit length of pipe line

E: Young's modulus (kg/cm^2)

A: Pipe sectional area (cm^2)

I: Secondary moment of inertia of pipe (cm^4)

U_h: Horizontal displacement amplitude (cm) of the ground above the pipe as shown in **1.4.4.** (Seismic deformation method)

D: Outer diameter of pipe (cm)

r: Factor considered of waves applied for calculation

2. Calculation of stress when there are flexible and expansion joints in the laid pipeline; calculation of the stress in such a case should follow the formula below.

$$\sigma_L'(x)=\xi_1(x)\cdot\sigma_L$$

$$\sigma_B'(x)=\xi_2(x)\cdot\sigma_B$$

where

$\sigma_L'(x)$, $\sigma_B'(\lambda)$: Axial and bending stresses, of pipe line respectively, at the point of x (m) from flexible and expansion joint (kg/cm^2)

σ_L, σ_B: Axial and bending stresses, respectively, as calculated by 1.96, 1.97 (kg/cm^2)

$\xi_1(x)$, $\xi_2(x)$: Reduction factors, stress of pipeline which has expansion joint (like steel pipe line) to the end of continuous pipeline

1.10.3. Calculations by seismic deformation method for axial-relative expansion (or contraction), transverse-relative displacement and relative rotational angle of pipe line

1. In case the spring constant is set as zero:

(1) axial relative expansion, or contraction amount

$$|u_J| = u_0 \bar{u}_J$$

where

$|u_J|$: Axial relative contraction or expansion amount (cm)

u_0: Axial relative displacement amount in case the beam is infinitely extended (cm)

$$\bar{u}_J = \frac{2\gamma_1 |\cosh \beta_1 - \cos \gamma_1|}{\beta_1 \sinh \beta}, \qquad u_0 = \alpha_1 U_a$$

$$\alpha_1 = \frac{1}{1+(\gamma_1/\beta_1)^2}, \qquad \beta_1 (= \lambda_1 l) = \sqrt{\frac{K_{g1}}{EA}} \cdot l$$

$$\gamma_1 = \frac{2\pi l}{L'}$$

EA: Extensive regidity (kg)

l: Length between joint (cm)

K_{g1}: Longitudinal stiffness coef. of ground per unit length along pipeline (**1.10.2**) (kg/cm^2)

L': Apparent wave length ($L' = \sqrt{2} L$) (cm)

L: Wave length of earthquake wave (cm)

$U_a(x)$: Horizontal displacement amplitude of ground along pipeline $\left(= \frac{1}{\sqrt{2}} U_h(x) \right)$

$U_h(x)$: Horizontal displacement amplitude (cm) at x (cm) depth from ground surface ($U_h(x)$ of **1.4.4.** used)

(2) Transverse relative displacement, relative rotation angle in pipeline joint.

$$|v_J| = v_0 \cdot \bar{v}_J, \qquad |\theta_J| = \theta_0 \cdot \bar{\theta}_J$$

where

$|v_J|$: Transverse relative displacement amount (cm)

$|\theta_J|$: Relative rotation angle

v_0, θ_0: Deflection & inclination angle amplitude in case the beam is infinitely contitnueing one (cm) (rad)

$$\bar{v}_J = \frac{2}{\Psi_5} \left(\frac{\gamma_2}{\beta_2} \right)^3 \cdot \left| \Psi_4 \cos \gamma_2 - \frac{\beta_2 \Psi_2 \sin \gamma_2}{\gamma_2} + \Psi_6 \right|$$

$$\bar{\theta}_J = \frac{2}{\Psi_5} \cdot \frac{\gamma_2}{\beta_2} \cdot \left| \Psi_2 \cos \gamma_2 + \frac{\gamma_2 \Psi_3 \sin \gamma_2}{\beta_2} - \Psi_7 \right|$$

$$v_0 = \alpha_2 U_h, \qquad \theta_0 = v_0 \frac{2\pi}{L}, \qquad \alpha_2 = \frac{1}{1+(1/4)(\gamma_2/\beta_2)^4}$$

$$\beta_2 \left(= \frac{1}{2} \lambda_2 l \right) = \sqrt[4]{\frac{K_{g2}}{4EI}} \cdot l, \qquad \gamma_2 = \frac{2\pi l}{L}$$

$\Psi_2=\frac{1}{2}(\sin\beta_2\cosh\beta_2+\cos\beta_2\cdot\sinh\beta_2$, $\quad \Psi_3=\frac{1}{2}\sin\beta_2\cdot\sinh\beta_2$

$\Psi_4=\frac{1}{4}(\sin\beta_2\cdot\cosh\beta_2-\cos\beta_2\cdot\sinh\beta_2)$, $\quad \Psi_5=\frac{1}{2}(\sinh^2\beta_2-\sin^2\beta_2)$

$\Psi_6=\frac{1}{8}(\sinh 2\beta_2-\sin 2\beta_2)$, $\quad \Psi_7=\frac{1}{4}(\sinh 2\beta_2+\sin 2\beta_2)$

EI: bend ridity rigidity ($kg\cdot cm^2$)

K_{g2}: Transverse stiffness coef. of ground per unit length of pipeline (cf. **1.10.2**) (kg/cm^2)

L: Wave length (cm)

U_h: Horizontal displacement amplitude (cf. **1.4.4.** $U_h(x)$)

2. Calculations in case the spring constant is not 0

(1) Axial relative expansion or contraction of pipe joint

$$\Delta u^{(j)}=u_1^{(j+1)}-u_2^{(j)}$$

where,

$\Delta u^{(j)}$: Axial relative expansion or contraction amount at joint j (cm)

$u_1^{(j+1)}$: Left end displacement of pipe $j+1$ (cm)

$u_2^{(j)}$: Right end displacement of pipe j

(2) Axial relative displacement, relative rotation angle

$$\Delta v^{(j)}=v_1^{(j+1)}-v^{(j)}, \qquad \Delta\theta^{(j)}=0_1^{(j+1)}-0_2^{(j)}$$

where,

$\Delta v^{(j)}$: Joint j's transverse relative displacement (cm)

$\Delta\theta^{(j)}$: Joint j's relative rotation angle (rad)

$v_1^{(j+1)}$: Left end deflection of pipe $j+1$ (cm)

$v_2^{(j)}$: Right end deflection of pipe j (cm)

$\theta_1^{(j+1)}$: Left end inclination angle of pipe $j+1$ (rad)

$\theta_2^{(j)}$: Right end inclination angle (rad) of pipe j

1.10.4. Earthquake resistant calculations for culvert & pipe utility conduit by seismic deformation method & seismic coefficient method

Earthquake resistant calculations for culvert and pipe utility conduit is, as a general rule, conducted by means of seismic deformation method; as regards design of transverse section and calculation of stability against sliding motion, however, seismic coefficient method might be applied.

1.10.5. Earthquake resistant calculations for shaft by seismic coefficient method and seismic deformation method

1. General principle:

In transverse-section designing for shaft, by fully respecting the results by earthquake resistant calculations described here, the structure must be designed satisfactory safe from the expected stress at the time of earthquake.

2. Earthquake resistant calculations for shaft

Earthquake resistant calculations for shaft should be performed by means of seismic coefficient method and seismic deformation method.

3. Earthquake resistant calculations for tunnel fixing part

When the stiffness of fixing part is not much different from that of the shaft, earthquake resistant calculations should be conducted according to the sort of the structure after referring to related standards of guideline.

1.10.6. Earthquake resistant calculations by dynamic analysis for laid pipelines, culvert, pipe-utility conduit & shaft

1. General principle:

Dynamic analysis used in earthquake resistant calculations should be conducted either for whole system or for part there of, according as is needed.

2. Earthquake response analysis:

The earthquake response analysis for the above-mentioned structures should be conducted either by **1.4.5.~1.1** or **1.2** above-described.

3. Models of dynamics system employed in calculations:

As to setting of dynamic-system models in the case of whole system, the structures, subordinate structures and environmental ground are treated as a total system, and, in the partial system, laid pipeline, culvert, pipe utility conduit and shaft are treated as a partial unit. The object of calculation in each unit is regarded as a single system and replaced as an adequate model of dynamic analysis.

4. vibration experiment:

For purposes of heightening the reliability of these structures based on earthquake response analysis, either by an entire model or by a partial model, the results of these calculations should better be examined.

1.11. EARTHQUAKE RESISTANT CALCULATIONS FOR AQUEDUCT BRIDGE & WATER PIPE BRIDGE

1.11.1. Earthquake resistant calculations

Earthquake resistant calculations for the subject bridges are conducted, in accordance with the characteristics of structures by seismic coefficient method or modified seismic coefficient method; if considered necessary, dynamic analysis should be conducted in addition for checking safety.

1.11.2. Influence of earthquake

As for earthquake influence, such inertia force as is due to self-weight, added load (including in-pipe water) etc., earth pressure during earthquake and hydrodynamic pressures must be taken into consideration. Also, the stress, deformation and stability of the structure at the time of full water, absence of water & mediam, condition must be investigated.

1.11.3. Checking of safety of the structures with their ultimate durability considered

As regards reinforced concrete bridge piers & abutment, after checking its stress by seismic coefficient method & modified seismic coefficient method, in case it is an important facility; its safety should be examined in consideration of its ultimate durability in principle.

When steel pier adopted, investigation of its ordinal limit and ultimate limit should desirably be examined.

1.11.4. Allowable stress & safety factor

The allowable stress and safety factor of water aqueduct bridge & waterpipe bridge construction materials should be in accordance with **1.7.** (Allowable degree of stress and safety) in principle.

1.12. EARTHQUAKE RESISTANT CALCULATION FOR BASIN-FORM STRUCTURES

1.12.1. Earthquake resistant calculations

As regards earthquake resistant calculations for basin-form structures, seismic coefficient method or seismic deformation method should be applied according to the shape and installing conditions of structures. However, in the case of a large-scaled and important structure or one of complicated from and construction, dynamic analysis should be applied conjointly for the sake of safety according to necessity.

1.12.2. Influence of earthquake

As for earthquake influence to structures, the following seismic force should be considered according to the installing conditions of basin-form structures:

1. Inertia force due to dead load of structures.

2. Inertia force due to added load.

3. Earth pressure during earthquake

4. Hydrodynamic pressure during earthquake

5. Displacement of ground (when needed).

1.12.3. Allowable stress & safety factor

Allowable stress & safety factor of basin-form structure materials should, in principle, follow the principles stated in **1.7** (Allowable stress degree & safety ratio).

1.13. EARTHQUAKE RESISTANT CALCULATIONS FOR INTAKE TOWER, DISTRIBUTION TOWER AND ELEVATED TANK, ETC. (ABOVE-GROUND STRUCTURES)

1. Earthquake resistant calculations

Earthquake resistant calculations for above-ground tanks like intake towers, distribution towers and elevated tanks are to be conducted, according to the characteristics of the structures, by seismic coefficient method or modified seismic coefficient method, and when necessary, by conjoint use of dynamic analysis, their safety performance should be examined.

2. Influences of earthquake

As regards earthquake influences on these, inertia force due to structures themselves, and added load, earth pressures during earthquake to the sidewalls, hydrodynamic pressures acting on the both outside & inside of the water basins & tanks, and the like must be the object of our consideration.

In addition, in the case of still larger and more important structures, if considered necessary, effects of water surface sloshing should be investigated, too.

3. Allowable stress and safety factor

Above ground tanks like intake tower, distribution tower and elevated tank should be in principle, in accordance with **1.7** (Allowable stress and safety ratio)

2. DETAILED EXPOSITION

2.1. STORAGE FACILITIES

As regards reservoirs, care must be taken lest erosion and landslides due to rainstorm, and earthquakes, and landslips should happen.

2.1.2. Dams and their structures

(The contents of this paragraph is omitted except **3**, **4** and **7**).

3. The dam-body seismic coefficient can be obtained by multiplying the seismic coefficient at the dam site by the value determined by the type of dam, and the ground seismic coefficient, by considering the dam-type, quality of the foundation ground and the importance of the dam.

4. Earthquake resistant calculations for concrete dams are in principle, based on seismic coefficient method; and in consideration of (1) inertia force at the time of earthquake (2) hydrodynamic pressure at the time of earthquake and (3) effect of the waves in earthquake the calculations are conducted in accordance with the dam-body and actual conditions around the dam site. In general dynamic sludge pressure is not included in such conditions.

7. The gates and valves should smoothly function, and be provided with necessary water-tightness, resisting pressure and endurance quality. Also, these must be provided with spare-gate and power.

2.2. INTAKE FACILITIES

2.2.1. Intake weir

1. Consideration is to be taken of riverbed changes, geological nature, topographical features, and river flow conditions, and the weir should better be constructed at right angles to the flow. The materials should be reinforced concrete.

2. Earthquake resistant designing for intake weir is, in principle, to be conducted by means of seismic coefficient method.

3. When the weir is to be built on other grounds than rock foundation, river-bed tightening structure must be provided.

4. Intake weir and bedding work must be built sufficiently into the banks or embankment of the river and in both upstreams and downstreams, bank revetment of necessary extension should be provided.

5. The structure of the gate and reserve power-equipment (motors, self generators etc.) follow **7** of **2.1.2.**

2.2.2. Intake-gate

1. Intake-gate structure, in principle, should be installed in consideration of river-bed changes, geological and topographical conditions. For gate-post construction reinforced concrete should be used in principle.

2. In the up and down-streams, bank revetment should be provided, of the length needed.

2.2.3. Intake-tower

1. Intake tower is to be installed in consideration of changes of the bed of rivers or lakes, and geological and topographical conditions. These are to be built, in principle, of reinforced concrete.

2. The cross-section of intake tower body should be circular or oval; when built-in a river, in principle, with the major axis towards the course of the river flow.

3. Earthquake, resistant calculations for the intake tower should depend upon those stated in **1.13.**

4. In case the river or lake beds adjoining to the tower is feared to be scoured, adequate tightening work becomes necessary.

5. Maintenance bridge should be of light weight so that no heavy load may be put upon the tower. Its construction and earthquake resistant calculations are to follow those of Specification for Earthquake Resistant Design of Highway Bridges (Japan Road Association).

2.2.4. Intake pipe

1. Intake pipe or conveyance conduit connecting to intake installation should resist the actual inner and outer pressures.

2. In case the pipe is installed in riverside land (the area inside the bank) the laying depth should, in principle, be deeper by two meters or more than the designed riverbed for preventing souring.

3. At the place where the bank is crossed, the pipe foundation should be particularly strong, the outside of the pipe be rolled around by reinforced concrete, and the pipe line connecting parts front and back must be installed with flexible joints. Moreover, for fear of accidents, double pipeline system should desirably be adopted.

2.2.5. Infiltration gallery

1. Infiltration gallery should be built of reinforced concrete structure sufficiently resisting against both inner and outer pressures, and buried deeply enough against scouring.

2. In case the gallery should be built where scouring is feared, it must be protected by wooden or reinforced concrete flame.

3. In case reinforced concrete pipe is used for the gallery, socket joints in which rubber rings are employed, in principle, should be used; when collar joints are used, one side of the joint should be void. (uncaulked with mortar)

2.2.6. Shallow well

When shallow well is made, well-side should be built of circular reinforced concrete and be sufficiently strong.

2.2.7. Deep well

1. For casing tube, in general, steel pipe is employed. The thickness of the pipe is in general, decided in consideration of the depth of well, ground nature (i.e., hard or soft) and the water quality, etc. It must be sufficiently strong.

2. Joints of the casing and strainer must be perfect.

2.3. CONVEYANCE FACILITIES

2.3.1. Open and closed conduits

1. Open and closed conduits lines should be determined in consideration of geological and topographical conditions, hydraulic and earthquake resistant conditions, and their maintenance and control.

2. Such places where the ground is unstable and danger feared as the surface and underground of the fill, reclaimed ground, top and toe of slope, weak and soft ground, border where topographical and/or geological condition changes and places where soil is feared to liquefy at the time of earthquakes are to be avoided as much as possible. When it is inevitable to construct at places where the ground seems unstable, earthquake resistant measures are of absolute necessity.

3. As for open or covered conduits, reinforced-concrete construction should be in principle, adopted with the cross sections combined in one.

4. Calculations for earthquake resistant structures should follow **1.10** (the Earthquake Resistant Calculations for Underground Pipelines, Culvert, Pipe Utility Conduit and Shaft).

5. For open and covered-conduits, it is desirable to install expansion joints at the distance of 10 m to 20 m, generally, in between.

6. At the place where geological and topographical conditions change and the front and back of bridge, weir, man-hole, sluice-gate and the like, flexible expansion joints should be installed.

2.3.2. Conveyance tunnels

1. Designing and work for a tunnel or shield tunnel should follow the standard specifications by Japan Society of Civil Engineers (Mountains tunnels and shield tunnels chapters).

2. In adopting tunnel line, such places as of cant load should be avoided.

3. Concrete lining is, in general, adopted for a tunnel.

4. Earthquake resistant calculations for tunnels should follow **1.10.4.** (Earthquake resistant calculations for covered conduit and pipe utility conduit by seismic deformation method and seismic coefficient method)

5. Since the entrance and outlet are especially easy to break down, sufficient protective steps should be adopted. At the place connecting with the interior, expansion joints be installed.

6. At the place where in the lengthwise direction is found a fault or the geological condition is vastly different, the tenacity of lining should better be large and the lining should be of flexible and expandable construction.

2.3.3. Aqueduct bridge

1. Structural materials for an aqueduct bridge should be reinforced concrete, prestressed concrete or steel.

2. Earthquake resistant designing for the super- and sub-structure of aqueduct bridge should follow **1.11** (Earthquake Resistant Calculations for Aqueduct and Water-pipe Bridge), and for other details, specifications for earthquake resistant design of highway bridges (Japan Road Association) should be referred to.

3. Aqueduct beam must be provided camber.

4. Since the water-bridge is to be a top-heavy structure, the bridge must be so constructed as to be safe from dropping off the supporting plate (shoe) against a crosswise-direction earthquake.

5. As for the bridge abutments and wing retain-walls, these must be provided with sufficient earthquake resistability, and sufficiently-studied design and work needed to prevent the aqueduct at this part from being broken down.

6. Connection part of the aqueduct and the bridge must be provided with reliable expansion joint and perfectly water-tight.

2.3.4. Conveyance pipe

As to conveyance pipe, **2.5** (Transmission, Distribution Pipes and & Their Accesary Facilities) should be referred to.

2.4 PURIFICATION FACILITIES & TRANSMISSION & DISTRIBUTION FACILITIES

2.4.1 Basin-form structures

1. Each of the following matters should be observed in earthquake resistant designs for basin-form structures:

(1) Since it is most desirable that the site of basin-form structures is of good foundation ground with satisfactory bearing power, sufficient and close survey is necessary before the decision for work made.

(2) Ground surveys needed for site determination and, foundation and basin body design should be based on **1.3** (GEOTECHNICAL INVESTIGATION).

(3) When the construction has to be conducted on an undesirable ground, the foundation work most adequate for the characteristics of the structure and ground conditions or ground improvement and the like should be devised.

(4) In earthquake resistant designing for basin-form structures, on the basis of the prescriptions of **1.8** (Earthquake Resistant Calculations for The Foundation) and **1.12** (Earthquake Resistant Calculations for Basin-form Structures), the method most suited to structural form, foundation, etc. should be adopted.

2. As for the construction of basin-form structures, each of the following items is checked.

(1) In the case of enclosed pressure basins without free surface of water, in considera-

tion of hydrodynamic pressure at the time of earthquakes, needed countermeasures must be devised.

(2) In the case of distribution reservoir equipped with expansion joints, earthquake resistant walls must be studied.

3. As to structural details of basin-form structure, each of the following must be observed.

(1) As regards structural style, it should better be simple without a sharp sectional changes; at corners of frame, proper-sized hunches provided.

(2) For purposes of absorbing temperature changes and relative displacements due to earthquakes, expansion joints are to be provided. Since these, sometimes, prove structural weakpoints, sufficient pre-checking needed.

(3) As for concrete and reinforcement material, in accordance with the respective specifications, designing and work execution should be carefully performed with sufficient strength and water-tightness secured.

(4) According as is needed, coating should be added, for protection from chemicals or water-proof.

4. As regards piping and other equipments thereto, each of the following specifications should be observed:

(1) It is desirable that the accessary sluice valves be installed on the same slab with the structure.

(2) The piping and other equipments installed in the basin should be tightly connected with the structure by solid material.

(3) At the connecting parts of buried pipe in the structure with the underground pipe, flexible-expansion joint must be installed.

(4) Valves of such important pipes as outlet pipe of distribution basin should be so built as to be able to close at the time of emergency, that is, the installing of automatic emergency stop-valve is desired.

2.4.2. Distribution tower

1. The foundation ground and structure should follow **2.4.1.**

2. The structure should, in principle, be of reinforced concrete, prestressed concrete and steel, and has sufficient safety and watertightness.

3. The earthquake resistant calculations should observe those of **1.13** (Earthquake Resistant Calculations for Intake Tower, Distribution Tower and Elevated Tank, etc.)

4. Rised pipes, etc. connecting to distribution tower should be firmly supported by sidewalls, support-pillars, etc. The fixing parts of inlet and outlet pipes for sidewalls and floor slab should be provided with flexible expansion joints.

5. For the upper part of the distribution tower in consideration of surface sloshing by the earthquake, sufficient free board should be given or particular case taken of overflows, roof structure, etc.

6. It is desired that the distribution tower should be installed with, when considered necessary, emergency stop devices such as emergency stop-valves.

2.4.3. Elevated tank

1. The decision for construction site of an elevated tank follows **2.4.1.**

2. The foundation should be strong enough to transmit the upper load to the ground, sufficiently strong and safe against sinking, floating, tumbling and sliding. The structure should, in principle, be of reinforced concrete.

3. The structure should, in principle, be of reinforced concrete, prestressed concrete and steel so that it may be provided with sufficient safety and watertightness. The supporting portion should be fully safe for water pressure, seismic force and wind force.

4. Earthquake resistant calculations for elevated tank should follow **1.13** (Earthquake Resistant Calculations for Intake Tower, Distribution Tower and Elevated Tank, etc.)

5. For the rised pipes, pipes of strong quality are to be employed, and where the ground surface is near, sufficiently flexible expansion joints are to be used.

6. At the part where pipeline is fixed with the basin, adequate earthquake resistant measures are to be adopted.

7. For elevated tanks, emergency stop valve should be provided according to need.

2.4.4. Transmission & distribution tunnels

1. Earthquake resistant design and countermeasures for transmission & distribution tunnels should follow **2.3.2.** (Conveyance Tunnel).

2. As to transmission & distribution tunnels, special consideration is needed for their watertightness lest they should be contaminated from outside of tunnels.

2.5. TRANSMISSION, DISTRIBUTION PIPELINES AND THEIR ACCESSARY FACILITIES

2.5.1. Pipeline planning

1. The basic principles for earthquake resistant pipelines consist of reinforcement of a single pipeline, establishing plural pipeline system mutual connection of systems, looping, block systematization, etc. According to the geological features and environmental conditions, the most adequate method should be employed.

2. Earthquake resistant measures should be materialized, starting from the part near the water source and progressing in the order of transmission pipe, distribution main and submain.

3. Pipeline site should be decided where the ground is good and such places as the conditions are unstable and dangerous like banking area, fill, weak gound, end of hill slope, spot where the geological changes, or liquefaction is feared at the time of earthquakes, should be avoided as much as possible.

4. In the pipelines, sluice valves should be installed at distances of approx. 500 m to 1,000 m. In addition, if necessary, emergency stop valves be provided so that the function of pipeline can be independently secured.

5. Pipelines should be installed either in the public road or in the waterworks authorized area. Such areas as are difficult of recovery should be avoided.

6. Pipelines, either horizontally or vertically should avoid sharp bending.

2.5.2. Kind of pipe

As regards transmission & distribution pipes, such kind of pipes and joints must be adopted as are safe from the usual load and the one at the time of earthquakes and from the expected deformation.

2.5.3. Designs and counter-measures for pipelines in general

1. In the pipelines as follows, especially careful, considerate earthquake resistant designing should be performed:

(1) Site where geologically checking is required.

1) Fill and banking ground.
2) Top and toe of slope of hills.
3) Where soft and feeble surface layer is thick.
4) Border of changes both geologically or topographically.
5) Where liquefaction feared at the time of earthquake.

(2) Site where checking required structurally.

1) Site where structure or special pipe such as bend or tee, etc. connect the pipe line in a place where the ground conditions are unsatisfactory.
2) A part where the pipe rises from shield tunnel or pipeline.
3) A part where hydrodynamic pressure is feared to occur.
4) Site where special earthquake resistant considerations are needed.

2. In case special earthquake resistant designing is needed, the procedure of designing are as follows:

(1) Investigation of environmental conditions.
(2) Ground condition investigation.
(3) Planning and designing of pipeline.
(4) Earthquake resistant calculations.
(5) Confirmation of safety.

3. Earthquake resistant countermeasures are as follows:

(1) In case the pipeline is laid in such a place as the ground is soft and weak like a reclaimed land or weak ground, joints and pipelines of high earthquake resistant quality should be used, and if necessary, foundation work or ground improvement work should be conducted.

(2) In case it is inevitable to lay pipelines at the top or toe of the slope of a hill, adequate counter-measure should be devised against breakdowns and slides of the ground.

(3) At the place where the topographical or geological changes exist, there are fears of relative displacements of grounds at the time of earthquake, so the pipelines in such areas should have sufficient expansion and flexibility.

(4) The kind of ground where liquefaction is feared at the time of a earthquake, should be avoided as far as practicable for the site of pipe laying.

(5) For a structure or special pipes where the ground is weak and where pipeline meet with them, earthquake resistant measures as countermeasures for irregular gound sinking, are to be considered.

(6) For such parts of pipelines where influences hydrodynamic pressures at the time of

an earthquake, countermeasures must be considered beforehand.

(7) In case it is necessary to lay pipeline with a soft curve, bend pipes of small angle should be inserted in the straight pipes adequately.

(8) Burying depth of the pipeline, without laying excessively deep, should be such as is convenient for maintenance of the pipeline and not difficult for repairs and recovery of the pipe.

(9) When a pipe is laid across or close to other underground facilities, at least 30 cm or more distance must be left between.

(10) In the case of a pipe of large diameter, manholes into pipes must be provided at proper distances that allow the inspections from inside of pipes in earthquake and other accidents. Further, in lowest parts of the pipeline, there must be without fail, drain devices provided.

2.5.4. Siphon

1. In case siphoning work is designed, conducting minute surveys around the neighbouring ground, and good foundation site must be selected for the work so far as possible.

2. The parts before and behind of siphon should be of such piping as of small bending so as to avoid the slope of ground sliding and moving.

3. The part of siphoning should better be of such strong and tenacious materials as steel pipe or ductile cast iron pipe.

4. Foundation work at the part of siphon should be performed with minute care in consideration of the quality of the ground and the condition of load.

5. Bending part before and behind the siphon should be performed by adequate technique such as sufficient fixing by means of concrete support board.

6. Before and behind the siphone, sluice valve should be installed. In the case of large size pipes and important trunk pipelines, the pipeline should be divided in two or more lines, the distance between the lines being as distant as possible from one another.

2.5.5. Pipe beam bridge and pipe supported on bridge

1. The installing position of pipe beam bridge, it is desirable, should be such as the foundation ground which has sufficient bearing power, is as shallowly located as possible; therefore, in consideration of wind and flow conditions, site of good constructive conditions should be chosen.

2. In designing on pipe beam bridge, earthquake resistant constructive type suitable for the conditions of the chosen site should be selected.

3. Earthquake resistant designing work for a pipebeam bridge in consideration of the characteristics of the structure and ground conditions, etc., work should be advanced on the basis of **1.11.** (Earthquake Resistant Calculations for Aqueduct Bridge and Water Pipe Bridge).

4. Movable shoe should be bridge-fall preventions construction, and at each supporting shoes, seismic force should be fully transmitted to under-structure.

5. Fill-back soil after completion of the bridge and that at the back of the abutment when the pipe is supported on the road-bridge should be of good quality and fully compacked.

6. Pipe supported on the bridge should be attached on a bridge of high earthquake resistant quality and at the same time should be able to follow the behavior of the bridge.

7. Approach of the abutment should be provided with a flexible expânsion pipe and if needed, a sluice valve be provided.

2.5.6. Driving Tunnel Method

1. The pipeline of driving tunnel method should be decided in consideration of geological and topographical features, conditions of underground water and ground conditions, etc.

2. Between the driving pipe and the surrounding earth, grouting must be made.

3. The kind of the driving pipe should be decided in consideration of the conditions of the ground, driving force, outer pressure, the strength and endurability against the earthquake, and workability.

4. The piping of the rising part, in particular, must be carefully conducted so as to resist seismic force.

2.5.7. Shield tunneling method

1. The course of shield tunneling method should be decided in view of topographical and geological features, the consideration of underground water and conditions of location.

2. Back-fill grouting should be performed between the segment and ground.

3. The shape of tunnel cross section should be decided in consideration of cost, safety and maintenance.

4. Shaft for maintenance should be of reinforced concrete-make: earthquake resistant calculations for the structure follow **1.10**.

5. Piping at the rising part should, in particular, be built with sufficient care against seismic shocks.

6. Segments should have such strength as are adequate for the purpose of use due to shield section type; these should be decided in consideration of water tightness, safety, and economy.

2.5.8. Attached facilities of pipelines

1. Attached facilities of pipelines should be, it is desired, installed in as good as possible a ground, not a place of an unstable ground.

2. In providing attached facilities, care must be taken lest the self-weight of the facilities and the shape of pipe laying should grow an unusual large stress in the pipeline.

In steel pipeline, lest the attached facilities should be damaged by the temperature stress, expansion joints should be installed before and behind the facilities.

3. For installing attached facilities, concrete structures such as valve rooms are built, studies have to be made beforehand to check safety at the time of earthquakes.

4. Before and behind the part where concrete structures such as valve boxes are fixed, flexible joints and the like should be installed according to need.

5. In large diameter trunk lines, inspection man hole or drain facilities have to be installed in view of the time of earthquake disasters.

2.6. MACHINES AND ELECTRIC FACILITIES

2.6.1. General earthquake resistant countermeasures for machines and electric facilities

For machines and electric facilities earthquake resistant countermeasures, together with an increase of direct earthquake resistant quality of facilities, countermeasures in systems intended to restrict the influences of disaster as much as possible and those for recovery as facile as possible must be considered.

2.6.2. Electric power sources

1. Power reception must be based upon each of the following items.

(1) As for power reception of a large-scale equipment, two-circuit reception system adopted.

(2) As for the reception of a small or middle-scale equipment, in accordance with the power conditions of the area concerned, two-circuit reception or, one-circuit reception combined with independent power system, adopted.

2. For facilities for purification, intake, conveyance, transmission and distribution, as security-power source, independent power facilities must be provided. However, in the case of small scale facilities, where no fear of water facilities being endangered, or there is substitute method of emergency water supply, or there is no need of emergency supply of water, independent power equipment may be sound.

2.6.3. Power facilities

The contents of this paragraph is omitted.

2.6.4. Pumping equipment

1. Installation of pumps should be based upon each of following.

(1) The foundation of pumping facilities, being of the same with that of motors or engines, is built of reinforced concrete, and the anchor bolt is welded with the reinforcing bar of the foundation.

(2) Pumps of vertical mixed flow or axial-flow, etc. which has long body must be tightly fixed with swing-stopper.

(3) Submerged motor pump used for intaking raw water has to be provided with reliably strong casing, and has to be fixed tightly.

2. Piping to the pump should follow each of the following instructions:

(1) For the part different from the pump foundation and for the part of penetration through side wall of the pumping station, flexible pipe should be employed.

(2) Supports of the piping (including accessary small piping for cooling water, etc.) should be located so as to be free from sympathetic vibration with the seismic tremor.

3. For pumping facilities, each of the following safety countermeasures should be employed:

(1) Unitization of the machines and accessaries should be realized, and for this purpose, the driving power-source and control power source must be separated as much as possible, because, even if any trouble should occur in the machinery, power system, the expected damage or influence should be restricted as much as possible.

(2) In the important pipe of pumping pipeline system, detective device for trans-

mission and distribution pipe line breakage should be installed for speedy, discovery of such troubles.

(3) Countermeasures against troubles due to electric power suspension in time of earthquake must have been established.

2.6.5. Equipment for disinfection and chemical dosing

1. Chlorination equipment using liquified chlorine as disinfectant should be decided in consideration of the following:

(1) Chlorine and its safety equipment, based on the stipulations in High Pressure Gases Control Law and other relevant rules, must be of such construction as have earthquake resistant function as an entire system including machines, and accessary pipings.

(2) Buildings where the chlorine equipment is installed should be capable of tight-closing, that is, if, in earthquake, chlorine leaks, it must not leak out of the storage-chamber.

On the floor of the liquid chlorine storage room and evaporater room, liquid bank or pit must be built to prevent flowout of liquid chlorine.

(3) As for the container or storage tank of liquified chlorine, measures for safety maintenance must be employed so as to prevent its leak occasioned by collision, break or fall. etc.

(4) Piping for chlorine, for fear of sympathetic vibration with the support-structure, should be supported at adequate interval, and the supporting fittings should fully resist the earthquake force.

(5) Equipments for removal of leaked chlorine should be effective enough for estimated leak-accident. Machines and pipes should have sufficient earthquake resistant effect and sufficient quality for leaked chlorine gas.

(6) Piping for chlorination equipment should be as simple as practicable.

2. Earthquake resistant countermeasures where the market-sold sodium hypochlorite, chlorine gas or sodium hypochlorite produced on-site by electrolytic process is employed as chlorine agent, should follow the prescriptions in **1.**

3. Earthquake resistant measures for chemical-dosing equipment for coagulation-sedimentation purposes should follow the prescriptions in **1.**

2.6.6. Instrumentation & communication facilities

1. Instrumentation-communication facilities must be secured to function even at the earthquake disaster, and the control-power source and circuit should be devided by each system so that no trouble will affect the other system.

2. For instrumentation and communication facilities, backup system must be established so that even at the time of earthquake disaster, the function can be ensured.

3. The antenna for wireless communication should be safe in accident from slanting, falling and breakage due to the earthquake.

2.7. WATER SERVICE INSTALLATION

2.7.1. Construction and materials

1. In selection of the service-pipe, in addition to that of sufficient flexibility, in case the rigidity is high, flexible joint must be employed.

2. At the part of branching and the part connecting with the building or house, flexible joint must be employed.

3. For service installations, only easy-to-handle stop-valve should be provided.

4. Materials used should desirably be authorized-standard ones or those better than the standard should be used according to installing conditions.

2.7.2 Branching work and installation work

1. In pipe-branching work, such method as reduces the strength of distribution pipe should be avoided.

2. As for installing a ferrule, it must be screwed in sufficiently to the specified position.

3. According to the kind and materials of the distribution pipe, the branching saddle must be adequately used.

4. As for installing a service pipe, earthquake resistant quality of the equipment must be fully considered.

2.8. BUILDINGS OF FILTER PLANT OFFICE, PUMP HOUSE, ETC.

1. In designing of buildings, after investigating the conditions of topography, ground and the site minutely, and studying ground stability of the site at the time of earthquakes, necessary countermeasures should be performed.

2. Adequate earthquake resistant designing should be performed, in accordance with the rules and regulations concerned and with the use, kind of the structure and the characteristics.

3. The foundation should be, in principle, supported by good-quality ground, and the earthquake force which act on the structure should be carried onto the ground.

4. In structural design of the building, in accordance with the seismic activities of the area, characteristics of topography and the ground, and function of the planned structure, etc. structural form and materials of high earthquake resistant nature should be selected. To prevent growth of harmful displacement, torsion, stress concentration and the like, structural members should be placed in good balance in order to give sufficient strength and tenacity to the structure.

5. In case part of the structure is made as a basin, the basin should be safe from hydrodynamic pressures and surface sloshing.

6. Water quality examination equipments, electric, mechanical equipments and, accessary wire and pipe-layings therefore should be safe in structure, from earthquakes and the subsequent troubles, such as power failure, fires and leaks of chemicals.