CHAPTER 5 CONSTRUCTION MATERIAL

5.1 Weight of Material (Dead Load)

The dead loads consist of the weight of the structure considered, including additional materials for construction or other utility services. The following unit weights of construction materials are in principle used in computing the dead loaded. In case that the actual unit weight of materials is evident, their unit weight is to be used.

No.	Material	Unit Weight	
		(tf/m^3)	(kN/m^3)
1	Reinforced Concrete (Thick Structure)	2.35	23.04
2	Reinforced Concrete (Thin Structure)	2.50	24.51
3	Prestressed Concrete	2.55	25.00
4	Plain/Mass Concrete	2.30	22.55
5	Cement Mortar	2.15	21.08
6	Stone	2.60	25.48
7	Wet Cobble/Rubble Masonry	2.30	22.54
8	Asphalt Concrete Pavement	2.30	22.55
9	Cement	3.17	31.08
10	Structural Steel	7.85	76.96
11	Cast Iron	7.25	71.05
12	Water	1.00	9.80

Unit weight of soil shall be determined by result of laboratory tests, but if there is no data available at hand, the following standards of unit weight may be used.

Type of Soil		Wet (tf/m^3)		Submerged (tf/m^3)	
		Loose	Compacted	Loose	Compacted
Natural Foundation	Sand or gravel	1.8	2.0	0.9	1.0
	Sandy soil	1.7	1.9	0.8	0.9
	Clayey soil	1.4	1.8	0.6	0.8
Embankment	Sand or gravel	2.0			1.0
	Sandy soil	1.9			0.9
	Clayey soil	1.8			0.8
	Back Fill	1.7			0.75

5.2 Property of Construction Materials

5.2.1 Concrete

(1) Classification

Concrete is classified according to its compressive strength (28th day, σ_{bk}) maximum size of aggregates and application as shown in the following table:

Class of Concrete	28th-day (σ_{bk}) Compressive Strength		Max. Size Aggregate (mm)	Application
	(Mpa)	(kgf/cm²)		
A – 1 (K – 500)	49.02	500	-	Prestressed concrete pile (ready made product)
A – 2 (K – 400)	39.20	400	25	Prestressed concrete for girder bridge, Prestressed concrete pile.
A – 3 (K – 350)	34.30	350	25	Prestressed concrete for slab deck of bridge, precast concrete pile
B (K – 250)	24.51	250	25	RC bridge girder
C1 (K – 225)	22.05	225	25	General use, reinforced concrete members with thickness more than 20 cm
C2 (K – 225)	22.05	225	25	General use, reinforced concrete members with thickness less than 20 cm.
D (K – 175)	17.15	175	40	Plain concrete for structure
E (K – 125)	12.25	125	25	Plain concrete for leveling

Note : 1 MPa = 10.2 kgf/cm², (MPa : mega pascal)
1 kgf/cm² = 0.098 MPa

(2) Modulus of Elasticity (Young's Modulus)

Young's Modulus of concrete to be used in calculation of the statically in determinate force or elastic deformation of a reinforced concrete structure and those for design calculation of presetressed concrete members are given in the table below.

Grade	σ_{bk} (kgf/cm²)	Ec (kgf/cm²)	n = Es / Ec	ν = Poisson's ratio
K – 175	175	215,000	9.77	0.2
K – 225	225	245,000	8.57	0.2
K – 250	250	255,000	8.24	0.2
K – 350	350	295,000	7.12	0.2
K – 400	400	310,000	6.77	0.2
K – 500	500	330,000	6.36	0.2

where,

σ_{bk} : compressive strength of concrete at relevant age (kgf/cm²)
Ec : elasticity of concrete (kgf/cm²)
Es : modulus of elasticity of steel (=2,100,000 kgf/cm²)
n : ratio of Young's modulus.
ν : Poisson's ratio

Ratio of Young's modulus n to be used in calculation of stress of reinforced concrete members is 15 (n = 2,100,000 / 140,000, Ec value is assumed to be 140,000 kgf/cm²).

5.2.2 Structural Steel

(1) Material of Steel Penstock

Materials used for steel penstock shall be those listed in table below. Materials other than those in the table below may be used provided that a sufficient study be made.

1.	Rolled steel for general structure	JIS G 3101(1995)
2.	Rolled steel for welded structure	JIS G 3106(1995)
3.	Carbon steel tubes for general structural purposes	JIS G 3444(1988)
4.	Carbon steel pipes for ordinary piping	JIS G 3452(1988)
5.	Carbon steel pipes for arc welded piping	JIS G 3457(1988)
6.	Carbon steel pipes for pressure service	JIS G 3454(1988)
7.	Carbon steel castings	JIS G 5101(1991)
8.	Carbon steel forging for general use	JIS G 3201(1988)

(2) Material of Hydraulic Gate, Valve and Trash Racks

The materials used for a hydraulic gate shall be equivalent or superior to those listed in the table below. This Article is applicable to the materials used for high pressure valves and trash racks. Materials other than in the table below may be used provided that a sufficient study be made.

Material of Hydraulic Gate, Valve and Trash Racks (1/2)

No.	Name	Type	Symbol	Place used
1.	Rolled steel for general structures	JIS G 3101	SS400 SS490	Leaf, guide, leaf support, anchorage, hoist base, bolt
2.	Rolled steel for welded structures	JIS G3106	SM400A(B or C) SM490A(B or C) SM490YA(B) SM520B(C) SM570	Leaf, guide, leaf support, anchorage
3.	Steel bars for concrete reinforcement	JIS G3112	SR235 SD295 SD345	Anchor
4.	Hot rolled atmospheric corrosion resisting steel for welded structures	JIS G3114	SMA400(B or C) SMA490(B or C) SMA570	Leaf, guide, leaf support, anchorage
5.	Cold finished carbon and alloy steel bars	JIS G3123	SGD290-D SGD400-D	Shaft, bolt
6.	Carbon steel tubes for general used	JIS G3201	SF390A SF440A SF490A SF540A SF590A	Major diameter of gear shaft, trunnion hub, flange
7.	Carbon steel tubes for general structure purpose	JIS G3444	STK290 STK400	Leaf, protective pipe, handrail, shaft for load transmission
8.	Carbon steel pipes for ordinary piping	JIS G3452	SGP	Low pressure oil hydraulic pipe, air pipe, handrail
9.	Carbon steel pipes for pressure service	JIS G3454	STPG370 STPG410	High pressure oil hydraulic pipe, feel & drainage pipe, oil hydraulic cylinder
10.	Stainless steel pipes	JIS G3459	SUS304TP SUS316TP	Leaf, protective pipe, shaft for load transmission

Material of Hydraulic Gate, Valve and Trash Racks (2/2)

No.	Name	Type	Symbol	Place used
11.	Wire rope	JIS G3525	637 6W(19) 6Fi(29) 6WS(36)	Hoisting cable
12.	Carbon steel for machine structural used	JIS G4051	S25C S30C S35C S40C S45C	Wheel, gear, gear shaft, transmission shaft, anchor, bolt
13.	Nickel chromium steels	JIS G4102	SNC236 SNC631 SNC836	Gear, shaft, bolt
14.	Chromium molybdenum steels	JIS 4105	SCM430 SCM432 SCM435 SCM440 SCM445	
15.	Stainless steel bars	JIS G4303	SUS304 SUS403 SUS410 SUS420J1(J2)	Wheel, shaft, sheave shaft, piston stem
16.	Hot rolled stainless steel sheets and plates	JIS G4304	SUS304 SUS316 SUS403 SUS410	Seal plate and sliding plate for leaf and guide, tread of a roller rail
17.	Cold rolled stainless steel sheets and plates	JIS G4305	SUS304 SUS316 SUS403 SUS410	Seal plate and sliding plate for leaf and guide, tread of a roller rail
18.	Hot rolled stainless steel strips	JIS G4306	SUS304 SUS316	
19.	Cold rolled stainless steel strips	JIS G4307	SUS304 SUS316 SUS329J1 SUS410 SUS420J2	
20.	Carbon steel casting	JIS G5101	SC360 SC410 SC450 SC480	Leaf, casting, leaf support, gear, roller, parts for hoist, hydraulic cylinder, sheave, drum
21.	Steel castings for welded structure	JIS G5102	SCW410 SCW480 SCW550 SCW620	
22.	High tensile strength carbon steel castings and low alloy steel castings for structural purposes	JIS G5111	SCMn1B SCMn2B SCMn3B SCMn5B SCMnCr2B SCMnCr3B SCMnCr4B SCC3B SCC5B SCNCrM2B	Main wheel, large gear
23.	Stainless steel castings	JIS G5121	SCS2 SCS12 SCS22	Main wheel, leaf bearing
24.	Gray iron castings	JIS G5501	FC200 FC250	Parts for hoist, sheave
25.	Spheroidal-graphite iron castings	JIS G5502	FCD450 FCD500	Piston, sheave
26.	Copper and copper-alloy sheets, plates, strip and cold sheets	JIS H3100	C2600P C2680P C2720P C2801P	Sliding plate
27.	High strength brass castings	JIS H5102	HBsC4	Bushing plate
28.	Bronze castings	JIS H5111	BC2 BC3 BC6	Sliding plate, seal plate, bushings
29.	Phosphorus bronze castings	JIS H5113	PBC2 PBC2B PBC3B	Bushings, worm wheel
30.	Aluminum bronze castings	JIS H5114	AlBC2 AlBC3	Corrosion-resistant bushings
31.	Leaded tin bronze castings	JIS H5115	LBC2 LBC3	Sliding plate, bushings
32.	Solid rolled carbon steel wheels for railway rolling stock	JIS E5402	SSW-R1(2 or 3) SSW-Q1S(2S or 3S) SSW-Q1R(2R or 3R)	Main wheel

It is standardized that steel types should be selected in relation to plate thickness as given below:

Type	Thickness (mm)						
	8	16	22	25	32	38	50
SS400	▒	▒	▒				
SM400A	▒	▒	▒	▒	▒		
SM400B	▒	▒	▒	▒	▒	▒	
SM400C	▒	▒	▒	▒	▒	▒	▒
SM490A	▒	▒	▒	▒			
SM490B	▒	▒	▒	▒	▒	▒	

5.2.3 Reinforcing Steel Bar

Reinforcing steel bars shall be U-24 or U-30 (SII, 02932-80) and conform to SII 0136 (Standard Industri Indonesia) as shown below.

Round Bars

Code No.	Diameter (mm)	Cross Sectional Area (cm^2)	Unit Weight (kgf/m)
ϕ6	6	0.283	0.222
ϕ8	8	0.503	0.395
ϕ9 *	9	0.636	0.499
ϕ10	10	0.785	0.617
ϕ12	12	1.13	0.888
ϕ13	13	1.33	1.04
ϕ14 *	14	1.54	1.21
ϕ16	16	2.01	1.58
ϕ18 *	18	2.54	2.00
ϕ19	19	2.84	2.23
ϕ20 *	20	3.14	2.47
ϕ22	22	3.80	2.98
ϕ25	25	4.91	3.85
ϕ28 *	28	6.10	4.83

Note * : The size is subject to order.

Deformed Bars

Code No.	Diameter (mm)	Cross Sectional Area (cm^2)	Unit Weight (kgf/m)
D10	10	0.785	0.617
D12 *	12	1.130	0.888
D13	13	1.330	1.040
D14 *	14	1.540	1.210
D16	16	2.010	1.580
D18 *	18	2.540	2.000
D19	19	2.840	2.230
D22	22	3.800	2.980
D25	25	4.910	3.850
D29	29	6.610	5.190
D32	32	8.040	6.310
D36	36	10.200	7.990

Note * : The size is subject to order.
Steel bars with the standard length of 6 m and 12 m are available

5.2.4 Tendon

(1) Tensile Strength of Wire, Strand and Bar

Material Type	Dia	Area	Minimum Breaking Load		Maximum Tensile Strength (σ p)	
	mm	mm²	kN	(kgf)	MPa	(kgf/cm²)
	5.0	19.6	30.4	310	1,550	15,810
Wire	5.0	19.6	33.4	341	1,700	17,340
	7.0	38.5	65.5	668	1,700	17,340
7 Wire Super	9.3	54.7	102.0	1,040	1,860	18,972
Strand	12.7	100.0	184.0	1,877	1,840	18,768
	15.2	143.0	250.0	2,550	1,750	17,850
7 Wire Regular	12.7	94.3	165.0	1,683	1,750	17,850
Strand						
	23.0	415.0	450.0	4,590	1,080	11,016
Bar	29.0	660.0	710.0	7,242	1,080	11,016
	32.0	804.0	870.0	8,874	1,080	11,016
	38.0	1,140.0	1,230.0	12,546	1,080	11,016

(2) Yield Strength of Tendon

The yield strength of tendon (σ py) are determined by test result or assumed as follows:

- for wire used in the as-drawn condition : 0.75 σpy (kgf/cm²)
- for stress relieved wire : 0.85 σpy (kgf/cm²)
- for all grade of strand and bar tendons : 0.85 σpy (kgf/cm²)

(3) Modulus Elasticity

The following modulus elasticity of tendon (Ep) is used for structural calculation.

- for stress-relieved wire : 200×10^3 MPa or 2.1×10^6 kgf/cm²
- for stress-relieved steel strand : 195×10^3 MPa or 1.9×10^6 kgf/cm²
- for cold worked high tensile alloy steel bar : 170×10^3 MPa or 1.7×10^6 kgf/cm²

Source : Structural Concrete Design Section 6

5.2.5 Steel Support for Tunnel

(1) Strength of Wire Mesh

(Unit: N/m²)

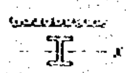
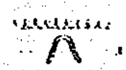
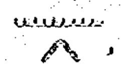
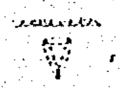
Diameter of wire (D)	100 x 100 mm	150 x 150 mm
6.0 mm	46.0	30.6
5.0 mm	31.9	21.3
4.0 mm	20.4	13.6
3.2 mm	13.1	8.8

(2) Mechanical Properties of Rock Bolt

Whole Surface Anchoring Type and Expanded Steel Pipe Type

Type	Symbol	Diameter	Screwed Part		Original Part	
			Yield Point (kN)	Break Load (kN)	Yield Point (kN)	Break Load (kN)
Screwed Steel Bar	STD510	TD21	153.9	207.8	188.2	252.8
		TD24	179.3	242.1	226.4	305.8
Deformed Steel Bar	SD345	D25	120.5	172.5	173.5	247.9
Whole Screwed Steel Bar	SD295	D22	113.7	185.2	-	-

(3) Properties of Steel used for Support

Type	Quality	Name Size (mm)	Cross Section A (cm²)	Unit of Mass W (kgf/m)	Moment of Inertia Ix (cm⁴)	Section Modulus Zx (cm³)	Minimum R (cm)	Direction in Usage
H Shape Steel	SS 400	H-100x100x6x8	21.59	16.9	378	75.6	120	
		H-125x125x6.5x9	30.00	23.6	839	134	150	
		H-150x150x7x10	39.65	31.1	1620	216	200	
		H-175x175x7.5x11	51.42	40.4	2900	331	340	
		H-200x200x8x12	63.53	49.9	4720	472	420	
		H-250x250x9x14	91.43	71.8	10700	860	550	
		H-300x300x10x15	118.40	93.0	20200	1350	850	
U Shape Steel	SM 490	MU-21	26.80	21.0	296	56.6	135	
		MU-29	37.00	29.0	581	97.4	150	
L Shape Steel	SS 400	L-90x90x7	12.22	9.59	38.3	11.0	150	
Steel Pipe	STK 400	φ76.3x3.2	7.349	5.77	49.2	12.9	65	
		φ 89.1x3.2	8.636	6.78	79.8	17.9	80	
		φ 101.6x5.0	15.17	11.9	117	31.9	100	
		φ 114.3x4.5	15.52	12.2	234	41.0	120	
		φ139.8x6.0	25.22	19.8	566	80.2	140	
		φ216.3x8.2	53.61	42.1	2190	269	250	
		φ267.4x9.3	75.41	59.2	6290	470	450	
		φ318.5x10.3	99.73	78.3	11900	744	550	
Steel Bar	SD 295	D16 x 3 + D10	6.0	7.4	94.4	26.2	-	

5.3 Allowable Stress

5.3.1 Concrete

Allowable compressive stress and allowable shear stress of each type of concrete are shown in the following table.

(1) Reinforced Concrete

Type of Concrete		Class of Concrete							
		K-175		K-225		K-250		K-350	
		MPa	kgf/cm²	MPa	kgf/cm²	MPa	kgf/cm²	MPa	kgf/cm²
Compressive strength (28th day σ_{bk})		17.15	175	22.05	225	24.51	250	34.31	350
Bending with or without normal stress	Compression	5.88	60	7.35	75	7.84	80	0.33 σ_{bk}	
	Tension	0.64	6.5	0.69	7	0.71	7.2	0.48 σ_{bk}	
Normal Stressed	Compression	5.88	60	7.35	75	7.84	80	0.33 σ_{bk}	
	Tension	0.49	5	0.54	5.5	0.56	5.7	0.36 σ_{bk}	
Shear caused by bending or torsion	without shear reinforcement	0.54	5.5	0.64	6.5	0.66	6.7	0.43 σ_{bk}	
	with shear reinforcement	1.37	14	1.57	16	1.47	15	1.08 σ_{bk}	
Shear caused by combination of bending and torsion	without shear reinforcement	0.69	7	0.78	8	0.83	8.5	0.54 σ_{bk}	
	with shear reinforcement	1.76	18	1.96	20	2.06	21	1.35 σ_{bk}	

Note: 1 Mpa = 10.2 kgf/cm²
1 kgf/cm² = 0.098 MPa

(2) Plain Concrete

Type of Strength		Class of Concrete			
		K-125		K-175	
		MPa	kgf/cm²	MPa	kgf/cm²
Compressive strength (28th day σ_{bk})		12.25	125	17.15	175
Normal Stressed	Compression	3.04	31	4.21	43
	Bearing	3.04	31	4.21	43
	Tension	-	-	0.29	3

Allowable bond stresses of concrete are given in the following table for reinforcement not greater than 32 mm in diameter.

Kind of Bar	Class of Concrete							
	K-175		K-225		K-250		K-350	
	MPa	kgf/cm²	MPa	kgf/cm²	MPa	kgf/cm²	MPa	kgf/cm²
Round Bar	0.59	6	0.74	7.5	0.79	8.1	1.18	12
Deformed Bar	1.18	12	1.47	15	1.70	17.3	2.36	24

5.3.2 Prestressed Concrete

Allowable stresses of concrete, namely compressive stress, tensile stress, shear stress, shear stress and diagonal stress are presented in the following table:

Allowable compressive stress of concrete (kgf/cm^2)

Kind of Stress			Compressive Strength		
			300	400	500
Immediately after pre-stressing	Flexure extreme compressive fiber stress	(1) for rectangular section	150	190	210
		(2) for T or box section	140	180	200
	(3) Axial compressive stress		110	145	160
Others	Flexure extreme compressive fiber stress	(4) for rectangular section	120	150	170
		(5) for T or box section	110	140	160
	(6) Axial compressive stress		85	110	135

Allowable tensile stress of concrete (kgf/cm^2)

Kind of Stress			Compressive Strength		
			300	400	500
Flexure extreme tensile fiber stress	(1) Immediately after pre-stressing		12	15	18
	(2) Principal loads excluding live load and impact		0	0	0
	Principal load and particular load to be regarded as principal load	(3) for floor slab or joint of pre-fabricated segment	0	0	0
		(4) Others	12	15	18
(5) Axial tensile stress			0	0	0

Allowable shear stress and allowable/diagonal tensile stress of concrete (kgf/cm^2)

Kind of Strength		Compressive Strength		
		300	400	500
(1) Shear stress		4.5	5.5	6.5
Diagonal tensile stress	(2) When considering only shear force or torsional moment	8	10	12
	(3) When considering shear force and torsional moment simultaneously	11	13	15

5.3.3 Reinforcing Steel Bar

Allowable stresses of reinforcing steel bars are as follows:

Kind of Stress		Steel Grade			
		SII U-24 or JIS SR-24		SII U-30 or JIS SD 30	
		(MPa)	(kgf/cm^2)	(MPa)	(kgf/cm^2)
Allowable tensile stress	Above ground elevation	137.25	1,400	176.47	1,800
	Below ground elevation	137.25	1,400	156.86	1,600
Allowable compressive stress		137.25	1,400	176.47	1,800

Where, U-24, U-30 : Indonesian Industrial Standard of steel bars with yield strength of 2,400 and 3,000 kgf/cm^2 respectively.

SR-24, SD-30 : Japanese Industrial Standard (JIS)

Yield Strength : SR-24 or U-24 $s \geq 2,400\ kgf/cm^2$

SD-30 or U-30 : SD-30 or U-30 $s \geq 3,000\ kgf/cm^2$

5.3.4 Structural Steel

Steel Penstock

(1) Allowable stresses used for design calculation shall be less than those listed in the table below. As for a joint made of the material concerned, its efficiency shall be taken into consideration.

(2) Allowable stresses of the materials not specified in the table below shall be decided after taking account the properties of the materials concerned.

Allowable Stress of Material

Material			Tensile stress (kgf/cm²)	Compressive stress (kgf/cm²)	Shearing stress (kgf/cm²)	Bearing stress (kgf/cm²)
Classification	Kinds (thickness: mm)					
Rolled steel for general structure	SS400	thickness 16	1,350	1,350	750	2,250
		16<thickness<40	1,300	1,300	750	2,200
		thickness>40	1,150	1,150	650	1,950
Rolled steels for welded structure or Hot rolled atmospheric corrosion resisting steels for welded structure	SM400 SMA400	thickness 16	1,350	1,350	750	2,250
		16<thickness<40	1,300	1,300	750	2,200
		thickness>40	1,150	1,150	650	1,950
	SM490	thickness 16	1,800	1,800	1,000	3,100
		16<thickness<40	1,750	1,750	1,000	3,000
		thickness>40	1,600	1,600	900	2,750
	SM490Y	thickness 16	2,000	2,000	1,150	3,450
		16<thickness<40	1,950	1,950	1,100	3,350
	SMA490 SMA520	thickness 16	2,400	2,400	1,350	4,100
		16<thickness<40	2,350	2,350	1,350	4,000
		40<thickness<75	2,250	2,250	1,250	3,850
Carbon steel pipes for ordinary piping	SGP	700	700	400	1,150	
Carbon steel pipes for pressure service	STP G 370	1150	1,150	650	1,950	
	STP G 410	1350	1,350	750	2,250	
Carbon steel pipes for arc welded piping	STPY400	1250	1,250	700	2,100	
Carbon steel casting	SC410	650	650	350	1,100	
	SC450	750	750	400	1,250	
	SC480	800	800	450	1,350	
Steel casting for welding structure	SCW410	1000	1,000	560	1,700	
	SCW480	1200	1,200	650	2,000	
Carbon steel forging for general use	SF390A	1050	1,050	600	1,750	
	SF440A	1250	1,250	700	2,100	
	SF490A	1350	1,350	750	2,250	
	SF540A	1500	1,500	850	2,600	
	SF590A	1600	1,600	900	2,750	

Gate Leaf, Guide, Anchorage, and Trash Rack

(1) Allowable Stress

The allowable stress used for a gate leaf, gate guide, anchorage and trash rack shall be as follows:

(a) Intake Gate and Lower Intake Gate (Hydraulic gate not in full-time use)

Structural Steel (unit: kgf/cm²)

Stress	SS400 SM400 SMA400		SM490		SMA490	
	Thickness 40 mm	> 40 mm	Thickness 40	> 40 mm	Thickness 40	> 40 mm
Axial tensile stress (For net sectional area)	1,350		1,800		2,000	
Axial compressive stress (For gross sectional area) l : buckling length of member(cm) r : radius of gyration of area for the gross section of members(cm)	l/r20 : 1,350 20<l/r93 : 1,350 - 8.1(l/r - 20) 93<l/r : 11,600,000 /(6,700+(l/r)²)		l/r15 : 1,800 15<l/r80 : 1,800 - 12(l/r - 15) 80<l/r : 11,600,000 /(5,000+(l/r)²)		l/r14 : 2,000 14<l/r76 : 2,000-14.1(l/r -14) 76<l/r : 11,600,000 /(4,500+(l/r)²)	
Compressive splice plate	1,350		1,800		2,000	
Bending stress girder's tensile side (for net sectional area)	1,350		1,800		2,000	
girder's compressive side (for gross sectional area) Aw : gross sectional area of web plate (cm²) Ac : gross sectional area of compressive flange (cm²) l : distance between fixed points of compressive flange(cm) b : width of compressive flange(cm) K=(1+Aw/(2Ac))	l/b9/K : 1,350 9/K<l/b30 : 1,350 - 12(Kl/b - 9) But, Say Aw/Ac<2 K=2 with	0.92 times the left stress	l/b8/K : 1,800 8/K<l/b30 : 1,800 - 18(Kl/b - 8) But, Say Aw/Ac<2 K=2 with	0.94 times the left stress	l/b7/K : 2,000 7/K<l/b27 : 2,000- 22(Kl/b - 7) But, Say Aw/Ac<2 K=2 with	0.95 times the left stress
When directly fixed to the skin plate etc.	1,350		1,800		2,000	
Shearing force	800		1,050		1,150	

Steel Casting and Steel Forging (unit: kgf/cm²)

Stress	SC450	SF440A
Axial tensile stress	1,350	1,350
Axial compressive stress	1,350	1,350
Bending stress	1,350	1,350
Shearing stress	800	800
Bearing stress	1,900	1,900

Note : Axial compressive stress is not considered to be buckling

(b) Control Gate and Guard Valve (High pressure hydraulic gate in full-time use)

Structural Steel (unit: kgf/cm²)

Stress	SS400 SM400 SMA400		SM490		SMA490	
	Thickness 40 mm	> 40 mm	Thickness 40 mm	> 40 mm	Thickness 40	> 40 mm
Axial tensile stress (For net sectional area)	1,050		1,400		1,550	
Axial compressive stress (For gross sectional area) l : buckling length of member(cm) r : radius of gyration of area for the gross section of members(cm)	l/r20 : 1,050 20<l/93 : 1,050 - 6.3(l/r – 20) 93<l/r : 9,000,000 /(6,700+(l/r)²)		l/r15 : 1,400 15<l/r80 : 1,400 - 9.4(l/r - 15) 80<l/r : 9,000,000 /(5,000+(l/r)²)		l/r14 : 1,550 14<l/r76 : 1,550-10.9(l/r -14) 76<l/r : 9,000,000 /(4,500+(l/r)²)	
Compressive splice plate	1,050		1,400		1,550	
Bending stress girder's tensile side (for net sectional area) girder's compressive side (for gross sectional area) Aw : gross sectional area of web plate (cm²) Ac : gross sectional area of compressive flange (cm²) l : distance between fixed points of compressive flange(cm) b : width of compressive flange(cm) K=(1+Aw/(2Ac))	1,050 l/b9/K : 1,050 9/K<l/b30 : 1,050 - 9(Kl/b - 9) But, Say Aw/Ac<2 K=2 with	0.92 times the left stress	1,400 l/b8/K : 1,400 8/K<l/b30 : 1,400 - 14(Kl/b - 8) But, Say Aw/Ac<2 K=2 with	0.94 times the left stress	1,550 l/b7/K : 1,550 7/K<l/b27 : 1,550- 16(Kl/b - 7) But, Say Aw/Ac<2 K=2 with	0.95 times the left stress
When directly fixed to the skin plate etc.	1,050		1,400		1,550	
Shearing force	600		800		900	

Steel Casting and Steel Forging (unit: kgf/cm²)

Stress	SC450	SF440A
Axial tensile stress	1,050	1,050
Axial compressive stress	1,050	1,050
Bending stress	1,050	1,050
Shearing stress	600	600
Bearing stress	1,500	1,500

Note : Axial compressive stress is not considered to be buckling

(c) Trash Racks (Hydraulic gate in full-time use)

Structural Steel (unit: kgf/cm²)

Stress	SS400 SM400 SMA400		SM490		SMA490	
	Thickness 40 mm	> 40 mm	Thickness 40 mm	> 40 mm	Thickness 40 mm	> 40 mm
Axial tensile stress (For net sectional area)	1,200	0.92 times the left stress	1,600	0.94 times the left stress	1,800	0.95 times the left stress
Axial compressive stress (For gross sectional area) l : buckling length of member(cm) r : radius of gyration of area for the gross section of members(cm)	l/r20 : 1,200 20<l/r93 : 1,200 - 7.5(l/r - 20) 93<l/r : 10,000,000 /(6,700+(l/r)²)		l/r15 : 1,600 15<l/r80 : 1,600-11.2(l/r - 15) 80<l/r : 10,000,000 /(5,000+(l/r)²)		l/r14 : 1,800 14<l/r76 : 1,800-13.3(l/r -14) 76<l/r : 10,000,000 /(4,500+(l/r)²)	
Compressive splice plate	1,200		1,600		1,800	
Bending stress girder's tensile side (for net sectional area) girder's compressive side (for gross sectional area) Aw : gross sectional area of web plate (cm²) Ac : gross sectional area of compressive flange (cm²) l : distance between fixed points of compressive flange(cm) b : width of compressive flange(cm) K=(1+Aw/(2Ac))	1,200 l/b9/K : 1,200 9/K<l/b30 : 1,200 - 11(Kl/b - 9) But, Say Aw/Ac<2 K=2 with		1,600 l/b8/K : 1,600 8/K<l/b30 : 1,600 - 16(Kl/b - 8) But, Say Aw/Ac<2 K=2 with		1,800 l/b7/K : 1,800 7/K<l/b27 : 1,800- 19(Kl/b - 7) But, Say Aw/Ac<2 K=2 with	
When directly fixed to the skin plate etc.	1,200		1,600		1,800	
Shearing force	700		900		1,050	

Steel Casting and Steel Forging (unit: kgf/cm²)

Stress	SC450	SF440A
Axial tensile stress	1,200	1,200
Axial compressive stress	1,200	1,200
Bending stress	1,200	1,200
Shearing stress	700	700
Bearing stress	1,700	1,700

Note : Axial compressive stress is not considered to be buckling

(d) The allowable stresses of materials not specified above shall be determined based on the above provisions.

(e) When other stress in addition to axial stress exists, the combined stress shall be determined from the following formula, and the stress should be within the allowable value.

$$\sigma_g = \sqrt{\left(\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1 \times \sigma_2 + 3\tau^2\right)}$$

Where,

σ_g : combined stress (kgf/cm^2)

σ_1 : axial stress (tension taken as positive) (kgf/cm^2)

σ_2 : axial stress square to σ_1(tension taken as positive) (kgf/cm^2)

τ : shearing stress (kgf/cm^2)

Allowable value for combined stress

- Normal condition : $1.5\ \sigma_a$
- During earthquake : $0.9\ \sigma_y$

Where,

σ_a : allowable stress (kgf/cm^2)

σ_y : yield stress (kgf/cm^2)

(2) Deflection by Gate Leaf and Trash Racks

The deflection of a span used for gate leaf ,trash racks, and hoist flame shall be less than the value shown in the table below.

Type	Deflection of Span	Note
Hydraulic gate (rubber seal)	1/600	Intake Gate Lower Intake Gate
High pressure hydraulic gate (metal seal)	1/2,000	Control Gate Guard Gate
Trash Racks	1/600	
Hoist flame	1/2,000	

(3) Safety Factor of Gate Hoist

The safety factor of a gate hoist calculated from the rated torque of the prime mover shall be more than those listed in the table below, and the stress calculated from the maximum torque shall be less than 90% of the yield point of the material used.

Materials not specified in the table below shall be corresponding to this Table.

Type	Safety factor		
	Tension	Compression	Shearing
Rolled steel for general structures & welded Structures (SS, SM)	5	5	8.7
Carbon steel forging for general used (SF)	5	5	8.7
Carbon steel for machine structural use (S-C)	5	5	8.7
Stainless steel castings (SUS)	5	5	8.7
Gray iron castings (FC)	10	3.5	17
Spheroidal-graphite iron castings (FCD)	7	2.5	12
Bronze castings (BC)	8	8	10
Wire rope	8 (for static operating loads)		
Plate link chains	6.5 (for static operating loads)		

(4) Trash Rack Bars

Generally trash rack bars are installed parallel to the stream lines and are spaced approximately 60mm to 150mm apart. The width of the bar is generally less than 12 times its thickness but approximately a minimum of 50mm. In order to prevent the trash rack bars from buckling horizontally, the supporting space is generally taken as less than 70 times the thickness. The allowable stress when horizontal buckling is considered can be determined from the following formula:

$$\sigma_a = 0.6 \cdot \sigma_y \cdot (1.23 - 0.0153 \cdot L/t)$$

Where,

σ_a : allowance bending stress of the bar (kgf/cm^2)

σ_y : yield stress (kgf/cm^2)

L : horizontal supporting space (cm)

t : thickness of the bar (cm)

The flow velocity passing through the trash rack is generally 0.6 m/s to 1.0 m/s but the mean velocity through the trash rack of a tailrace or an intake at a pumped storage power station sometimes reaches 3 to 4 m/s.

(5) Increase in Allowable Stress during an Earthquake

The allowable stress, when the effects of an earthquake are considered, may be increased by 50 % above the value in the previous Article, but this shall not apply to steel for pre-stressed concrete.

CHAPTER 6 STRUCTURAL DESIGN

6.1 Concrete Structure

6.1.1 Loading Condition to be considered

The safety of the concrete structure should be verified through detailed structural calculations. The combination of loads needed for the structural calculation is given hereunder.

Structure facing Reservoir Water

Case	Condition of Reservoir	Combination of Loads
1	Normal Water Surface	Self weight Earth pressure with earthquake (100 %) Hydrostatic pressure Hydrodynamic pressure (100 %) Inertial force during seismic motion (100 %) Uplift pressure
2	Surcharge Water Surface	Self weight Earth pressure with earthquake (50 %) Hydrostatic pressure Hydrodynamic pressure (50 %) Inertial force during seismic motion (50 %) Uplift pressure
3	Maximum Water Surface	Self weight Earth pressure Hydrostatic pressure Uplift pressure
4	Empty Reservoir	Self weight Inertial force during seismic motion (50 %)

Structure with Gate Leaf

Case	Condition	Combination of Loads
1	Normal Condition	Self weight including equipment Earth pressure Hydrostatic pressure Uplift pressure Operating force
2	Earthquake Condition	Self weight including equipment Earth pressure with earthquake (100 %) Hydrostatic pressure Hydrodynamic pressure (100 %) Inertial force during seismic motion (100 %) Uplift pressure

Common Structure

Case	Condition	Combination of Loads
1	Normal Condition	Self weight Earth pressure Hydrostatic pressure Uplift pressure
2	Earthquake Condition	Self weight Earth pressure with earthquake (100 %) Hydrostatic pressure Hydrodynamic pressure (100 %) Inertial force during seismic motion (100 %) Uplift pressure

6.1.2 Loads

Self Weight

Self weight for analyzing the safety of a structure shall be determined based on unit weights of the materials. Self weight will be calculated by following equation:

$$G = W \cdot V$$

Where,

G	:	self weight (tf)
W	:	weight of concrete per unit volume (tf/m^3)
V	:	volume (m^3)

Earth Pressure

(1) Earth pressure under the Normal Condition

(a) The earth pressure acting on movable walls is calculated by the following Coulomb's formulas:

(i) Sandy Soil

$$p_a = Ka \cdot \gamma \cdot h + Ka \cdot q$$

$$p_P = Kp \cdot \gamma \cdot h + Kp \cdot q$$

(ii) Clayey Soil

$$p_a = Ka \cdot \gamma \cdot h - 2c \cdot \sqrt{Ka} + Ka \cdot q \qquad (p_a \geq 0)$$

$$p_p = Ka \cdot \gamma \cdot h + 2c \cdot \sqrt{Kp} + Kp \cdot q$$

$$Ka = \frac{\cos^2(\phi - \theta)}{\cos^2\theta \cdot \cos(\theta + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}}\right]^2}$$

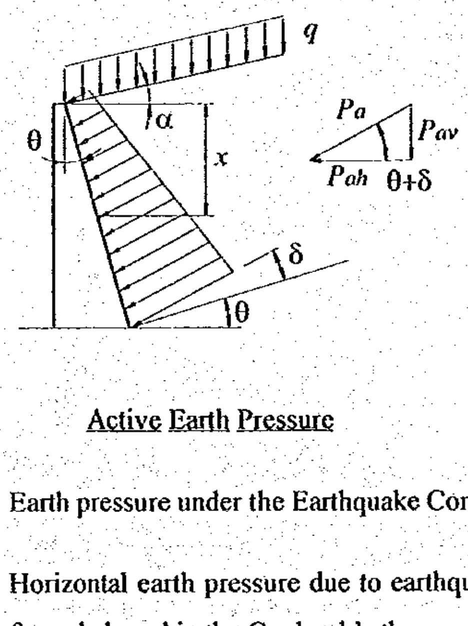
$$K_p = \frac{\cos^2(\phi + \theta)}{\cos^2\theta \cdot \cos(\theta + \delta) \cdot \left[1 - \sqrt{\frac{\sin(\phi - \delta) \cdot \sin(\phi + \alpha)}{\cos(\theta + \delta) \cdot \cos(\theta - \alpha)}}\right]^2}$$

(b) The earth pressure acting on fixed walls is calculated by the following formula:

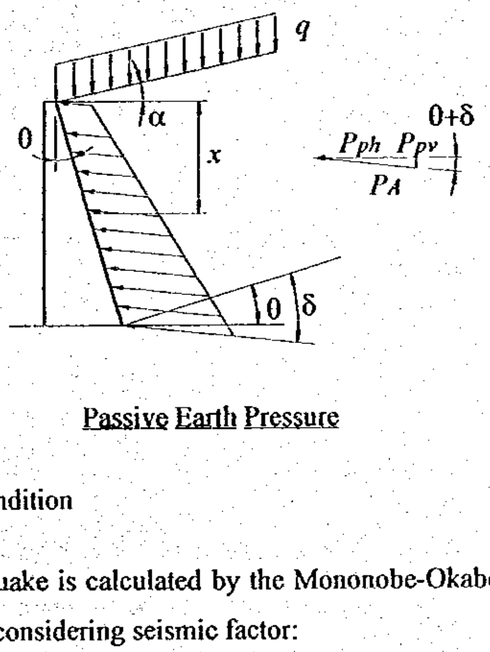
$$p_s = Ks\,(\gamma \cdot h + q)$$

Where,

- p_a : active earth pressure (tf/m²)
- p_p : passive earth pressure (tf/m²)
- p_s : steady earth pressure (tf/m²)
- γ : unit weight of soil (tf/m³)
- Ka : coefficient of active earth pressure
- Kp : coefficient of passive earth pressure
- Ks : coefficient of steady earth pressure (0.5)
- h : earth depth to acting point of earth pressure p_a, p_p and p_s (m)
- c : soil cohesion (tf/m²)
- ϕ : internal friction angle of soil (degree)
- q : surcharge in normal condition (tf/m²)
- θ : angle between wall backside surface and vertical plane (degree)
- α : angle between ground surface and horizontal plane (degree)
- δ : friction angle of soil to concrete (degree) ($\delta = 2/3\ \phi$)



Active Earth Pressure



Passive Earth Pressure

(2) Earth pressure under the Earthquake Condition

Horizontal earth pressure due to earthquake is calculated by the Mononobe-Okabe's formula based in the Coulomb's theory considering seismic factor:

$$p_{ae} = Kea \cdot \gamma \cdot h - 2C \cdot \sqrt{Kea} + Kea \cdot q'$$

$$p_{pe} = Kep \cdot \gamma \cdot h + 2C \cdot \sqrt{Kep} + Kep \cdot q'$$

$$Kea = \frac{\cos^2(\phi - \theta_0 - \theta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta + \theta_0 + \delta) \cdot \left[1 + \sqrt{\dfrac{\sin(\phi+\delta)\cdot\sin(\phi - \alpha - \theta_0)}{\cos(\theta+\theta_0+\delta)\cdot\cos(\theta-\alpha)}}\right]^2}$$

$$Kep = \frac{\cos^2(\phi - \theta_0 + \theta)}{\cos\theta_0 \cdot \cos^2\theta \cdot \cos(\theta - \theta_0 + \delta) \cdot \left[1 + \sqrt{\frac{\sin(\phi - \delta) \cdot \sin(\phi + \alpha - \theta_0)}{\cos(\theta - \theta_0 + \delta) \cdot \cos(\theta - \alpha)}}\right]^2}$$

Where,

Kea : coefficient of active earth pressure

Kep : coefficient of passive earth pressure

q' : surcharge in seismic case (tf/m^2)

θ_0 : angle expressed below (degree)

$$\tan\theta_0 = \frac{Kh}{1 - Kv}$$

Where,

Kv : seismic coefficient in vertical direction

Kh : seismic coefficient in horizontal direction

The others are defined in normal condition.

Hydrostatic Pressure

Hydrostatic pressure acts perpendicularly on the surface of the structure and its value will be determined using the following equation:

$$P = W_o \cdot h$$

Where,

P : hydrostatic pressure (tf/m^2)

W_o : unit weight of water (1.0 tf/m^3)

h : depth of water (m)

Hydrodynamic Force due to Earthquake

Hydrodynamic pressure at any depth of impounded water acting on a concrete structure during an earthquake shall be considered. It acting on wall structure facing impounded water on one side only is calculated based on the following Westergaard formula:

$$pd = 0.875 \cdot K \cdot W \cdot h^2 \sqrt{H \cdot h}$$

Where,

pd : hydrodynamic pressure caused by earthquake (tf/m^2)

K : seismic coefficient

W : unit weight of water (1.0 tf/m^3)

h : water depth from reservoir water surface to the point (m)

H : water depth from reservoir water surface to foundation (m)

In the above formula, the total hydrodynamic pressure Pd, and the height of the acting point above the foundation Hd are expressed as follows:

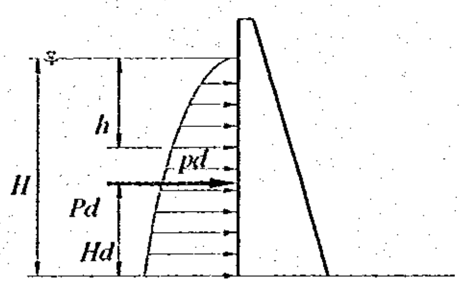
$$Pd = \frac{7}{12} K \cdot W \cdot H^2$$

$$Hd = 0.4\ H$$

Where,

Pd : total hydrodynamic pressure (tf)

Hd : hydrodynamic force acting depth from the bottom (m)



Inertial Force during Seismic Motion

For inertial force during seismic motion, the value of self weight of the structure multiplied by seismic coefficient is applied and treated to act horizontally. The force can be calculated as follows:

$$I = G \cdot k$$

Where,

I : inertial force during seismic motion (tf)

G : self weight of structure (tf)

k : seismic coefficient

Uplift Pressure

Uplift pressure should be considered for the design of structure, which are fully or partially submerged. It acting on the bottom of a structure is assumed to act as a load normal to the plane of contact of the dam and foundation. The distribution of the uplift pressure for the case ,where an appropriate foundation treatment has been made, takes values as shown in the table below at the position of the upstream toe, at the drainage hole and at the downstream toe:

Drainage Hole	Uplift Pressure		
	Upstream Toe	At Position of Drainage	Downstream Toe
Drainage hole is present	Upstream side pressure	Value of downstream side pressure added by value greater than 1/5 of difference of pressure between upstream and downstream side	Downstream side pressure
Drainage hole is absent	Value of downstream side pressure added by value greater than 1/3 of difference of pressure between upstream and downstream side		Downstream side pressure

Operating Force

The operating load shall be calculated in combination with the weight of the gate leaf and weight of ballast, friction force of wheel rotation, rubber seal friction force, buoyancy of gate leaf, bearing plate friction force and so on. The details are described in Clause 6.2 Steel Structure.

6.1.3 Structural Stability

The concrete structures with rock foundation should be safe against shear and overturning. It is a usual practice to determine the cross sectional area for a two-dimensional design process based on the assumption that the structure consists of a number of cantilevered beams which are independent of each other. The required conditions of the structural safety are described hereinafter.

(1) Conditions for Safety against Shear

Regarding shear safety, an evaluation should be made using Henny's formula for the contact plane of the rock foundation.

$$SF = \frac{\tau_0 \cdot l + f \cdot V}{H}$$

Where,

SF : safety factor

H : total shearing force acting in the shear plane per unit width (tf/m)

V : total normal force acting on the shear plane per unit width (tf/m)

τ_0 : shear strength of rock foundation (tf/m^2)

l : length of shear plane (m)

f : coefficient of internal friction of rock foundation

(2) Overturning

When the location of the resulting force of a load is within the central one-third point, tensile stress in the vertical direction is not produced at the upstream face of the structure.

The following formula is used for the stability evaluation.

$$e = \left| \frac{b}{2} - \frac{M}{V} \right|$$

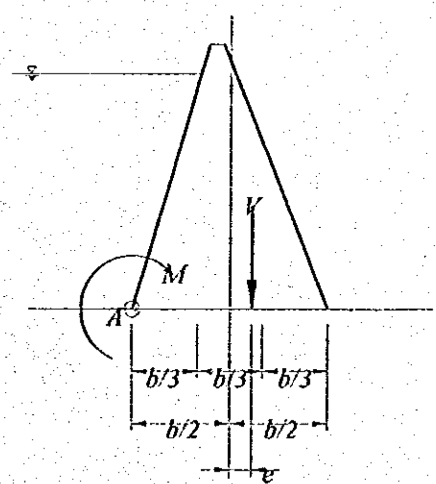
Where,

b : width of base (m)

M : total moment at point A per unit width (tf-m/m)

V : total normal force acting on the shear plane per unit width (tf/m)

e : eccentricity (m)



(3) Bearing Capacity of Foundation

The maximum principal stress in the foundation must be kept within allowable rock bearing capacity, which derived from the following:

$$q_1 = \frac{V}{b} \cdot \left(1 + \frac{6e}{b}\right)$$

$$q_2 = \frac{V}{b} \cdot \left(1 - \frac{6e}{b}\right)$$

Where,

q_1 : maximum principal stress ($tf/m^2/m$)

q_2 : minimum principal stress ($tf/m^2/m$)

V : total normal force acting on the shear plane per unit width (tf/m)

b : width of base (m)

e : eccentricity (m)

(4) Required Conditions

The following conditions shall be satisfied in stability calculations:

Structure facing Reservoir Water

Case	Condition of Reservoir	Earthquake	Structural Stability	
			Against Shear	Against Overturning
1	Normal Water Surface	100 %	$SF \geq 4$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$
2	Surcharge Water Surface	50 %	$SF \geq 4$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$
3	Maximum Water Surface	0 %	$SF \geq 4$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$
4	Empty Reservoir	50 %	$SF \geq 4$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$

Structure with Gate Leaf

Case	Condition	Earthquake	Structural Stability	
			Against Shear	Against Overturning
1	Normal Condition	0 %	$SF \geq 1.5$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$
2	Earthquake Condition	100 %	$SF \geq 1.2$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{3}$

Common Structure

Case	Condition	Earthquake	Structural Stability	
			Against Shear	Against Overturning
1	Normal Condition	0 %	$SF \geq 1.5$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{6}$
2	Earthquake Condition	100 %	$SF \geq 1.2$	$e = \frac{b}{2} - \frac{M}{V} < \frac{b}{3}$

6.1.4 Details in Design

Reinforcement

(1) Minimum Concrete Cover

Protective cover for steel reinforcement shall not be less than the following:

- Common concrete footing and slab : 100 mm
- Concrete structure (Wall thickness less than 30 cm) : 50 mm

(2) Bar Spacing

The minimum space of the reinforcing steel bars shall satisfy the following requirements.

- Four (4) cm of net spacing or wider
- Four-thirds (4/3) of the maximum size of the coarse aggregate or wider, and

The maximum space of the bar arrangement for slab shall be,

- Two times of the slab thickness but 30 cm intervals in space or narrower for the section where the maximum bending moment occurs, and
- Three times of the slab thickness but 40 cm intervals or narrower in space for the other section.

(3) Lap Splice and Embedding Length

For tensile bar, the length of lap splice and embedding shall be the length obtained from the following formula or thirty times of the bar diameter or longer.

with hook : $L = \dfrac{\phi \cdot \sigma_{sa}}{6 \cdot \tau_{oa}} \geq 30\phi$

without hook : $L = \dfrac{\phi \cdot \sigma_{sa}}{4 \cdot \tau_{oa}} \geq 30\phi$

Where,

L : length of lap joint (cm)

ϕ : diameter of reinforcing bar (cm)

σ_{sa} : allowable tensile stress of bar (kgf/cm^2)

τ_{oa} : allowable bond stress of concrete (kgf/cm^2)

When deformed bars are use, the joints may be without hook. For compressive bar, the length of the lap splice and embedding shall be eighty percents (80%) of the length obtained from above formula or twenty (20) times of the bar diameter or longer.

(4) Hook and Bend of Reinforcement

The hooks of reinforcements shall be specified as below.

(a) The hook of round bar shall be 180 degree bend.

(b) The hook of deformed bar shall be 180 degree bend, 90 degree bend or 135 degree bend.

(c) The hook of reinforcement shall be extended from the end of bend beyond the following length.

(i)	180 degree bend	Four (4) times the diameter of the reinforcement or 6 cm, whichever is greater.
(ii)	90 degree bend	Twelve (12) times the diameter of the reinforcement.
(iii)	135 degree bend	Six (6) times the diameter of reinforcement or 6 cm, whichever is greater.

(5) Anchorage of Reinforcements

The ends of reinforcement shall be anchored sufficiently in concrete by any method specified below. However, round bar use as tension reinforcement shall be anchored by hook.

(a) The reinforcements are buried in concrete and anchored by bond between the reinforcements and concrete.

(b) The reinforcements are buried in concrete and are anchored by means of hook.

(c) The reinforcement are anchored mechanically by means of anchor plate.

(6) Minimum reinforcement requirement for crack control and temperature and shrinkage

For crack control small bars at close spacing are provided. In general the maximum bar spacing shall be not greater than 300 mm. The following bar spacing will be adopted.

(a) When the steel bars of D10 or ϕ 9 are used, spacing distance = 12.5 cm.

(b) When the steel bars of D13 or ϕ 13 are used, spacing distance = 25.0 cm.

Joints

(1) Construction Joint

Construction joints shall provided where necessary for the practical placement of concrete. Reinforcement shall be continuously through the construction joints. As a rule, the location and the structural details of these joints need not be shown in the design drawing but be shown in the construction drawings. The location of these joints is to be determined from the type and the scale of structures or the construction conditions.

(2) Expansion Joint

Expansion joints are used to prevent cracks caused by the expansion of the concrete. In generally, they are used for the structure, which is exposed to the ground surface at the portion where the shape of structures varies. The void of the joint is usually filled with a rubber or elastic filler.

(3) Contraction Joint

Contraction Joints are used to prevent the development of cracks caused by contraction of concrete. The location and structural details of these joints shall be shown in the design drawing. The location of these joints shall be determined from the type of structure, conditions of foundation and construction. Usually, the intervals of these joints for the road and river structures are as follows:

- Compressibility foundation (earth)	:	10.0 ~ 15.0 m
		10.0 m or less
- Non-Compressibility foundation (rock)	:	15.0 ~ 20.0 m
		15.0 m or less

6.2 Steel Structure

6.2.1 General

This chapter set out design criteria for steel civil structure. Detail design of structure should be delivered to manufacture as maker and should be approved by an expert.

6.2.2 Penstock

Load to be considered

An embedded pipes shall be so designed as to be safe against internal pressure , temperature charge , external pressure.

Combination of Loads

The loads in the previous Article shall be taken into consideration with the following combination. For embedded pipes,

(1)	With water fully filled in the pipe :	internal pressure, temperature charge
(2)	When the pipe is empty :	external pressure

Design Condition for Pressure Lining Part

The pressure lining part shall be designed against the loads in accordance with the following conditions:

With water fully filled in the pipe

(1) Circumferential stress, longitudinal stress, perpendicular stress to a pipe axis and resultant stress shall be less than allowable stresses of the materials used. In case that a local bending stress (secondary stress) of a pipe shell is added, it shall be permissible to increase the allowable stress up to 1.35 times.

(2) The resultant stress shall be calculated from the following formula:

$$\sigma_g = \sqrt{\left(\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2 + 3\tau^2\right)}$$

Where

σg : resultant stress (kgf/m^2)

σ_1 : circumferential stress (tension to be positive) (kgf/m^2)

σ_2 : longitudinal stress (tension to be positive) (kgf/m^2)

τ : perpendicular shearing stress to pipe axis (kgf/m^2)

<u>During water filling in the pipe</u>

The circumferential stress shall not exceed 1.5 times the allowable stress of the material used.

<u>When the pipe is empty</u>

Buckling shall not take place by external pressure equivalent to 1.5 times the design external pressure.

<u>**Stress to be Considered**</u>

As for the design, the following stress for embedded pipes shall be calculated respectively:

(1) With water fully filled in the pipe

(a) Circumferential stress

- Tensile stress due to internal pressure.

(b) Longitudinal stress

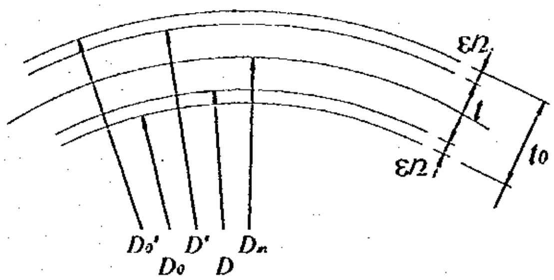
- Local bending stress due to the restraint of the pipe shell displacement by means of a stiffener, etc.
- Temperature stress.
- Stress due to Poisson's effect.

(2) When the pipe is empty

- Stress due to external pressure and critical buckling pressure

For calculation the stresses listed in this Article , formulae commonly used are shown below.

Nomenclatures in the formula are shown in each paragraph, but plate thickness, corrosion allowance, diameter and radius and longitudinal length are defined as illustrated below.



Dimension used for calculation should all be the nominal dimensions when manufactured.

Where,

Do	:	internal diameter (cm)
Do'	:	external diameter (cm)
D	:	internal diameter subtracting 1/2 the corrosion allowance from the internal surface of the pipe shell = Do + (cm)
D'	:	external diameter subtracting 1/2 the corrosion allowance from the external surface of the pipe shell = Do'- (cm)
Dm	:	diameter to the center of plate thickness=$2r_m$ (cm)
r_m	:	radius to the center of plate thickness (cm)
to	:	shell thickness (cm)
t	:	shell thickness excluding corrosion allowance = to- (cm)
ε	:	allowance thickness for corrosion and wear (cm)
La	:	pipe length from anchor block to expansion joint (cm)
L	:	length of pier span (cm)
l	:	interval of stiffeners (cm)

Corrosion Allowance

For thickness of plates used for a pressure lining part, an allowance of more than 1.5mm shall be provided against corrosion and wear. The corrosion allowance may be reduced provided an appropriate measure be taken against corrosion and wear in particular.

Minimum Shell Thickness

Minimum shell thickness used for the pressure lining part shall be more than those determined from the following formula if stiffeners are not used. The minimum shell thickness shall not be less than 6mm even if the pipe diameter is small and stiffeners are used.

$$t = (D+800)/400$$

Where,

t : shell thickness including corrosion allowance (mm)

D : internal diameter of pipe (mm)

6.2.3 Hydraulic Gate, High Pressure Valve and Trash Rack

Loads to be considered

In designing a hydraulic gate, consideration shall be given to the following loads and effects: weight of the gate, hydrostatic pressure, buoyancy, gate opening force, dynamic pressure during earthquake, inertial force during earthquake, wind load, effects of temperature charges.

(1) Hydrostatic pressure

$$P = Wo \cdot ho$$

Where,

P : hydrostatic pressure at a given point on the contact face (tf/m^3)

Wo : weight of water per unit volume (1.0 tf/m^3)

ho : head from water level just upstream of a gate plus the wave height to any point on the contact face (m)

(2) Wave height by wind

$$hw = 0.00086 \cdot V^{1.1} \cdot F^{0.45}$$

Where,

hw : total wavo height (one third maximum wave) (m)

V : wind velocity (average of 10minutes) (m/s)

F : distance to opposite bank (m)

(3) Wave height by earthquake

$$he = \frac{k \cdot \tau}{2\pi} \cdot \sqrt{g \cdot H}$$

Where,

he : one half wave height (m)

k : seismic intensity of design

τ : seismic period (s)

g : acceleration of gravity (9.8 m/s^2)

H : water depth from reservoir water level to foundation ground (m)

(4) Dynamic pressure during earthquake

$Pd = C \cdot Wo \cdot k \cdot H$

$C = Cm/2 \cdot [h/H \cdot (2 - h/H) + \sqrt{h/H \cdot (2 - h/H)}\,]$

Where,

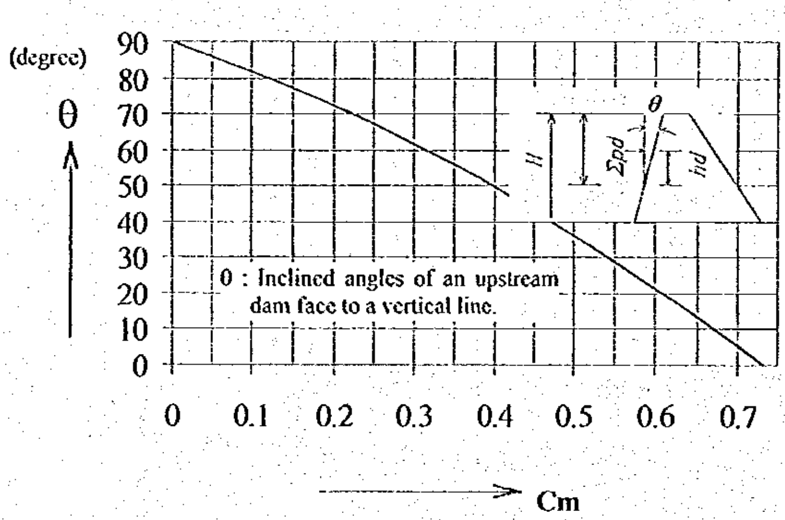
- Pd : dynamic pressure (tf/m^2)
- Wo : unit weight of water (tf/m^3)
- k : seismic intensity of design
- H : water depth from reservoir water level to foundation ground (m) (wave height by wind and earthquake not included)
- h : water depth from reservoir water level to a given point (m)
- Cm : value of C when ΣPd becomes maximum

$\Sigma Pd = \alpha \cdot Cm/2 \cdot wo \cdot k \cdot H^2 \cdot \sec\theta$

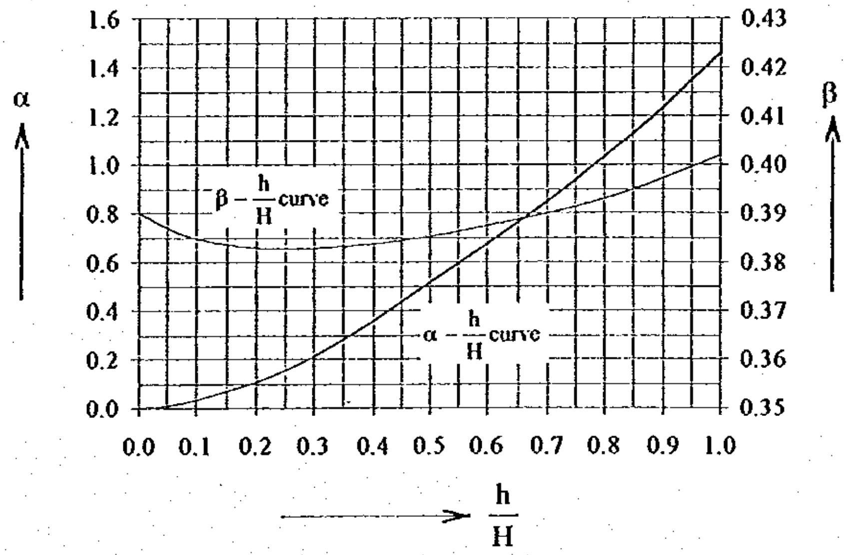
$hd = \beta \cdot h$

Where,

- ΣPd : total dynamic pressure (tf)
- hd : height from the foundation ground to the working point of the total dynamic pressure (m)
- α,β : they can be obtained from the following graphs.



θ – Cm Curve



α–h/H Curve and β–h/H Curve

(5) Inertia force during earthquake

An inertia force during earthquake acting on the gate leaf should be the value obtained by multiplying the weight of the gate leaf by the seismic intensity. This force acts horizontally.

The seismic intensity for design of a hydraulic gate installed on top of a dam should be a seismic intensity of the dam different from the above value.

The seismic intensity for design upward and downward is not normally considered, but if this directional earthquake force is considered to greatly influence the stability of a hydraulic gate it should be included in the study.

(6) Wind load

A wind load is assumed to act on a clear projected area, and can be obtained by multiplying the following value by shape factors.

For a vertical projected area 300(kgf/cm^2)

Where shape factor is:

- flat shape 1.2
- trussed shape the windward 1.6
- trussed shape the leeward 1.2
- cylindrical shape (single) 0.7

(7) Effect by temperature change

"Effect by temperature change" means shrinkage and expansion of the gate leaf due to the temperature change in conjunction with the condition when the gate was installed. When the gate leaf is restrained, the leaf, roller bearing, guide and concrete are adversary affected, and thus consideration should be given to the temperature change by providing a clearance for the gate guides and guide rollers.

Combination of Loads

The load in the previous Article shall be considered in combination with the following:

(1) Normally: own weight, hydrostatic pressure, buoyancy, wind load, effect by temperature change, and gate operating force.

(2) During earthquake: own weight, hydraulic pressure, buoyancy, dynamic pressure during earthquake, and inertia force during earthquake.

Operating Load

The operating load shall be calculated in combination with the following items so as to be prepared for all imaginable operating conditions.

The operating load should be calculation in appropriate combination with the above items. It is desirable for the allowance of the closing force to be more than 25% of the total resistance force. When there is a lack of closing force, it is recommended that ballast be added to the gate leaf.

(1) Weight of the gate leaf and weight of ballast

(2) Friction force of wheel rotation

Fixed wheel gate:

$$Fw = (\mu_1 - \mu_2 \cdot d/2)/(D/2) \cdot P$$

Where,

Fw : frictional force of the wheel rotation (tf)
P : total hydraulic pressure during gate operation (tf)
μ_1 : coefficient of rolling friction of the wheel (0.1cm)

μ_2 : coefficient of sliding friction of pin

d : diameter of the wheel pin (cm)

D : wheel diameter (cm)

(3) Rubber seal friction force

$$Fr = \mu_r \cdot (q + P \cdot b)\ \Sigma l$$

Where,

Fr : frictional force of the rubber seal (tf)

μ_r : coefficient of sliding friction between metal and rubber

q : initial pressure force of rubber (tf/m)

P : mean hydraulic pressure working on the rubber (tf/m^2)

b : clear width of rubber subject to pressure (m)

Σl : total sliding length of the rubber (m)

(4) Buoyancy

$$Fb = Wo \cdot V$$

Where,

Fb : buoyancy (tf)

Wo : water unit volume weight (tf/m^3)

V : water volume displaced by the gate leaf (m^3)

(5) Bearing plate friction force (for slide gate)

$$Fs = \mu_s \cdot P$$

Where,

Fs : frictional force of the bearing plate (tf)

μ_s : coefficient of sliding friction between metal and metal

P : total hydraulic pressure during gate operation (tf)

<u>**Corrosion Allowance**</u>

As for a member of a hydraulic gate either to be submerged or to be worm, more than the valves shall be added to the calculated plate thickness.

(Unit: mm)

Kind of Water	Always used water			Not always used water		
	Skin plate		Other main members	Skin plate		Other main members
	One face	Both face	Both face	One face	Both face	Both face
Fresh water	1.0	2.0	2.0	0.5	1.0	1.0
Sea water	1.5	3.0	2.0	1.0	2.0	1.0

If there is a fear of abrasion, this value should be added to the corrosion allowance.

Rigidity, Minimum Plate Thickness and Slenderness Ratio of Gate Leaf

(1) Each part of the gate leaf shall be placed in the position required and shall be provided with enough rigidity.

(2) The minimum steel thickness of primary members used for a gate leaf shall be more than 6mm for steel plates and more than 5mm for steel shapes and shall include a corrosion allowance.

(3) The slenderness ratio shall be less than the valve shown below:

Members		Slenderness Ratio
Compressive member	Main member	120
	Secondary member	150
Tensile member	Main member	200
	Secondary member	240

Coefficient of Friction

Sliding part and rotation part of gate leaf

Item	Coefficient of Friction
1. Rolling friction of the wheel	0.1
2. Sliding friction of the pin	
(1) Plain bearing	0.2
(2) roller bearing	0.1 - 0.02
3. Sliding friction between robber and stainless plate	
(1) Wetting	0.5 - 0.7
(2) Drying	0.9 - 1.2
4. Sliding friction between metal and meal	0.3 - 0.6

Mechanical Efficiency of Each Part of the Gate Hoist

The mechanical efficiency of each part of the gate hoist shall be in accordance with those values listed in the table below:

Driving part	Mechanical Efficiency
Per sheave (plain bearing)	0.95
Per sheave (roller bearing)	0.98
Drum	0.95
Spur gear and bevel gear	0.98
Per set open (bearing inclusive)	0.95
Per set oil bath (bearing inclusive)	0.97

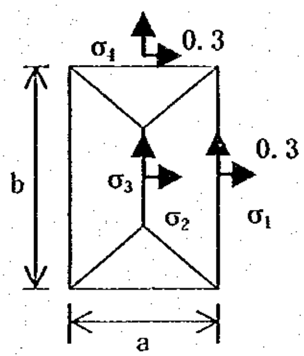
Skin Plate

The bending stress generated in a flat plate by hydraulic pressure shall be calculated from the following formula:

$$\sigma = 1/100 \cdot k \cdot a^2 \cdot p/(t - \varepsilon)^2$$

Where,

- σ : stress (kgf/cm^2)
- k : factor in table below
- a : short side of a rectangle (cm)
- b : long side of a rectangle (cm)
- p : hydraulic pressure (kgf/cm^2)
- t : plate thickness (cm)
- ε : corrosion allowances (cm)



Stress of Skin Plate

k value

b/a	σ_1	σ_2	σ_3	σ_4
1.00	9	13.7	13.7	30.9
1.25	40.3	18.8	13.5	33.9
1.50	45.5	22.1	12.2	34.3
1.75	48.4	23.9	10.8	34.3
2.00	49.9	24.7	9.5	34.3
2.50	50.0	25.0	8.0	34.3
3.00	50.0	25.0	7.5	34.3
~	50.0	25.0	7.5	34.3

The short side (a) and the long side (b) of a block usually mean the distance between weld lines in case of welded structure.

If a skin plate is welded to a girder as a mono-structure, it is permissible to have the plate work together with its effective width.

6.2.4 Details in Design

(1) Seal (Water pump)

The material use for water stop should be with durable material. This seal/water stop will be attached to gate frame by the strong steel plate, so as the water pressure on the seal/water stop is acting. At the corner of the gate the vertical and horizontal seal should be vulcanized to obtained a good joint.

(2) Anchorage

The steel structure that is set up on the concrete should be anchorage sufficiently in concrete. The anchors will be made from steel are buried in concrete and are anchored by means of hook or anchor plate.

(3) The gate frame and stop-log

The steel frame for gate and stop-log with arm of frame for gate should be designed so rigid in order to fulfil a condition of making,, transporting and erecting.

6.3 Tunnel

6.3.1 Rock Classification and Steel Support

The shape of the cross section of the diversion tunnel will be designed as standard horseshoe with 2 r. The structural lining of diversion tunnel consisting of permanent supports and concrete lining, either acting separately or in combination.

Steel supports are made of steel ribs, steel lagging, steel lines plate, shotcrete, reinforcement sheet, rock bolts, or without chain link fabric or a combination of these. The choice of one or a combination of these materials should depend upon geologic condition, groundwater levels, and economic factors.

The guidelines for excavation and support of rock tunnels in accordance with the rock mass classification standard issued by Japan Society of Civil Engineers and estimated of rock load will be used to determine a materials and loading condition for steel supports. The tables, which explain the standardized selection of support categories, working efficiency of shotcrete and working efficiency of rock bolt, are given as follows:

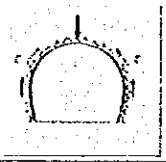
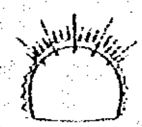
Rock Mass Classification Standard (JSCE)

Rock Class	Rock Type	(1) Elastic Wave Velocity (vp km/s) < 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	> 5.0	(2) Com-petence Factor	(3) Boring Core: Condition of Core	(3) Boring Core: RQD (%)	(4) Geological Condition (Result of investigation)	(5) Observation: Appearance of rock broken by hammer	(5) Observation: Fissure int. (cm)	(6) State of after excavation: Nature of self-support at face	(6) State of after excavation: Inner disp. (mm)
C I	a				—			——	The rate of core sampling is 40 – 70% and has lot of fissures. It is easily broken into small pieces and sampled as many small fragments of under 5 cm. It is from nearly impossible to impossible to return to the original form.	70 ~ 20	Due to weathering, rock has changed in quality and became slightly soft. Even rock is fairly hard and solid, there are some cracks and they contain thin layer of clay. The rock has clear stratifications and easily split into very thin layers. The rock has narrow fault. There is little deterioration caused by	Easily broken by hammering. It breaks into considerably small pieces along cracks, however it is rather difficult to break at other than cracks.	Less than approx. 50	Cutting face stands by itself. Shotcrete lining be required at the crown right after blasting operations. Loosening height be 2.0 – 4.0 m.	Less than 50
C I	b				—										
C I	c				—										
C I	d1			—				more than 4							
C I	d2		—	—	- -										
C II	a				—			——						Cutting face stands by itself. No support face may fall of rocks at crown and needs of rock support in advance. Loosening height be 2.0 – 4.0 m.	
C II	b				—										
C II	c				—										
C II	d1			—				more than 4							
C II	d2		—	—	- -										
D I	a			— (partial)	— (partial)			4 ~ 2	The ratio of core sampling decreases; it generally get under 40%. Core becomes like splinters and sometimes it appears as sand or clay with fragment having angles.	Less than 20 in general	Caused by sever weathering, there are some parts already changed into soil. Some hard parts remains but generally soft and breakable. There are joints in the rock to a very high degree and can be scaled easily at any part even other than fissured.	Easily broken into pieces by hammering. The rock is breakable and easily disintegrated by fingertips.	----	Rock well falls from cutting face and no support surface. Sometimes side wall squeezes slightly. Face support in advance and timely conventional support are required. Plastic or loosed height	Less than 60
D I	b			— (partial)	— (partial)										
D I	c			— (partial)											
D I	d1		— (partial)	—											
D I	d2		— (partial)	—											
D I	c							> 2							
D II	a		- - (partial)	— (partial)				2 ~ 1			It is a fault but not became to clay yet. It is a mixture of clay like material and small pieces of rock fragment. There contains some fairly hard parts. Earth and soil, talus, etc. If face become soft by water, it is DH	It disintegrates with slight hammerings. Hammer point penetrates into the rock.	----	Rock falls from cutting face considerably. No support side wall squeezes. Plasticized range or loosened height will be 3.0 – 6.0 m.	Less than 200
D II	b		- - (partial)	— (partial)											
D II	c		- - (partial)	— (partial)											
D II	d1	- - (partial)	— (partial)												
D II	d2	- - (partial)	— (partial)												
D II	c														

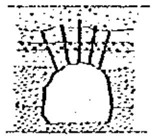
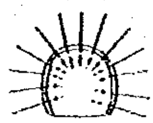
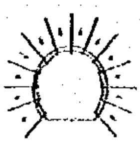
Standardized Selection of Support Categories

Classification of rock mass	Characteristics	Object of Support	Support Categories: Shotcrete	Rock-bolt	Steel supp.	Lining: Secondary	Lining: Invert	Auxiliary method	Description
Hard rock	Less cracks	Falling rock lumps.	Δ	Δ					No stress affect on secondary lining.
	Many cracks but no clay in them	Falling rock lumps. Loosening pressure.	Δ	O	Δ				Steel support may set upper half only.
	Many cracks and crushed	Falling rock lumps. Loosening pressure. True earthpressure.	O	O	O		Δ	Face stabilization measures (cutting face, crown stabilization)	For maintaining roadbed during services, it is recommended to place invert.
Soft rock	Larger competence factor	Falling rock lumps.	Δ	Δ			O		For maintaining roadbed during services, mudstone and the like needs invert in principle.
	Smaller competence factor	Loosening pressure. True earthpressure.	O	O	O		O		Early construction of invert.
	Extremely smaller competence factor	Loosening pressure. True earthpressure.	O	O	O	Δ	O	Face stabilization measures (cutting face stabilization)	Early closure of lining, high efficient shotcrete, confirmation of converging movement, allow some margin for movement.

Working Efficiency of Shotcrete

	Working Efficiency of Shotcrete	Concept Sketch
1	Effect of support by bonding power with rock mass, shear resistance Using bonding power of shotcrete and rock mass, let the ground to form arch near inner surface of tunnel wall.	
2	Effect of internal pressure, effect of closing ring Supporting rock mass by relatively thick shotcrete which act as one solid member of consequence, working efficiency of support will demonstrate further. This is very effective at soft rock and soil ground.	
3	Distribution effect of external force Act as conveying earth pressure toward steel support or rockbolt.	
4	Reinforcing effect of weak zone Achieve effect by filling dents of rock mass, and bonding across weak zones, avoid concentration of forces and reinforcing weak zone	
5	Covering effect Because of tunnel surface be covered soon after excavation, it will prevent inner wall from weathering, control groundwater inflow, and prevent wash out of fine particles from rock mass.	

Working Efficiency of Rock Bolt

Working Efficiency of Rock Bolt	Concept Sketch
1 Fastening effect (Suspending effect) Falling rocks which is loosened by blasting operation, etc. are fastened into sound rock mass so that they would not fall and this is the most principal effect.	
2 Building up beam effect Rock mass made of bedding strata around the tunnel has tendency of working as a built-up beam. However where those joints are fastened by rockbolts, it enables to deliver shear stress at joints, and it will produce such effect of working as a composite beam.	
3 Internal pressure effect Rockbolts produce internal pressure toward the tunnel wall as strong as tensile force applied to them.	
4 Building up arch effect rock mass around the tunnel builds up arch in the rock mass by rockbolting	
5 Improvement of rock mass effect increases residual strength even the rock mass has already yielded.	

6.3.2 Loading Condition to be considered

The loading system is as follows:

(1) External loads

The external load consists of the rock surrounding the excavated tunnel, groundwater pressure and grouting pressure.

The external loads will be resisted by permanent steel supports such as shotcrete, steel ribs and rock bolts.

(2) Internal loads

The concrete lining where in adequate cover unstable supporting rock prevails should withstand the high internal hydrostatic load.

6.3.3 Structural Stability

Stability of shotcrete, steel ribs and concrete lining are checked for cross sectional and loading conditions as follows:

(1) Shotcrete

$$\overline{Q} = \frac{Q_{max}}{SF}$$

Where,

$\overline{Q}$: Allowable bearing capacity (t/m^2)
Q_{max}: Maximum bearing capacity (t/m^2)

Q_{max} calculated by the following formula:

$$Q_{max} = 4 \cdot t \cdot L \cdot \overline{\tau}$$

Where,

t : thickness of shotcrete (m)
L : the width of shotcrete element (= 1 m)
$\overline{\tau}$: allowable shearing strength of shotcrete (t/m^2)
SF : safety factor (= 2)

(2) Steel Ribs

$$\sigma_e = \frac{P}{F} + \frac{M}{W} < \overline{\sigma}_e$$

Where,

σ_e : The existing tension on the steel rib (kg/cm^2)
P : The existing normal force
F : The cross sectional area of steel rib
M : The existing bending moment
W : The withstand moment of the steel rib
$\overline{\sigma}_e$: Allowable tensile strength

(3) Concrete lining

Stability of concrete lining is checked for cross sectional direction and loading conditions as follows:

- Pressure condition with uniform internal radial load.
- Non pressure condition with triangular internal radial load

Analysis of these shapes for different loading will be carried out by using the Beggs deformeter coefficient, USBR (1968), US Army Corps Engineer (1978) and ASCE (1989).

6.4 Earth Work

(1) Slope of embankment (excluding dam)

The gradient of fill slopes are determined based on the filling materials and height of fills as shown in the following table

Filling Material	Slope	Berms	
		Width (m)	Interval ΔH (m)
Excavated rock	1 : 1.5	1.5	5.0
Earth (Common Material)	1 : 1.5	1.5	5.0
Earth (spoil bank)	1 : 3.0 to 5.0	1.5	5.0

Where, 1 : N means 1 vertical to N horizontal

(2) Excavation

Open cut excavation is basically made with the cut slopes mentioned below.

Material	Permanent Cut		Temporary cut	Berms	
	Coated	Exposed		Width (m)	Interval ΔH (m)
Hard rock	1 : 0.3	1 : 0.5	1 : 0.15 to 0.3	1.5	7.5
Weathered rock	1 : 0.5	1 : 0.8	1 : 0.5	1.5	7.5
Common Material	1 : 0.8	1 : 1.0 to 1.5	1 : 0.5 up to 5 m	1.5	7.5
			1 : 0.8 over 5 m	1.5	7.5

Where, 1 : N means 1 vertical to N horizontal

6.5 Road

The design of the access road is made according to the standard specification for geometric design of rural highway No. 13/1970, Directorate Generals of Bina Marga.

6.5.1 Geometric Design

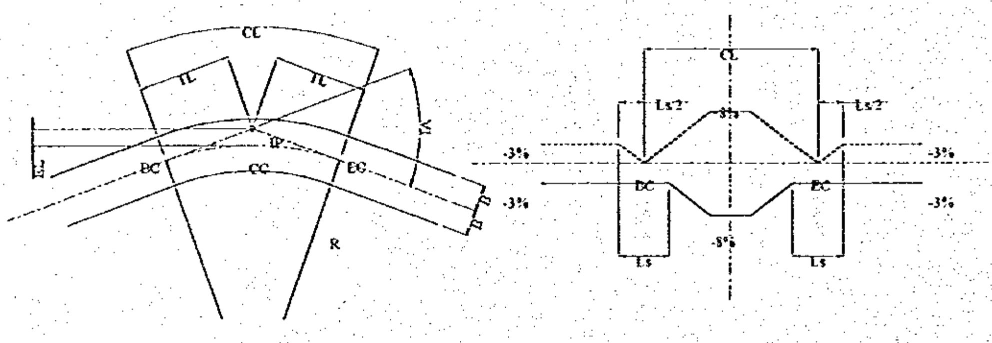
(1) Basic Design Criteria

Description	Characteristic of Access Road	
Average traffic intensity per day (LHR)	500<LHR<1,500	< 500
Design speed	30 km/h	20 km/h
Road width		
- Pavement	4.0 m	4.0 m
- Shoulder	0.5 m	0.5 m
Maximum longitudinal gradient	11.0 %	12.0 %
Sight distance	30.0 m	20.0 m
Desirable radius of curvature	65.0 m	30.0 m
Minimum radius of curvature	30.0 m	15.0 m
Minimum length of curvature	350/(inter angle) or 40.0m	280/(inter angle) or 40.0m
Superelevation		
- Pavement		
· Normal	3.0 %	3.0 %
· Maximum	8.0 %	8.0 %
- Shoulder	6.0 %	6.0 %
- Run-off ratio	Less than 1/75	Less than 1/50
Type of loading should be in accordance with Guide Line for Highway and Bridge Design Loads, SNI-1725-1989		

The following design speeds are applied:

Access Road	Design Speed (km/h)
Left Side Access Road	30.0
Right Side Access Road	30.0
Access Road to Hydropower Station	20.0
Access Road to Intake Structure	20.0

(2) Horizontal Alignment



Where,

IP : intersection point

IA : intersection angle (degree)

R : radius of curvature (m)

CL : length of curve (m)

BC : beginning of curve

CC : center of curve

EC : end of curve

TL : distance between IP and BC, and IP and EC (m)

EL : distance between IP and curve (m)

Ls : superelevation run-off length = $(B \cdot \Delta I)/q$

B : half of road width (m)

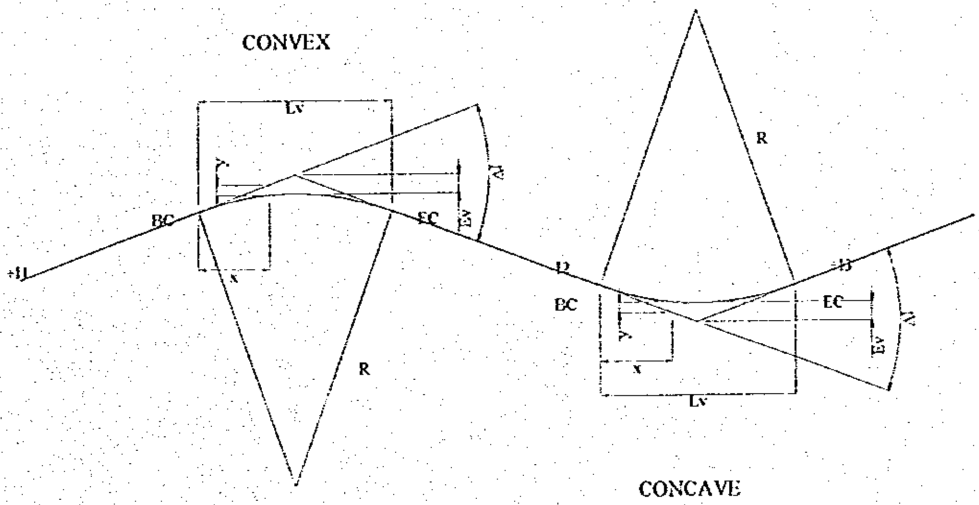
ΔI : difference between superelevation (%)

q : superelevation run-off ratio (%)

Superelevation for each Radius of Curvature

Design Speed 30 km/h		Design Speed 20 km/h	
Radius of Curvature (m)	Maximum Superelevation (%)	Radius of Curvature (m)	Maximum Superelevation (%)
220 – 500	3.0	100 – 200	3.0
150 – 220	3.0	70 – 100	3.0
110 – 150	4.0	50 – 70	4.0
80 – 110	5.0	40 – 50	5.0
60 – 80	6.0	30 – 40	6.0
40 – 60	7.0	20 – 30	7.0
30 – 40	8.0	15 – 20	8.0

(3) Vertical alignment



Where,

BC : beginning of curve

EC : end of curve

I1, I2, I3 : longitudinal gradient (%)

R : radius of curvature (m)

ΔI : difference between longitudinal gradients (%)

Lv : length of vertical convex or concave (m)

Formula for vertical shifting is given as follows:

$$E_V = \frac{\Delta i \cdot L_V}{800}$$

$$y = \left(\frac{x}{\frac{1}{2}L_V}\right)^2 \cdot E_V = \frac{\Delta I}{200 \cdot L_V} \cdot x^2$$

Where,

E_V = vertical shifting (m)

x = distance (m)

y = vertical sifting (m)

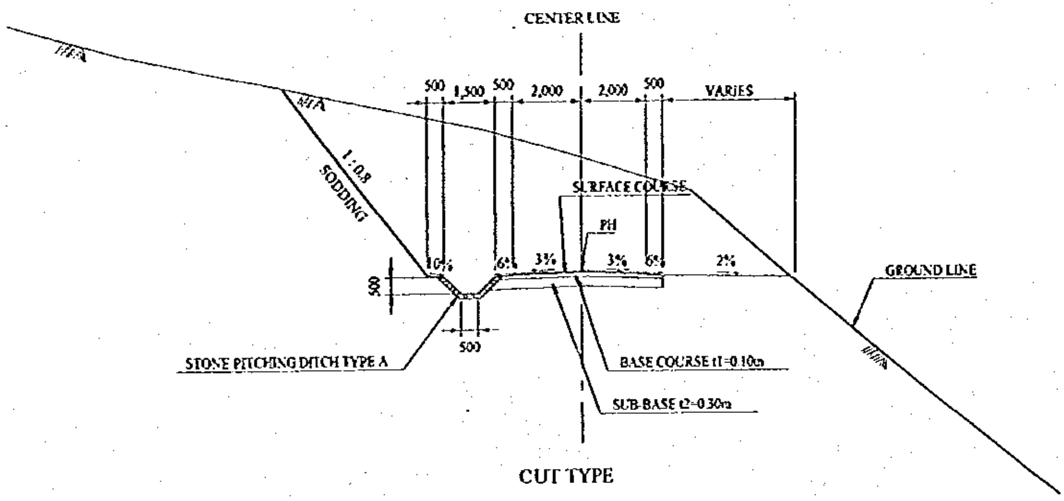
The length of vertical Convex and Concave is as follows:

Difference between Gradients (ΔI)	Design Speed 30 km/h		Design Speed 20 km/h	
	L_V (m)	Vertical Curve Length R (m)	L_V (m)	Vertical Curve Length R (m)
1	25	2,500	20	2,000
2	25	1,250	20	1,000
3	25	830	20	670
4	25	630	20	500
5	25	500	20	400
6	25	420	20	330
7	25	360	20	290
8	25	310	20	250
9	25	280	20	220
10	25	250	20	200
11	28	250	20	180
12	30	250	20	170
13	33	250	20	150
14	35	250	20	140

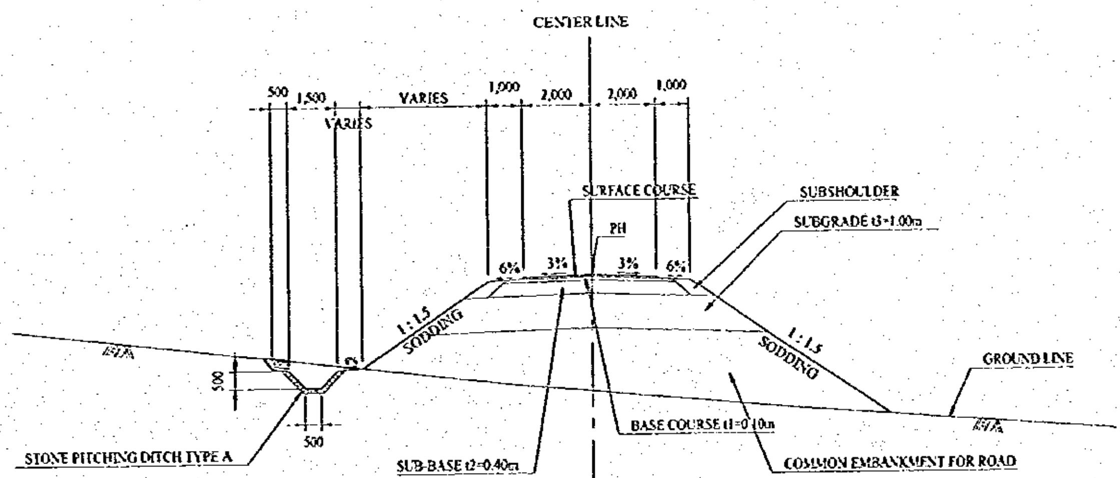
6.5.2 Cross Section

(1) Typical Cross Section

The typical cross sections for cut and embankment type are shown below.



CUT TYPE



EMBANMENT

TYPICAL CROSS SECTION

Design standard of embankment layer, drainage and slope protection is explained hereinafter.

(2) Design of Layer

(a) Sub-grade

The road will be made by spreading out on the filling of rock (or earth) or the cutting of rock (or earth). The filling as sub-grade should be compacted until 98% of the maximum dry compaction according to the AASHO Design Standard. The minimum thickness is 1.0 meter.

(b) Sub-base Course

The gradation of the sub-base course is to be decided in accordance with the AASHO Design Standard T.96, where a part of material passing through No. 200 sieve should be less than 2/3 of material passing through No. 40 sieve. The maximum percentage of material retained on No. 8 sieve is 50 %. Thickness of Sub-Base Course are as follows:

In Case of Cut Sub-Grade		In Case of Fill Sub-Grade	
Thickness	Sub-base Material	Thickness	Sub-base Material
0.3 m	Crushed Stone	0.4 m	Crushed Stone

Note : Fill sub-grade is constructed using selected common and unsound rock materials extracted from the required excavation nearby the road construction areas.

(c) Base Course

The construction can be made of dry bound macadam or water bound macadam, which is consisting of gravel or crushed stone bounded with fine aggregate as one or more layers on the sub-grade or sub-base course. The gradation of these layers is decided in accordance with the AASHO Design Standard T.96.

(d) Surface Course (pavement)

The following pavement design standard is applied; "Guide for Flexible Pavement Design (Petunjuk Perencanaan Tebel Perkerasan lentur Jalan Raya dengan metode analisa komponen : SKBI-2.3.26.1987, UDC : 625.73(02), Bina Marga).

(3) Drainage Design Standard

Drainage facilities design is based on rainfall intensity in a year return period as stipulated in Bina Marga Standard (No. 008/T/BNKT/1190, Petunjuk Desain Drainase Permukaan Jalan)

To determine the flow in the road drainage facilities the modified rational formula is used and the dimensions of the road drainage facilities are determined using Manning's Formula.

(4) Slope Protection

Slope protection work is planned to protect slope surface from erosion and weathering and to stabilize it by covering it with vegetation or structure. An optimum method should be selected in consideration of topographical, geological and meteorological conditions.

Slope protection work using vegetation is a sod facing method, while the slope protection works by structure are stone masonry, block masonry work, concrete leaning wall works and shotcrete.

PART II DRAWING STANDARD

1. GENERAL STANDARD

1.1 General

This drafting standard aims to standardize the drawings to be prepared for the detailed design for "Flood Control, Urban Drainage and Water Resources Development in Semarang". In preparing this drafting standard, "Irrigation Design Standard, Volume : Drawing Standard" is used.

(1) Drawing sizes

In principle, the sheet size will conform to size A1(Width=594 mm x Length=841 mm). In case that the topographic maps such as river plans are used as the design drawing, the sheet size A0 can be applied. In this case, the width of sheet will be the same as that of the sheet A1, and then the length of sheet varies with the length of 841mm or more. The typical layout for A1 size drawing sheet is shown in Fig. 1.1.

(2) Title blocks

The title block as shown in Fig. 1.2 will be arranged at the right and bottom corner of drawings basically.

(3) Line and letter

The line for drawing will be used adequately in accordance with the classification of line as shown in Fig. 1.3. The lettering for drawing will comply with the standard as shown in Fig. 1.4.

(4) Notation

All notations (Note, General Note, Specific Note, Local Note and so on) necessary for design and construction of structures written on the drawing will be mentioned on the drawing. These notes are mentioned on the designated area on the left and bottom part of sheet as shown in Fig. 1.1. Notes for general plan and profile drawings will be placed in the lower part of drawing.

1.2 Dimensions

The dimension will be expressed in millimeter (mm) of metric system unless otherwise noted. For the description of dimension, the following care shall be taken.

(1) Unit of dimensions

Unless otherwise specified, the dimensions will be as follows;

Type of Dimensions	Unit	Example
Length	millimeter (mm)	12,300
Elevation	meter (m)	EL. 123.45
Angle	degree, minute, second	12° 34' 56"
Gradient	% or ratio at	5% or 1 : 2.0
Coordinates	meter	X=550,000.000, Y=31,000.000

(2) Description of dimensions

Description of dimensions will comply with the standard as shown in Fig. 1.5.

1.3 Abbreviation and Symbol

(1) Abbreviation

The abbreviation to be used for drawing will be as described in Table 1.1.

(2) Symbol

The symbol to be used for description of materials and for mapping will be shown in Figs. 1.6 , 1.7 and Fig. 1.8, respectively.

(3) Indication of reinforcing bar

The indication of reinforcing bars shall follow the Indonesian Concrete Standard 1971 (PB I 71), further more the descriptions of kind, diameter and spacing of reinforcing bars are presented as follows :

Example

ϕ 16 @ 300

where,	ϕ	:	round reinforcing bar
	16	:	nominal diameter is 16 mm
	@ 300	:	spacing is 300 mm

D16 @ 300

where,	D	:	deformed reinforcing bar
	16	:	nominal diameter is 16 mm
	@ 300	:	spacing is 300 mm

2. DRAWING FOR STRUCTURAL DESIGN

2.1 Kinds of Drawings

The drawings are classified into the following three kinds.

(1) General Plan, Profile, Channel Cross Sections and layout of Structures

Plan of rivers/drainage channels, channel profile, cross sections of channel, location maps, and general layout of major structures are included in this category. This kind of drawing will indicate the river improvement plan, longitudinal profile and cross sections of channel, location of structures and principal features of construction works for major structures.

(2) Structural drawings

Plan, profile and section of structures are included in this category. This kind of drawings will indicate the principal dimensions of structures.

(3) Detail drawings

Drawings for details of structures and drawings for reinforcing bar arrangement are included in this category.

Typical scales for the drawings are summarized in Table 1.2.

2.2 Arrangement of Drawings

(1) Orientation

For topographical and location maps the north direction will be indicated in the drawing. Drawings showing plan of river/drainage channel will be oriented as the flow direction is situated from the right side to the left side of drawings. Orientation of longitudinal profiles of river/drainage channel is made in such a manner as the upstream side of stream is situated on the right side of drawing sheet. Other drawings will be oriented properly in consideration of the consistency with the orientation in relevant maps or drawings.

(2) Arrangement of figures in drawing

In case that plural figures are to be presented in one drawing sheet, principal view which shows main feature of structure will be arranged at the top and the left corner of drawings. The secondary view which shows the side view or sectional view of structures will be arranged at the right side of or below the principal view. The views or sections explaining the specific details structure will be arranged at the right side of or below the principal and secondary views.

TABLE 1.1 (1/2) GLOSSARY OF TERMS AND ABBREVIATION

(1) LOCAL ADMINISTRATION AND ORGANIZATION

Kab. (Kabupaten)	: Regency	Kali, Sungai	: River
Kec. (Kecamatan)	: Township	Rawa	: Swamp
Desa	: Village	Laut	: Sea
Kp. (Kampung)	: Community	Gunung	: Mountain

(2) ABBREVIATION OF MEASURES

Length

mm	: millimeter
cm	: centimeter
m	: meter
km	: kilometer

Weight

gf	: gram
kgf	: kilogram
tf	: ton

Area

cm^2	: square centimeter
m^2	: square meter
ha	: hectare = 10^4 m^2
km^2	: square kilometer

Force

kgf	: kilogram force
N	: newton
	(1kgf=9.80665N)

Volume

cm^3	: cubic centimeter
m^3	: cubic meter
lit, 1	: liter = 1,000 cm^3
mcm	: million cubic meter

Stress

kgf/cm^2	: kilogram force per square centimeter
tf/m^2	ton per square meter

Discharge

m^3/s	: cubic meter per second
1/s	: liter per second
m^3/d	: cubic meter per day
mcm/y	: million cubic meter per year

Pressure

P_a	: pascal
kP_a	: kilo-pascal
MP_a	: mega-pascal
	(kgf/cm^2=9.80665×10^4 P_a)

Other Measures

kV	: kilovolt	℃	: degree centigrade
kW	: kilowatt	%	: percentage
MW	: megawatt = 1,000 kW	no/no s	: number / numbers
kVA	: kilovolt ampere	EL m	: elevation meter
Hz	: hertz		

TABLE 1.1(2/2) GLOSSARY OF TERMS AND ABBREVIATION

(3) OTHER ABBREVIATION

BC	= Beginning Point of Curve
BM	= Bench Mark
BOTT	= Bottom
BP	= Beginning Point
BR.	= Bridge
BT	= Bent
CJ	= Construction Joint
L	= Center Line
CL	= Curve Length
CMP	= Corrugated Metal Pipe
CONC	= Concrete
CTC	= Center to Center
C-Bx	= Culvert Box
C-P	= Culvert Pipe
D	= Diameter of Deformed Bar
DFWL	= Design Flood Water Level
DIAG	= Diagonal Bar
DL	= Datum Line
DHWL	= Design High Water Level
DWG	= Drawing
EL	= Elevation
EC	= Ending Point of Curve
EP	= Ending Point
° E	= East Longitude
EF	= Each Face
EXP.J	= Expansion Joint
FF	= Far Face
FIG.	= Figure
FP-MG	= Foot Protection, Mat Gabion
GALV	= Galvanized
GH	= Ground Height
GR	=Guard Rail
HWL	= High Water Level
HHWL	= Highest High Water Level
I	= I- beam
IF	= Inside Face
IA	= Intersection Angle
ID	= Inside Diameter
IF	= Inside Face
IP	= Intersection Point
i	= Grade
L	= Length
LLWL	= Lowest Low Water Level
LWL	= Low Water Level
MAX	= Maximum
MIN	= Minimum
MSL	= Mean Sea Level
N	= North
ND	= Naked Ditch
NF	= Near Face
NIC	= Not Including in This Contract
NWL	= Normal Water Level
No.	= Number
° N	= North Latitude
OF	= Outside Face
OD	= Outside Diameter
PC	= Prestressed Concrete
PL	= Plain Bar
PH	= Proposed Height
PMF	= Probable Maximum Flood
PVC	= Polivinyl Chloride
P	= Plate
RC	= Reinforced Concrete
ROW	= Right of Way
RW-SM	= Retaining Wall, Stone Masonry
R	= Radius
SL	= Secant Length
SP	= Spiral
SPD	= Stone Pitching Ditch
SP-SP	= Slope Protection, Stone Pitching
STA	= Station
STD	= Standard
STIR	= Stirrup
STR	= Straight
SWL	= Surcharge Water Level
TF	= Top Face
TL	= Tangent Length
TYP	= Typical
VCL	= Vertical Curve Length
WP	= Working Point
WS	= Water Stop
O	= Diameter of Round Bar, Pipe
a,x	= Repetition of Same Spacing°
° ’’’’	= Angle (degree, minute, second)

TABLE 1.2 STANDARD SCALE OF DRAWING

Kinds of Drawings	Scale
River / Drainage Channel, Weir, Pumping Station and related structures	
- General plan	1/10,000, 1/5,000, 1/2,000
- Plan of river/ drainage channel	1/2,000, 1/1,000
- Cross section of river/ drainage channel	Horizontal : 1/200, Vertical : 1/100
- Profile of river/drainage channel	H : 1/10,000, 1/5,000, Vertical : 1/100
- Structural general, plan, section	1/500, 1/200, 1/100, 1/50
- Structural detail	1/50, 1/20, 1/10, 1/5
Dam, diversion works, spillway, waterway and related structures	
- General plan	1/10,000, 1/5,000, 1/2,000
- Site plan	1/2,000, 1/1,000
- Plan, section, profile	1/2,000, 1/1,000
- Structural general, plan, section	1/500, 1/200, 1/100, 1/50
- Structural detail	1/50, 1/20, 1/10, 1/5, 1/2
Road	
Site plan	1/20,000
Detail design; plan	1/1,000
Detail; profile	v:1/100, H:1/1,000
Detail; cross section	1/200
Concrete structures and steel structures	
Plan, view and profile	(1/600), 1/500, (1/400), (1/300), 1/200, 1/100
Structural general	1/200, 1/100, 1/50
Structural element	(1/60), 1/50, (1/40), 1/30, 1/20
Details	1/20, 1/10, 1/5, 1/2, 1/1

Note : Scales mentioned in brackets or other scales which are not mentioned above may only be used for technical reasons.

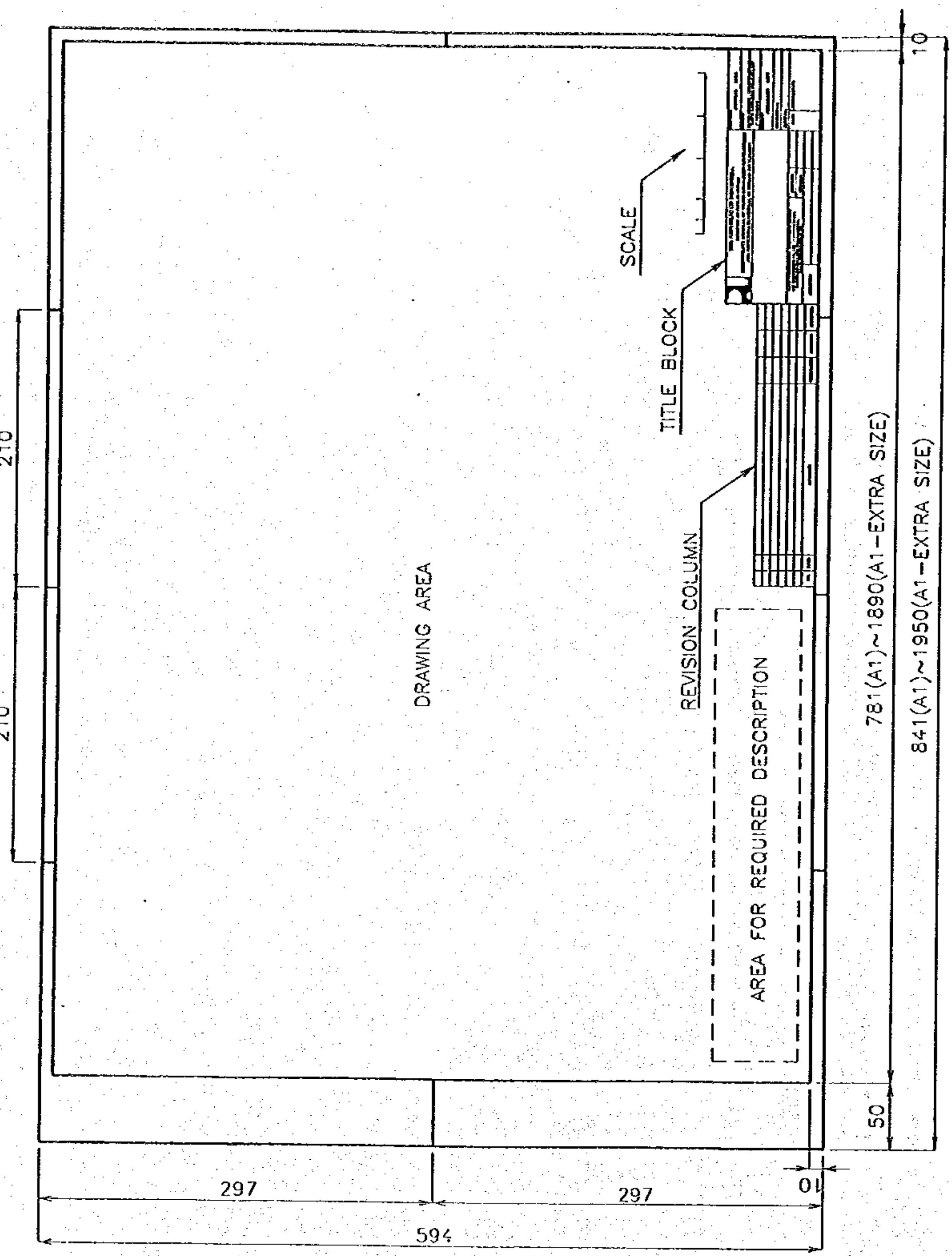


Fig. 1.1 TYPICAL LAYOUT OF DRAWING SHEET

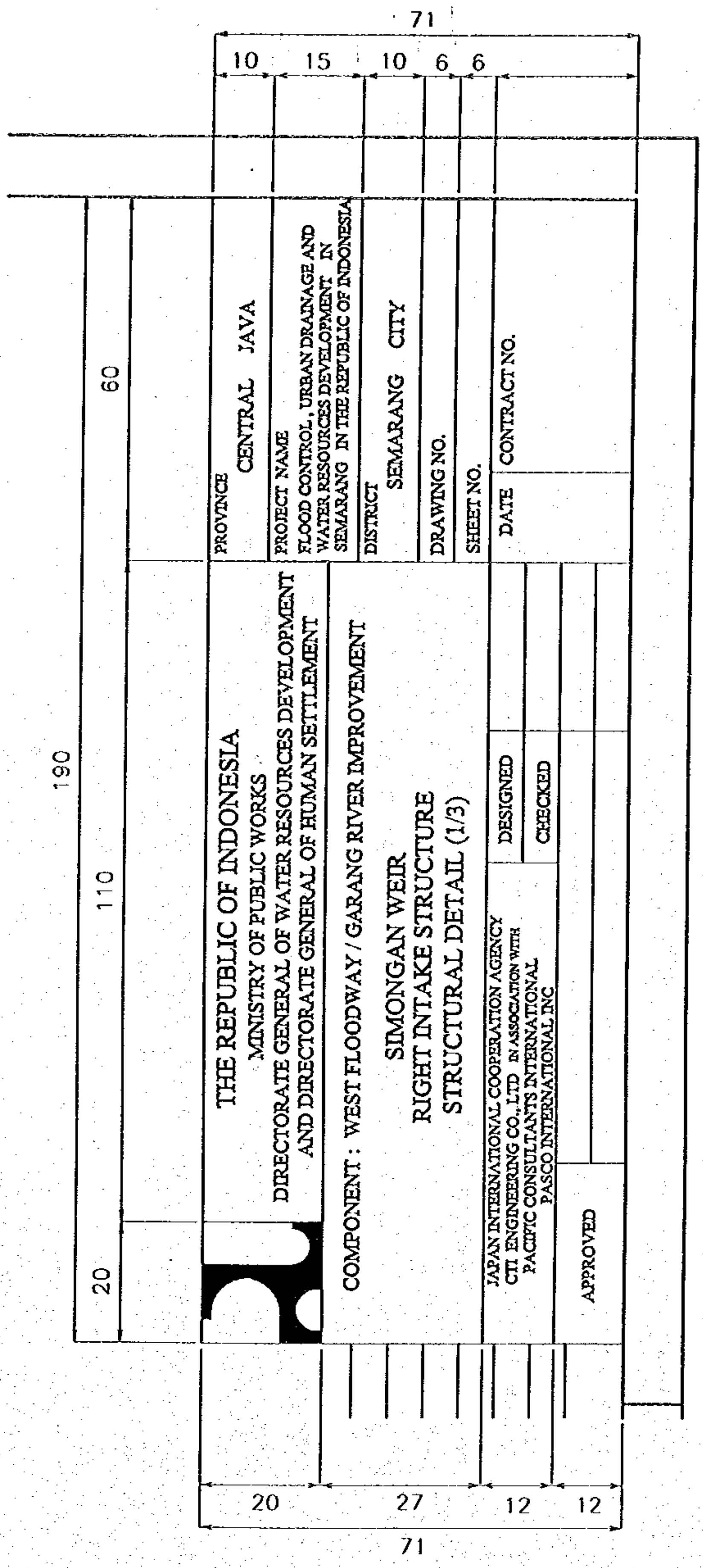


Fig. 1.2 STANDARD OF TITLE BLOCK (SCALE 1:1)

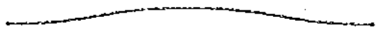
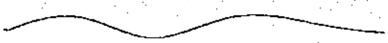
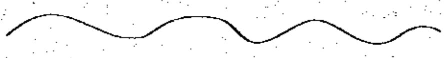
Thickness (mm)	Line	Application
0.4		Outline of structures in section, profile and section plan as well as reinforcing bars.
0.4		Boundary between rock and concrete structures, as well as excavated line in sections. (Freehand line)
0.4		Invisible reinforcing bars
0.2		Visible lines of structures in plan, elevation, etc., contraction and expansion joints in section, etc.
0.2		Index contour
0.2		Invisible structure outline except in reinforcement drawings.
0.2		Out of function line to show construction boundary.
0.1		Dimension line and its extension line, concrete outline in reinforcement drawing, blockout line, breaking line, contraction and expansion joints in plan and original ground line in section.
0.1		Leader (Freehand line)
0.1		Principal contour (Freehand line)

Fig. 1.3(1/2) LINES AND APPLICATIONS

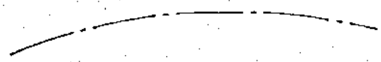
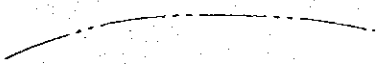
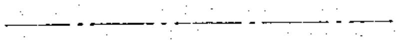
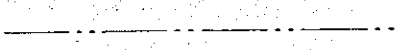
Thickness (mm)	Line	Application
0.1		Invisible structure outline in reinforcement drawing.
0.1		Original contours after excavation, if required (Freehand line)
0.1		Assumed hard rock line, if required (Freehand line)
0.1		Assumed soft rock line, if required (Freehand line)
0.1		Center line
0.1		Imaginary line, match line, construction joint line and concrete placing lift in section, (Match line shows the dividing section of along protruding feature in drawing sheet).

Fig. 1.3(2/2) LINES AND APPLICATIONS

APPLICATION	SIZE	STYLE
DIMENSIONS AND NOTINGS	3mm	123 ABC
MAIN TITLES	5mm	PLAIN PROFILE SECTION
SUB TITLE, HEADING OF NOTES LEGENDS AND REFERENCES	4mm	NOTES LEGEND
SCALE	3mm	SCALE A
TITLE OF DRAWING IN TITLE BLOCK	5mm / 4mm	DAM SPILLWAY DETAILS OF EMBANKMENT
DRAWING AND SHEET NO. IN TITLE BLOCK	4mm	I - DAM - 25

Fig. 1.4 STANDARD OF LETTERING

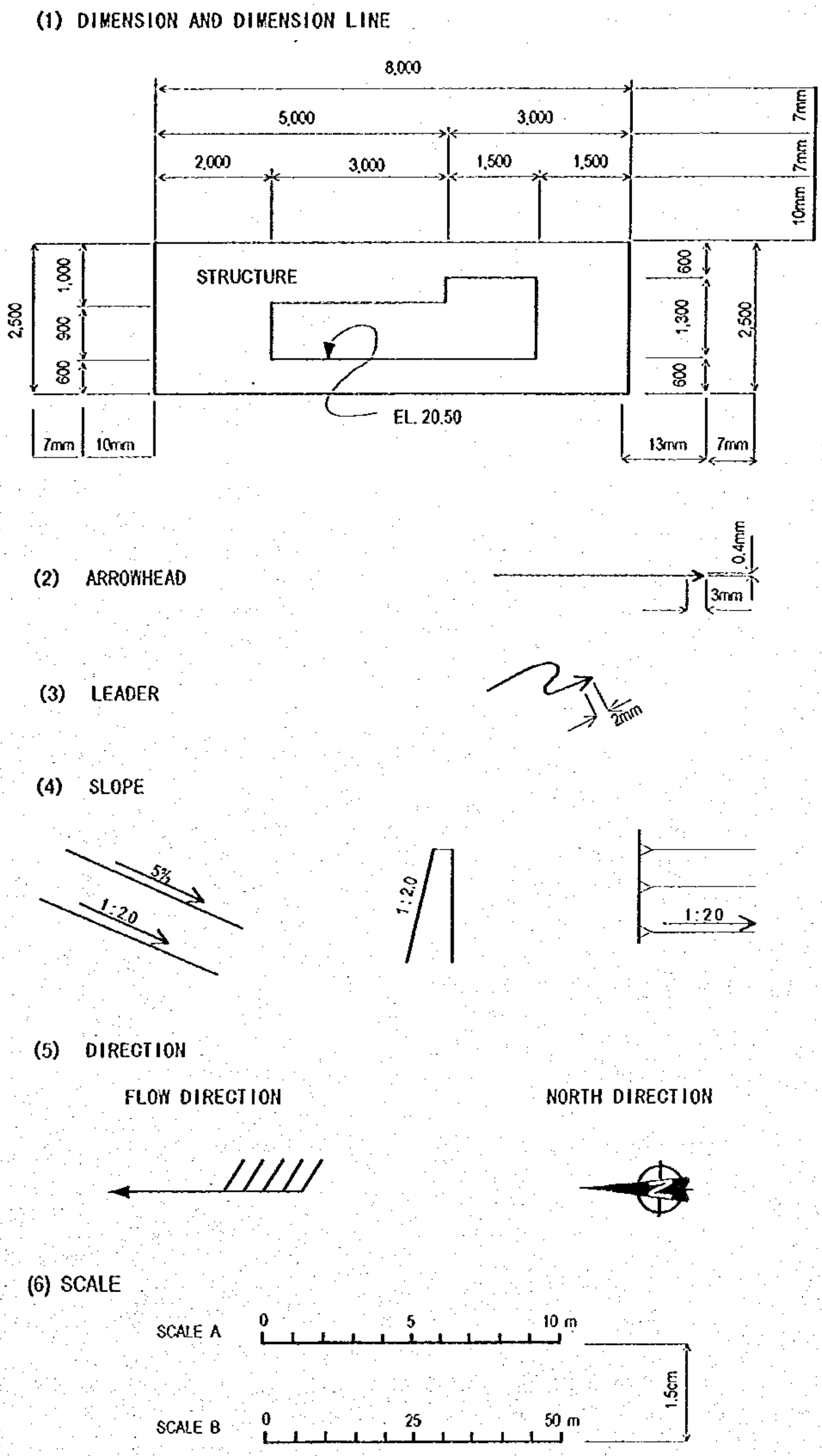
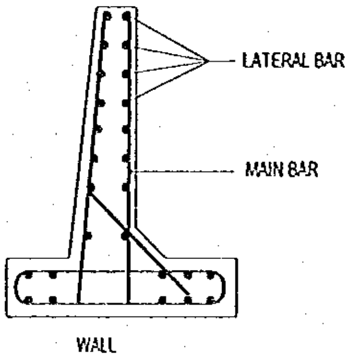
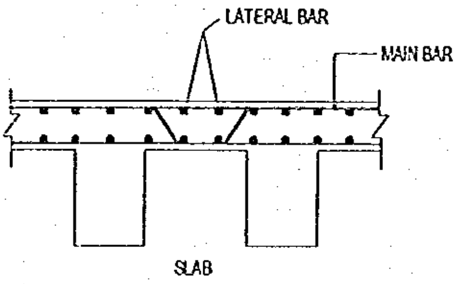
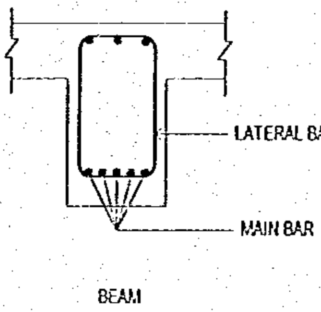


Fig. 1.5(1/2) STANDARD DESCRIPTION

BAR ARRANGEMENT







SECTION ARROWHEAD

Fig. 1.5(2/2) STANDARD DESCRIPTION

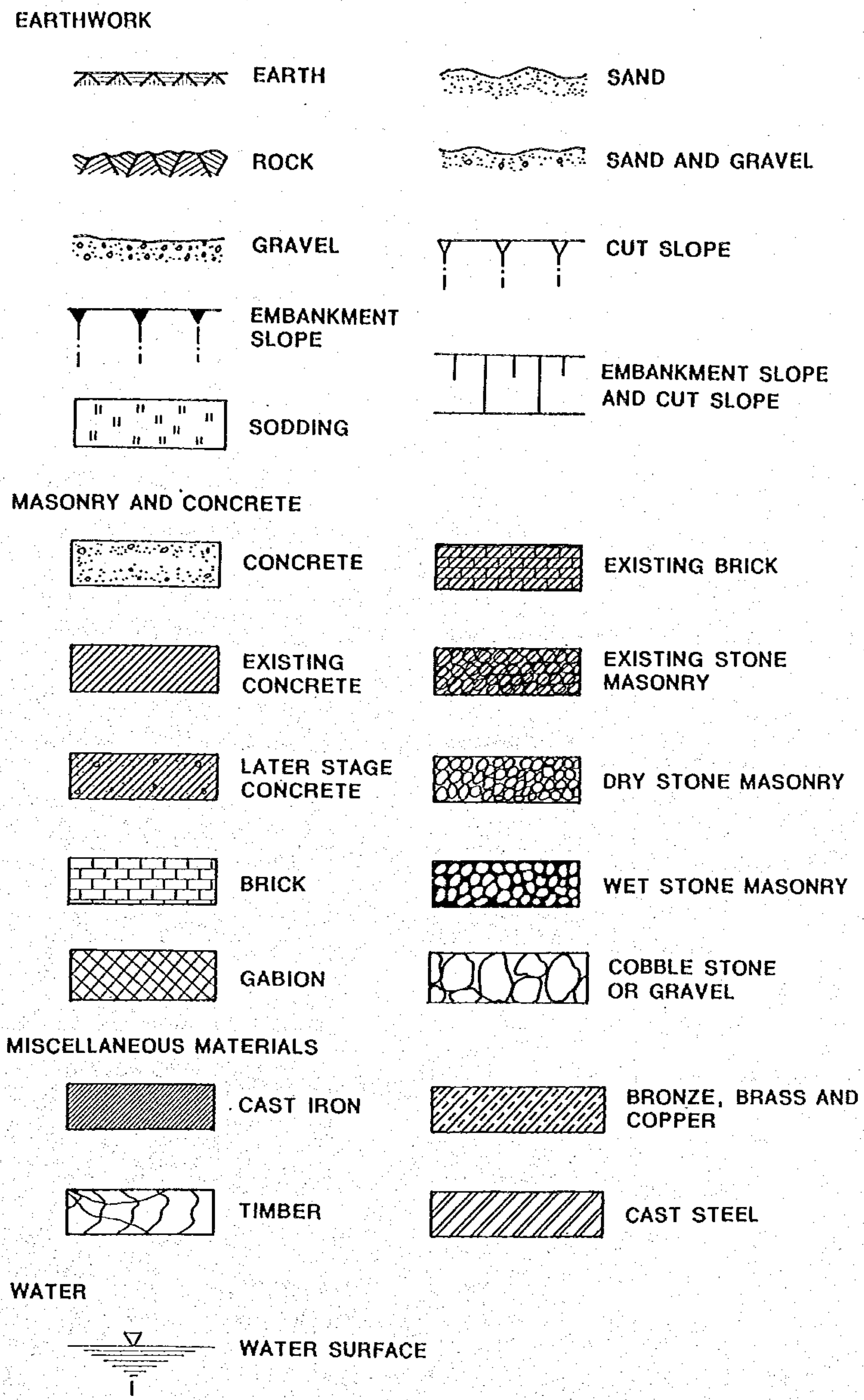


Fig. 1.6 SYMBOLS FOR DRAWING

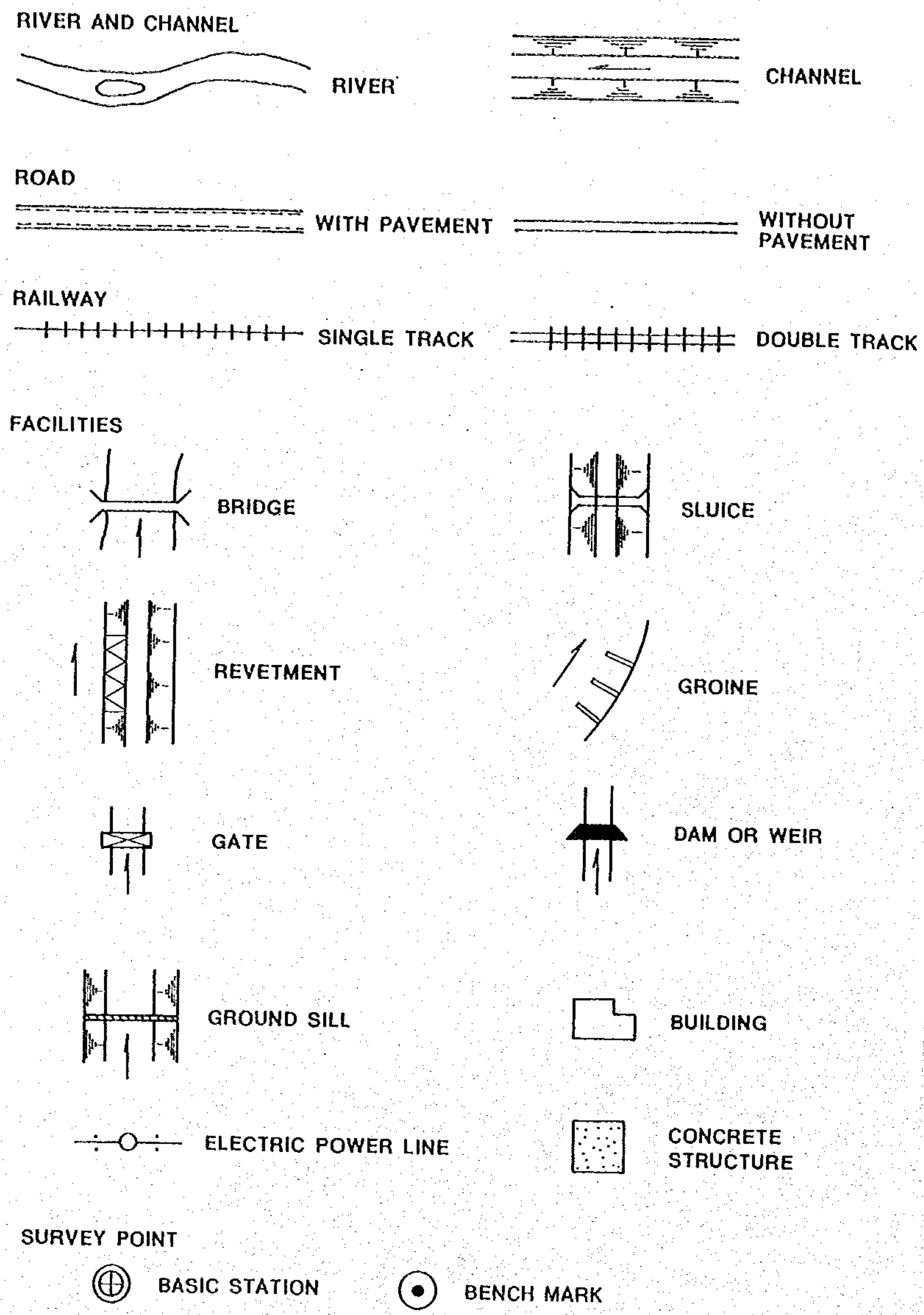


Fig. 1.7 (1/2) SYMBOLS FOR MAPPING

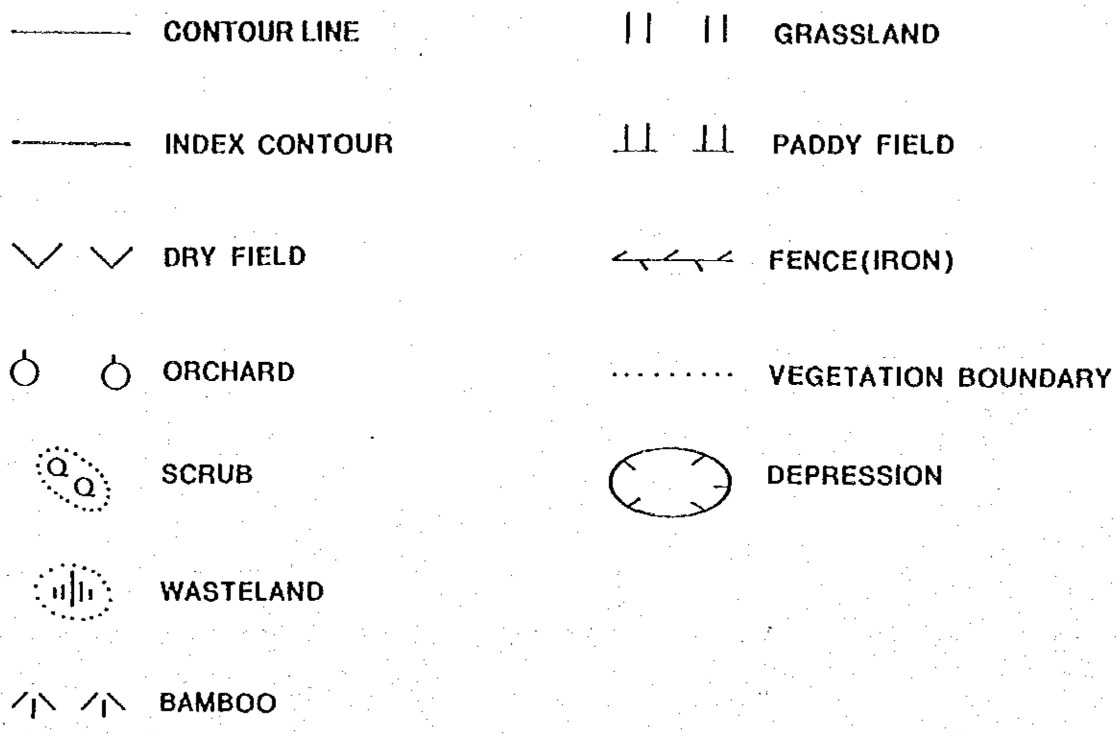


Fig. 1.7 (2/2) SYMBOLS FOR MAPPING