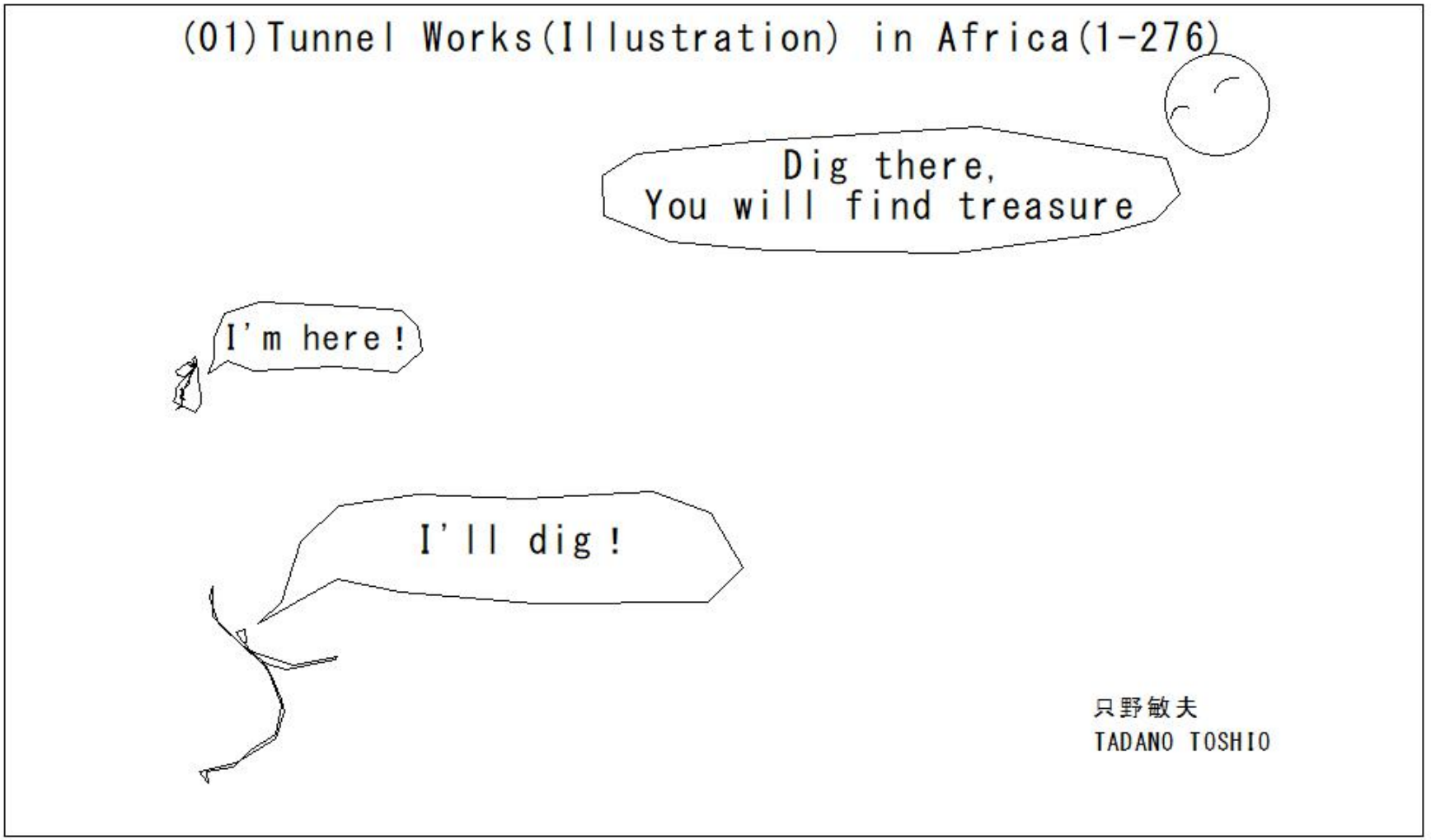
(01)Tunnel Works(Illustration) in Africa(1-276)



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只野敏夫
Tadano Toshio

(T1)The Role of the Tunnel	The Role of the Tunnel
(T2)The Role of the Tunnel	The Role of the Tunnel
(T3)The Role of the Tunnel	The Role of the Tunnel
(T4)Tunnel(investigation)	Tunnel(investigation)
(T5)Tunnel(investigation-Landslides)	investigation-Landslides
(T6)Tunnel(investigation-soil cover)	investigation-soil cover
(T7)Tunnel(investigation- Fault fracture zone)	investigation- Fault fracture zone
(T8)Tunnel(investigation- Hydrous-containing unconsolidated ground)	investigation
(T9)Tunnel(investigation-Expansive ground)	investigation-Expansive ground
(T10)Tunnel(investigation-High ground pressure, etc)	investigation-High ground pressure, etc
(T11)Tunnel(Geology-Expansion)	Geology-Expansion
(T12)Tunnel(Geology-Groundwater and spring water)	Geology-Groundwater and spring water
(T13)Tunnel(Geology-Surface water inundation)	Geology-Surface water inundation
(T14)Tunnel(Geology-Geothermal heat)	Geology-Geothermal heat
(T15)Tunnel(Geology-Spouting of natural gas)	Geology-Spouting of natural gas
(T16)Tunnel(Geology-Stress in the ground)	Geology-Stress in the ground
(T17)Tunnel(Geology-Movement of ground)	Geology-Movement of ground
(T18)Tunnel(Topography-Fault zone)	Topography-Fault zone
(T19)Tunnel(Topography-Folds)	Topography-Folds
(T20)Tunnel(Topography-Terraces)	Topography-Terraces
(T21)Tunnel(Topography-Cliff: Landslide)	Cliff: Landslide
(T22)Tunnel(Topography-Landslide)	Landslide
(T23)Tunnel(Construction plan-Tunnel design)	Tunnel design
(T24)Tunnel(Construction plan-construction method)	construction method
(T25)Tunnel(Construction equipment-surface installations)	surface installations
(T26)Tunnel(Construction equipment-tunnel equipment)	tunnel equipment
(T27)Tunnel(Construction equipment-Electrical equipment)	Electrical equipment
(T28)Tunnel(Excavation methods)	Excavation methods
(T29)Tunnel(Excavation methods-Full-section excavation method)	Full-section excavation method
(T30)Tunnel(Excavation methods-heading excavation method)	heading excavation method
(T31)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)	Bottom-heading tunnel advanced upper half
(T32)Tunnel(Side wall heading(pilot) tunnel advanced upper half section excavation method)	Side wall heading(pilot) tunnel advanced
(T33)Tunnel(Excavation method-Bench cut method)	Bench cut method
(T34)Tunnel(Excavation method-Ring cut method)	Ring cut method

(T35)Tunnel(Large section tunnel excavation method）	Large section tunnel excavation method
(T36)Tunnel(Rock drilling）	Rock drilling
(T37)Tunnel(Rock drilling）	Rock drilling
(T38)Tunnel(Rock drilling）	Rock drilling
(T39)Tunnel(cut）	Tunnel(cut）
(T40)Tunnel(cut）	Tunnel(cut）
(T41)Tunnel(Burn cut）	Burn cut
(T42)Tunnel(No-cut method）	No-cut method
(T43)Tunnel(Precautions for blasting）	Precautions for blasting
(T44)Tunnel(Loading machines）	Loading machines
(T45)Tunnel(Muck transport method）	Muck transport method
(T46)Tunnel(Muck Handling-Rails and turnouts）	Muck Handling-Rails and turnouts
(T47)Tunnel(Muck Handling-Tire method）	Muck Handling-Tire method
(T48)Tunnel(Muck Handling-Tire method）	Muck Handling-Tire method
(T49)Tunnel(ventilation）	ventilation
(T50)Tunnel(ventilation）	ventilation
(T51)Tunnel(timbering(support)）	timbering(support)
(T52)Tunnel(timbering(support)）	timbering(support)
(T53)Tunnel(Steel arch supports)	Steel arch supports
(T54)Tunnel(Steel arch supports)	Steel arch supports
(T55)Tunnel(Steel arch supports)	Steel arch supports
(T56)Tunnel(Rock Bolt)	Rock Bolt
(T57)Tunnel(Rock Bolt)	Rock Bolt
(T58)Tunnel(Rock Bolt)	Rock Bolt
(T59)Tunnel(Shotcrete-Dry system diagram)	Shotcrete
(T60)Tunnel(Shotcrete-Wet system diagram)	Shotcrete
(T61)Tunnel(NATM（New Austrian Tunneling Method）)	NATM
(T62)Tunnel(NATM（New Austrian Tunneling Method）)	NATM
(T63)Tunnel(Coverings (lining))	Coverings (lining)
(T64)Tunnel(Coverings (lining)-shrinkage cracking (strain))	Coverings (lining)-shrinkage cracking (strain)
(T65)Tunnel(Coverings (lining)-Crack protection)	Coverings (lining)-Crack protection
(T66)Tunnel(Shape of the Coverings (lining))	Coverings (lining)
(T67)Tunnel(Enlarged sidewall concrete)	Coverings (lining)
(T68)Tunnel(Shape of the cover)	Coverings (lining)

(T69)Tunnel(coverings (lining))	coverings (lining))
(T70)Tunnel(coverings (lining)-formwork)	coverings (lining)-formwork
(T71)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T72)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T73)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T74)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T75)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T76)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T77)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T78)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T79)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T80)Tunnel(Grouting)	Grouting
(T81)Tunnel(Grouting)	Grouting
(T82)Tunnel(Grouting)	Grouting
(T83)Tunnel(Grouting)	Grouting
(T84)Tunnel(Grouting（injection pipe）)	Grouting
(T85)Tunnel(Grouting（injection pipe）)	Grouting
(T86)Tunnel(Special methods)	facing stabilization measures
(T87)Tunnel(facing stabilization measures-Measures against ground settlement)	facing stabilization measures
(T88)Tunnel(Injection method)	Injection method
(T89)Tunnel(Freezing method)	Freezing method
(T90)Tunnel(Drainage boring)	Drainage boring
(T91)Tunnel(Well point method)	Well point method
(T92)Tunnel(Pipe roof methods)	Pipe roof methods
(T93)Tunnel(Special steel sheet pile jacking method)	Special steel sheet pile jacking method
(T94)Tunnel(Barrier wall method)	Barrier wall method
(T95)Tunnel(Downward bolt from the ground)	Tunnel(Downward bolt from the ground
(T96)Tunnel(Deep well method)	Deep well method
(T97)Tunnel(Investigations during construction)	Investigations during construction
(T98)Tunnel(Expansive ground)	Tunnel(Expansive ground)
(T99)Tunnel(Weathered rock zone)	Tunnel(Weathered rock zone)
(T100)Tunnel(Tunnel survey)	Tunnel survey
(T101)Tunnel(Tunnel alignment)	Tunnel alignment
(T102)Tunnel(Tunnel gradient)	Tunnel gradient

(T103)Tunnel(Tunnel gradient)	Tunnel gradient
(T104)Tunnel(Tunnel gradient)	Tunnel gradient
(T105)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T106)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T107)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T108)Tunnel(Mountain tunnels)	Mountain tunnels
(T109)Tunnel(Urban tunnels)	Urban tunnels
(T110)Tunnel(Underwater tunnels)	Underwater tunnels
(T111)Tunnel(Full cross-section excavation method)	Full cross-section excavation method
(T112)Tunnel(Shield construction method)	Shield construction method
(T113)Tunnel(Bench cut method)	Bench cut method
(T114)Tunnel(Advance heading(Pilot) tunnel excavation method)	Advance heading(Pilot) tunnel excavation
(T115)Tunnel(Open cut method)	Open cut method
(T116)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T117)Tunnel(Assembled formwork)	Assembled formwork
(T118)Tunnel(traveling form form)	traveling form form
(T119)Tunnel(NATM (New Austrian Tunneling Method)	NATM (New Austrian Tunneling Method)
(T120)Tunnel(Tunnel survey)	Tunnel survey
(T121)Tunnel(Outline survey)	Outline survey
(T122)Tunnel(Detailed survey)	Detailed survey
(T123)Tunnel(Surveys before construction)	Surveys before construction
(T124)Tunnel(Surveys during construction)	Surveys during construction
(T125)Tunnel(Survey after completion)	Survey after completion
(T126)Tunnel(alignment)	alignment
(T127)Tunnel(Slope)	Slope
(T128)Tunnel(Cross-sectional shape)	Cross-sectional shape
(T129)Tunnel(Ancillary facilities)	Ancillary facilities
(T130)Tunnel(Ancillary facilities)	Ancillary facilities
(T131)Tunnel(Excavation method)	Excavation method
(T132)Tunnel(tunnel section)	tunnel section
(T133)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)	Bottom-heading tunnel advanced upper half
(T134)Tunnel(Advanced low heading-installation conduction)	Advanced low heading-installation conduction
(T135)Tunnel(Side wall heading(guide) tunnel advance)	Side wall heading(guide) tunnel advance
(T136)Tunnel(Upper half section excavation method)	Upper half section excavation method

(T137)Tunnel(tunnel boring machine)	tunnel boring machine
(T138)Tunnel(Blast work)	Blast work
(T139)Tunnel(Blasting work)	Blasting work
(T140)Tunnel(Blasting work)	Blasting work
(T141)Tunnel(Blasting work)	Blasting work
(T142)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T143)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T144)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T145)Tunnel(Tunnel excavation soil treatment(Muck disposal))	Muck disposal
(T146)Tunnel(Support)	Support
(T147)Tunnel(Rock bolt)	Rock bolt
(T148)Tunnel(Sprayed concrete(Shotcrete))	Sprayed concrete(Shotcrete)
(T149)Tunnel(NATM (New Austrian Tunneling Method))	NATM (New Austrian Tunneling Method)
(T150)Tunnel(Coverings (lining))	Coverings (lining)
(T151)Tunnel(Formwork)	Formwork
(T152)Tunnel(traveling form(Mobile formwork))	Mobile formwork)
(T153)Tunnel(Coverings (lining)	Coverings (lining)
(T154)Tunnel(waterproof・drainage pipes)	waterproof・drainage pipes
(T155)Tunnel(Shield method)	Shield method
(T156)Tunnel(Shield tunneling)	Shield tunneling
(T157)Tunnel(Air pressure shield tunneling)	Air pressure shield tunneling
(T158)Tunnel(Muddy water pressurized shield method)	Muddy water pressurized shield method
(T159)Tunnel(Earth pressure balance shield method)	Earth pressure balance shield method
(T160)Tunnel(Open cut excavation without timbering)	Open cut excavation without timbering
(T161)Tunnel(Open cut method Full-section)	Open cut method Full-section
(T162)Tunnel(Partial excavation method (trench method))	Partial excavation method (trench method)
(T163)Tunnel(edge cutting pipe jacking)	edge cutting pipe jacking
(T164)Tunnel(Semi-shield pipe jacking method)	Semi-shield pipe jacking method
(T165)Tunnel(shield -pipe jacking method)	shield -pipe jacking method
(T166)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T167)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T168)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T169)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T170)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)

(T171)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T172)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T173)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T174)Tunnel(immersed tunnel(Hydraulic joint))	immersed tunnel(trench tunnel)
(T175)Tunnel(immersed tunnel(Flexible joint))	immersed tunnel(trench tunnel)
(T176)Tunnel(Injection method/Deviation water drainage method)	Injection method
(T177)Tunnel(Injection material: grout)	grout
(T178)Tunnel(Grouting)	Grouting
(T179)Tunnel(Grouting)	Grouting
(T180)Tunnel(Injection method/Detour drainage method)	Injection method/Detour drainage method
(T181)Tunnel(Pipe parallel /Messer method)	Pipe parallel /Messer method
(T182)Tunnel(Pipe parallel method)	Pipe parallel method
(T183)Tunnel(Messer method)	Messer method
(T184)Tunnel(Freezing methods)	Freezing methods
(T185)Tunnel(Freezing methods)	Freezing methods
(T186)Tunnel(Invert)	Invert
(T187)Tunnel(Return packing)	Return packing
(T188)Tunnel(Payment line)	Payment line
(T189)Tunnel(bracing)	bracing
(T190)Tunnel(Upper half section advanced construction method)	Upper half section advanced construction
(T191)Tunnel(Full-section advanced construction method)	Full-section advanced construction method
(T192)Tunnel(Side wall heading(Pilot) tunnel excavation work advanced upper half section method)	Side wall heading(Pilot) tunnel excavation work
(T193)Tunnel(Enlarged sidewall concrete)	Enlarged sidewall concrete
(T194)Tunnel(Shaft)	Shaft
(T195)Tunnel(Soil cover)	Soil cover
(T196)Tunnel(Tunnel axis direction)	Tunnel axis direction
(T197)Tunnel(NATM (New Austrian Tunneling Method))	NATM (New Austrian Tunneling Method)
(T198)Tunnel(Bottom heading(pilot) tunnel advance ring cut method)	Bottom heading(pilot) tunnel advance ring
(T199)Tunnel(Sidewall heading tunnel advanced ring cut construction method)	Sidewall heading tunnel advanced ring
(T200)Tunnel(Full cross-section method)	Full cross-section method
(T201)Tunnel(Upper half section ring excavation method)	Upper half section ring excavation method
(T202)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)	Bottom-heading tunnel advanced upper
(T203)Tunnel(Side wall guide shaft advanced upper half section construction method)	Side wall guide shaft advanced upper
(T204)Tunnel(Lining concrete)	Lining concrete

(T205)Tunnel(payment lines)	payment lines
(T206)Tunnel(Short step system)	Short step system
(T207)Tunnel(Shield tunnel)	Shield tunnel
(T208)Enlarged sidewall concrete(Protecting concrete wall)	Enlarged sidewall (Protecting concrete wall)
(T209)Immersed tunnel	Immersed tunnel
(T210)Tunnel(telescopic form)	telescopic form
(T211)Tunnel(Inner section)	Inner section
(T212)Tunnel(Inner section)	Inner section
(T213)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T214)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T215)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T216)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T217)Bernold method	Bernold method
(T218)Waterproofing sheet	Waterproofing sheet
(T219)Thickness of lining	Thickness of lining
(T220)shield tunneling	shield tunneling
(T221)support(timbering)	support(timbering)
(T222)inclined adit :inclined shaft	inclined adit :inclined shaft
(T223)pipe jacking method(Tensioning method)	pipe jacking method(Tensioning method)
(T224)pipe jacking method(Middle push-out method)	pipe jacking method(Middle push-out method)
(T225)heading(Pilot)	heading(Pilot)
(T226)NATM（New Austrian Tunneling Method）	NATM（New Austrian Tunneling Method）
(T227)Tunnel(swelling heaving)	swelling heaving
(T228)Tunnel(swelling heaving)	swelling heaving
(T229)Tunnel(swelling heaving)	swelling heaving
(T230)Tunnel(chipping)	chipping
(T231)Tunnel(pneumatic method)	pneumatic method
(T232)Tunnel(bottom of bore hole)	bottom of bore hole
(T233)Tunnel(clay tamping)	clay tamping
(T234)Tunnel(traveling form(Mobile formwork))	traveling form(Mobile formwork)
(T235)Tunnel(Invert)	Invert
(T236)Tunnel(Invert)	Invert
(T237)Tunnel(wall plate)	wall plate
(T238)Tunnel(Wall plate type support(timbering))	Wall plate type support(timbering)

(T239)Tunnel(pumice-stone(Floating stones))	pumice-stone(Floating stones)
(T240)Tunnel(logging)	logging
(T241)Tunnel(adit(Horizontal pit))	adit(Horizontal pit)
(T242)Tunnel(heading(guide) drilling)	heading(guide) drilling
（T243）open cut・trench method	open cut・trench method
（T244）erection fixture(Temporary Installations)	erection fixture(Temporary Installations)
（T245）tunnel(enlargement)	enlargement
（T246）tunnel(segmental arch timber)	segmental arch timber
（T247）tunnel(glory hole system)	glory hole system
（T248）tunnel(steel centre)	steel centre
（T249）tunnel(pit)	pit
（T250）tunnel(undermining blast method)	undermining blast method
(T251)Portal -pit gate	Portal -pit gate
(T252)Concrete bed	Concrete bed
（T253）open cut method	open cut method
(T254)tunnel(shunt heading)	shunt heading
(T255)tunnel(mucking)	mucking
(T256)tunnel(mucking)	mucking
(T257)tunnel(wedging)	wedging
(T258)Enlarged sidewall	Enlarged sidewall
(T259)tunnel(core method of tunnel construction)	core method of tunnel construction
(T260)tunnel(upraise)	upraise
(T261)tunnel(top heading of tunnel construction)	top heading of tunnel construction
(T262)tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T263)tunnel(earth pressure shield)	earth pressure shield
(T264)tunnel(heading(Pilot))	heading(Pilot)
(T265)tunnel(timbering of heading)	timbering of heading
(T266)tunnel(trolley(Earth transport vehicle))	trolley(Earth transport vehicle)
(T267)tunnel(drll jambo)	drll jambo
(T268)tunnel(tunnel surveying)	tunnel surveying
(T269)tunnel(Inclined Shaft)	Inclined Shaft
(T270)tunnel(fuse)	fuse
(T271)tunnel(pipe roofing protection)	pipe roofing protection
(T272)tunnel(lining)	lining

(T273)edge cutting pipe jacking	edge cutting pipe jacking
(T274)Tunnel(half section excavation)	half section excavation
(T275)Tunnel(shot crete)	shot crete
(T276)Tunnel(bench cut method)	bench cut method

(T138)Tunnel(Blast work)	Blast work
(T241)Tunnel(adit(Horizontal pit))	adit(Horizontal pit)
(T114)Tunnel(Advance heading(Pilot) tunnel excavation method)	Advance heading(Pilot) tunnel excavation
(T134)Tunnel(Advanced low heading-installation conduction)	Advanced low heading-installation conduction
(T157)Tunnel(Air pressure shield tunneling)	Air pressure shield tunneling
(T126)Tunnel(alignment)	alignment
(T129)Tunnel(Ancillary facilities)	Ancillary facilities
(T130)Tunnel(Ancillary facilities)	Ancillary facilities
(T117)Tunnel(Assembled formwork)	Assembled formwork
(T94)Tunnel(Barrier wall method)	Barrier wall method
(T33)Tunnel(Excavation method-Bench cut method）	Bench cut method
(T113)Tunnel(Bench cut method)	Bench cut method
(T276)Tunnel(bench cut method)	bench cut method
(T217)Bernold method	Bernold method
(T139)Tunnel(Blasting work)	Blasting work
(T140)Tunnel(Blasting work)	Blasting work
(T141)Tunnel(Blasting work)	Blasting work
(T198)Tunnel(Bottom heading(pilot) tunnel advance ring cut method)	Bottom heading(pilot) tunnel advance ring
(T232)Tunnel(bottom of bore hole)	bottom of bore hole
(T202)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)	Bottom-heading tunnel advanced upper
(T31)Tunnel(Bottom-heading tunnel advanced upper half section excavation method）	Bottom-heading tunnel advanced upper half
(T133)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)	Bottom-heading tunnel advanced upper half
(T189)Tunnel(bracing)	bracing
(T41)Tunnel(Burn cut）	Burn cut
(T230)Tunnel(chipping)	chipping
(T233)Tunnel(clay tamping)	clay tamping
(T21)Tunnel(Topography-Cliff: Landslide）	Cliff: Landslide
(T252)Concrete bed	Concrete bed
(T24)Tunnel(Construction plan-construction method）	construction method
(T259)tunnel(core method of tunnel construction)	core method of tunnel construction
(T63)Tunnel(Coverings (lining))	Coverings (lining)
(T66)Tunnel(Shape of the Coverings (lining))	Coverings (lining)
(T67)Tunnel(Enlarged sidewall concrete)	Coverings (lining)
(T68)Tunnel(Shape of the cover)	Coverings (lining)

(T153)Tunnel(Coverings (lining)	Coverings (lining)
(T150)Tunnel(Coverings (lining))	Coverings (lining)
(T69)Tunnel(coverings (lining))	coverings (lining))
(T71)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T72)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T73)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T74)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T75)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T76)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T77)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T78)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T79)Tunnel(coverings (lining)-Concrete placing)	coverings (lining)-Concrete placing
(T65)Tunnel(Coverings (lining)-Crack protection)	Coverings (lining)-Crack protection
(T70)Tunnel(coverings (lining)-formwork)	coverings (lining)-formwork
(T64)Tunnel(Coverings (lining)-shrinkage cracking (strain))	Coverings (lining)-shrinkage cracking (strain)
(T128)Tunnel(Cross-sectional shape)	Cross-sectional shape
(T105)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T106)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T107)Tunnel(Cross-sectional shape of the tunnel)	Cross-sectional shape of the tunnel
(T96)Tunnel(Deep well method)	Deep well method
(T122)Tunnel(Detailed survey)	Detailed survey
(T90)Tunnel(Drainage boring)	Drainage boring
(T267)tunnel(drll jambo)	drll jambo
(T159)Tunnel(Earth pressure balance shield method)	Earth pressure balance shield method
(T263)tunnel(earth pressure shield)	earth pressure shield
(T163)Tunnel(edge cutting pipe jacking)	edge cutting pipe jacking
(T273)edge cutting pipe jacking	edge cutting pipe jacking
(T27)Tunnel(Construction equipment-Electrical equipment）	Electrical equipment
(T258)Enlarged sidewall	Enlarged sidewall
(T208)Enlarged sidewall concrete(Protecting concrete wall)	Enlarged sidewall (Protecting concrete wall)
(T193)Tunnel(Enlarged sidewall concrete)	Enlarged sidewall concrete
（T245）tunnel(enlargement)	enlargement
（T244）erection fixture(Temporary Installations)	erection fixture(Temporary Installations)
(T131)Tunnel(Excavation method)	Excavation method

(T28)Tunnel(Excavation methods）	Excavation methods
(T142)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T143)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T144)Tunnel(Explosives: Gunpowder, explosives)	Explosives: Gunpowder, explosives
(T86)Tunnel(Special methods)	facing stabilization measures
(T87)Tunnel(facing stabilization measures-Measures against ground settlement)	facing stabilization measures
(T151)Tunnel(Formwork)	Formwork
(T89)Tunnel(Freezing method)	Freezing method
(T184)Tunnel(Freezing methods)	Freezing methods
(T185)Tunnel(Freezing methods)	Freezing methods
(T111)Tunnel(Full cross-section excavation method)	Full cross-section excavation method
(T200)Tunnel(Full cross-section method)	Full cross-section method
(T191)Tunnel(Full-section advanced construction method)	Full-section advanced construction method
(T29)Tunnel(Excavation methods-Full-section excavation method）	Full-section excavation method
(T270)tunnel(fuse)	fuse
(T11)Tunnel(Geology-Expansion)	Geology-Expansion
(T14)Tunnel(Geology-Geothermal heat）	Geology-Geothermal heat
(T12)Tunnel(Geology-Groundwater and spring water）	Geology-Groundwater and spring water
(T17)Tunnel(Geology-Movement of ground）	Geology-Movement of ground
(T15)Tunnel(Geology-Spouting of natural gas）	Geology-Spouting of natural gas
(T16)Tunnel(Geology-Stress in the ground）	Geology-Stress in the ground
(T13)Tunnel(Geology-Surface water inundation）	Geology-Surface water inundation
（T247）tunnel(glory hole system)	glory hole system
(T177)Tunnel(Injection material: grout)	grout
(T80)Tunnel(Grouting)	Grouting
(T81)Tunnel(Grouting)	Grouting
(T82)Tunnel(Grouting)	Grouting
(T83)Tunnel(Grouting)	Grouting
(T84)Tunnel(Grouting（injection pipe）)	Grouting
(T85)Tunnel(Grouting（injection pipe）)	Grouting
(T178)Tunnel(Grouting)	Grouting
(T179)Tunnel(Grouting)	Grouting
(T274)Tunnel(half section excavation)	half section excavation
(T30)Tunnel(Excavation methods-heading excavation method）	heading excavation method

(T242)Tunnel(heading(guide) drilling)	heading(guide) drilling
(T225)heading(Pilot)	heading(Pilot)
(T264)tunnel(heading(Pilot))	heading(Pilot)
(T209)Immersed tunnel	Immersed tunnel
(T116)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T166)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T167)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T168)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T169)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T170)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T171)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T172)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T173)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T174)Tunnel(immersed tunnel(Hydraulic joint))	immersed tunnel(trench tunnel)
(T175)Tunnel(immersed tunnel(Flexible joint))	immersed tunnel(trench tunnel)
(T216)Tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T262)tunnel(immersed tunnel(trench tunnel))	immersed tunnel(trench tunnel)
(T222)inclined adit :inclined shaft	inclined adit :inclined shaft
(T269)tunnel(Inclined Shaft)	Inclined Shaft
(T88)Tunnel(Injection method)	Injection method
(T176)Tunnel(Injection method/Deviation water drainage method)	Injection method
(T180)Tunnel(Injection method/Detour drainage method)	Injection method/Detour drainage method
(T211)Tunnel(Inner section)	Inner section
(T212)Tunnel(Inner section)	Inner section
(T186)Tunnel(Invert)	Invert
(T235)Tunnel(Invert)	Invert
(T236)Tunnel(Invert)	Invert
(T8)Tunnel(investigation- Hydrous-containing unconsolidated ground)	investigation
(T7)Tunnel(investigation- Fault fracture zone)	investigation- Fault fracture zone
(T9)Tunnel(investigation-Expansive ground)	investigation-Expansive ground
(T10)Tunnel(investigation-High ground pressure, etc)	investigation-High ground pressure, etc
(T5)Tunnel(investigation-Landslides)	investigation-Landslides
(T97)Tunnel(Investigations during construction)	Investigations during construction
(T6)Tunnel(investigation-soil cover)	investigation-soil cover

(T22)Tunnel(Topography-Landslide）	Landslide
(T35)Tunnel(Large section tunnel excavation method）	Large section tunnel excavation method
(T272)tunnel(lining)	lining
(T204)Tunnel(Lining concrete)	Lining concrete
(T44)Tunnel(Loading machines）	Loading machines
(T240)Tunnel(logging)	logging
(T183)Tunnel(Messer method)	Messer method
(T152)Tunnel(traveling form(Mobile formwork))	Mobile formwork)
(T108)Tunnel(Mountain tunnels)	Mountain tunnels
(T145)Tunnel(Tunnel excavation soil treatment(Muck disposal))	Muck disposal
(T46)Tunnel(Muck Handling-Rails and turnouts）	Muck Handling-Rails and turnouts
(T47)Tunnel(Muck Handling-Tire method）	Muck Handling-Tire method
(T48)Tunnel(Muck Handling-Tire method）	Muck Handling-Tire method
(T45)Tunnel(Muck transport method）	Muck transport method
(T255)tunnel(mucking)	mucking
(T256)tunnel(mucking)	mucking
(T158)Tunnel(Muddy water pressurized shield method)	Muddy water pressurized shield method
(T61)Tunnel(NATM（New Austrian Tunneling Method）)	NATM
(T62)Tunnel(NATM（New Austrian Tunneling Method）)	NATM
(T119)Tunnel(NATM (New Austrian Tunneling Method)	NATM (New Austrian Tunneling Method)
(T149)Tunnel(NATM (New Austrian Tunneling Method))	NATM (New Austrian Tunneling Method)
(T197)Tunnel(NATM (New Austrian Tunneling Method))	NATM (New Austrian Tunneling Method)
(T213)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T214)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T215)Tunnel(NATM（New Austrian Tunneling Method）)	NATM（New Austrian Tunneling Method）
(T226)NATM（New Austrian Tunneling Method）	NATM（New Austrian Tunneling Method）
(T42)Tunnel(No-cut method）	No-cut method
(T160)Tunnel(Open cut excavation without timbering)	Open cut excavation without timbering
(T115)Tunnel(Open cut method)	Open cut method
（T253）open cut method	open cut method
(T161)Tunnel(Open cut method Full-section)	Open cut method Full-section
（T243）open cut・trench method	open cut・trench method
(T121)Tunnel(Outline survey)	Outline survey
(T162)Tunnel(Partial excavation method (trench method))	Partial excavation method (trench method)

(T188)Tunnel(Payment line)	Payment line
(T205)Tunnel(payment lines)	payment lines
(T224)pipe jacking method(Middle push-out method)	pipe jacking method(Middle push-out method)
(T223)pipe jacking method(Tensioning method)	pipe jacking method(Tensioning method)
(T181)Tunnel(Pipe parallel /Messer method)	Pipe parallel /Messer method
(T182)Tunnel(Pipe parallel method)	Pipe parallel method
(T92)Tunnel(Pipe roof methods)	Pipe roof methods
(T271)tunnel(pipe roofing protection)	pipe roofing protection
（T249）tunnel(pit)	pit
(T231)Tunnel(pneumatic method)	pneumatic method
(T251)Portal -pit gate	Portal -pit gate
(T43)Tunnel(Precautions for blasting）	Precautions for blasting
(T239)Tunnel(pumice-stone(Floating stones))	pumice-stone(Floating stones)
(T187)Tunnel(Return packing)	Return packing
(T34)Tunnel(Excavation method-Ring cut method）	Ring cut method
(T56)Tunnel(Rock Bolt)	Rock Bolt
(T57)Tunnel(Rock Bolt)	Rock Bolt
(T58)Tunnel(Rock Bolt)	Rock Bolt
(T147)Tunnel(Rock bolt)	Rock bolt
(T36)Tunnel(Rock drilling）	Rock drilling
(T37)Tunnel(Rock drilling）	Rock drilling
(T38)Tunnel(Rock drilling）	Rock drilling
（T246）tunnel(segmental arch timber)	segmental arch timber
(T164)Tunnel(Semi-shield pipe jacking method)	Semi-shield pipe jacking method
(T194)Tunnel(Shaft)	Shaft
(T220)shield tunneling	shield tunneling
(T112)Tunnel(Shield construction method)	Shield construction method
(T155)Tunnel(Shield method)	Shield method
(T165)Tunnel(shield -pipe jacking method)	shield -pipe jacking method
(T207)Tunnel(Shield tunnel)	Shield tunnel
(T156)Tunnel(Shield tunneling)	Shield tunneling
(T206)Tunnel(Short step system)	Short step system
(T275)Tunnel(shot crete)	shot crete
(T59)Tunnel(Shotcrete-Dry system diagram)	Shotcrete

(T60)Tunnel(Shotcrete-Wet system diagram)	Shotcrete
(T254)tunnel(shunt heading)	shunt heading
(T203)Tunnel(Side wall guide shaft advanced upper half section construction method)	Side wall guide shaft advanced upper
(T135)Tunnel(Side wall heading(guide) tunnel advance)	Side wall heading(guide) tunnel advance
(T32)Tunnel(Side wall heading(pilot) tunnel advanced upper half section excavation method)	Side wall heading(pilot) tunnel advanced
(T192)Tunnel(Side wall heading(Pilot) tunnel excavation work advanced upper half section method)	Side wall heading(Pilot) tunnel excavation work
(T199)Tunnel(Sidewall heading tunnel advanced ring cut construction method)	Sidewall heading tunnel advanced ring
(T127)Tunnel(Slope)	Slope
(T195)Tunnel(Soil cover)	Soil cover
(T93)Tunnel(Special steel sheet pile jacking method)	Special steel sheet pile jacking method
(T148)Tunnel(Sprayed concrete(Shotcrete))	Sprayed concrete(Shotcrete)
(T53)Tunnel(Steel arch supports)	Steel arch supports
(T54)Tunnel(Steel arch supports)	Steel arch supports
(T55)Tunnel(Steel arch supports)	Steel arch supports
(T248)tunnel(steel centre)	steel centre
(T146)Tunnel(Support)	Support
(T221)support(timbering)	support(timbering)
(T25)Tunnel(Construction equipment-surface installations)	surface installations
(T125)Tunnel(Survey after completion)	Survey after completion
(T123)Tunnel(Surveys before construction)	Surveys before construction
(T124)Tunnel(Surveys during construction)	Surveys during construction
(T227)Tunnel(swelling heaving)	swelling heaving
(T228)Tunnel(swelling heaving)	swelling heaving
(T229)Tunnel(swelling heaving)	swelling heaving
(T210)Tunnel(telescopic form)	telescopic form
(T1)The Role of the Tunnel	The Role of the Tunnel
(T2)The Role of the Tunnel	The Role of the Tunnel
(T3)The Role of the Tunnel	The Role of the Tunnel
(T219)Thickness of lining	Thickness of lining
(T265)tunnel(timbering of heading)	timbering of heading
(T51)Tunnel(timbering(support))	timbering(support)
(T52)Tunnel(timbering(support))	timbering(support)
(T261)tunnel(top heading of tunnel construction)	top heading of tunnel construction
(T18)Tunnel(Topography-Fault zone)	Topography-Fault zone

(T19)Tunnel(Topography-Folds）	Topography-Folds
(T20)Tunnel(Topography-Terraces）	Topography-Terraces
(T118)Tunnel(traveling form form)	traveling form form
(T234)Tunnel(traveling form(Mobile formwork))	traveling form(Mobile formwork)
(T266)tunnel(trolley(Earth transport vehicle))	trolley(Earth transport vehicle)
(T101)Tunnel(Tunnel alignment)	Tunnel alignment
(T196)Tunnel(Tunnel axis direction)	Tunnel axis direction
(T137)Tunnel(tunnel boring machine)	tunnel boring machine
(T23)Tunnel(Construction plan-Tunnel design）	Tunnel design
(T26)Tunnel(Construction equipment-tunnel equipment）	tunnel equipment
(T102)Tunnel(Tunnel gradient)	Tunnel gradient
(T103)Tunnel(Tunnel gradient)	Tunnel gradient
(T104)Tunnel(Tunnel gradient)	Tunnel gradient
(T132)Tunnel(tunnel section)	tunnel section
(T100)Tunnel(Tunnel survey)	Tunnel survey
(T120)Tunnel(Tunnel survey)	Tunnel survey
(T268)tunnel(tunnel surveying)	tunnel surveying
(T39)Tunnel(cut）	Tunnel(cut）
(T40)Tunnel(cut）	Tunnel(cut）
(T95)Tunnel(Downward bolt from the ground)	Tunnel(Downward bolt from the ground
(T98)Tunnel(Expansive ground)	Tunnel(Expansive ground)
(T4)Tunnel(investigation)	Tunnel(investigation)
(T99)Tunnel(Weathered rock zone)	Tunnel(Weathered rock zone)
（T250）tunnel(undermining blast method)	undermining blast method
(T110)Tunnel(Underwater tunnels)	Underwater tunnels
(T190)Tunnel(Upper half section advanced construction method)	Upper half section advanced construction
(T136)Tunnel(Upper half section excavation method)	Upper half section excavation method
(T201)Tunnel(Upper half section ring excavation method)	Upper half section ring excavation method
(T260)tunnel(upraise)	upraise
(T109)Tunnel(Urban tunnels)	Urban tunnels
(T49)Tunnel(ventilation）	ventilation
(T50)Tunnel(ventilation）	ventilation
(T237)Tunnel(wall plate)	wall plate
(T238)Tunnel(Wall plate type support(timbering))	Wall plate type support(timbering)

(T154)Tunnel(waterproof・drainage pipes)	waterproof・drainage pipes
(T218)Waterproofing sheet	Waterproofing sheet
(T257)tunnel(wedging)	wedging
(T91)Tunnel(Well point method)	Well point method

(T1)The Role of the Tunnel

(T1)The Role of the Tunnel

The Role of the Tunnel

①Railway tunnel

②Road tunnel

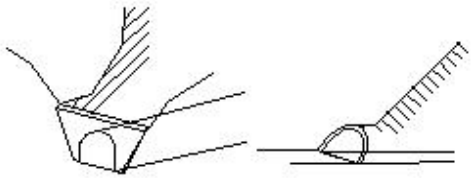
③Waterway tunnel (irrigation/power generation)

④Water supply/sewerage tunnel

⑤Electricity/hydroelectric power generation tunnel

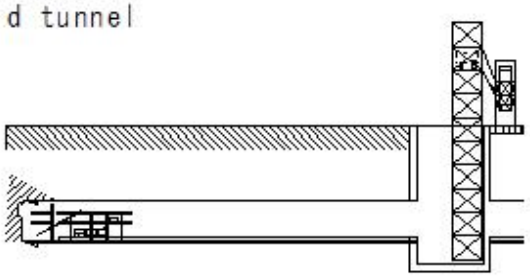
⑥Storage tunnel

Tunnel entrance stance



C1317

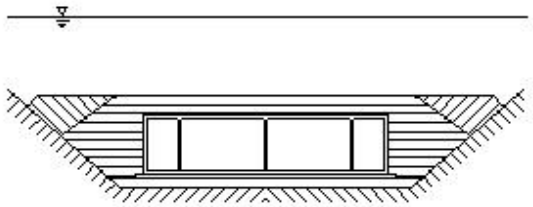
shield tunnel



C1051

M420

immersed tunnel



C1072

(T2)The Role of the Tunnel

(T2)The Role of the Tunnel

The Role of the Tunnel

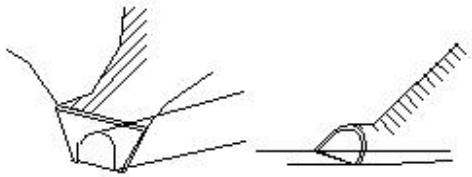
Construction location

① Mountain tunnels

② Urban tunnels

③ Undersea tunnels

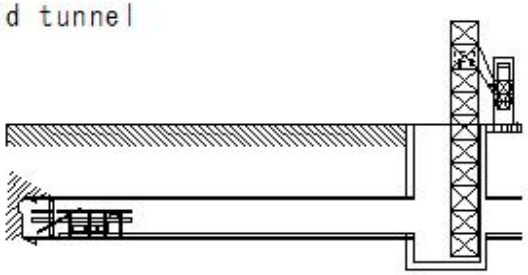
Tunnel entrance stance



① Mountain tunnels

C1317

shield tunnel

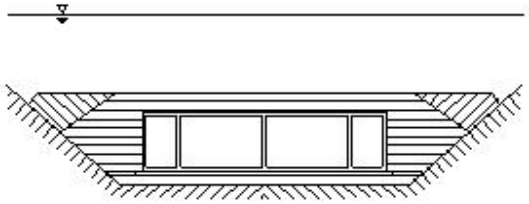


② Urban tunnels

C1051

M420

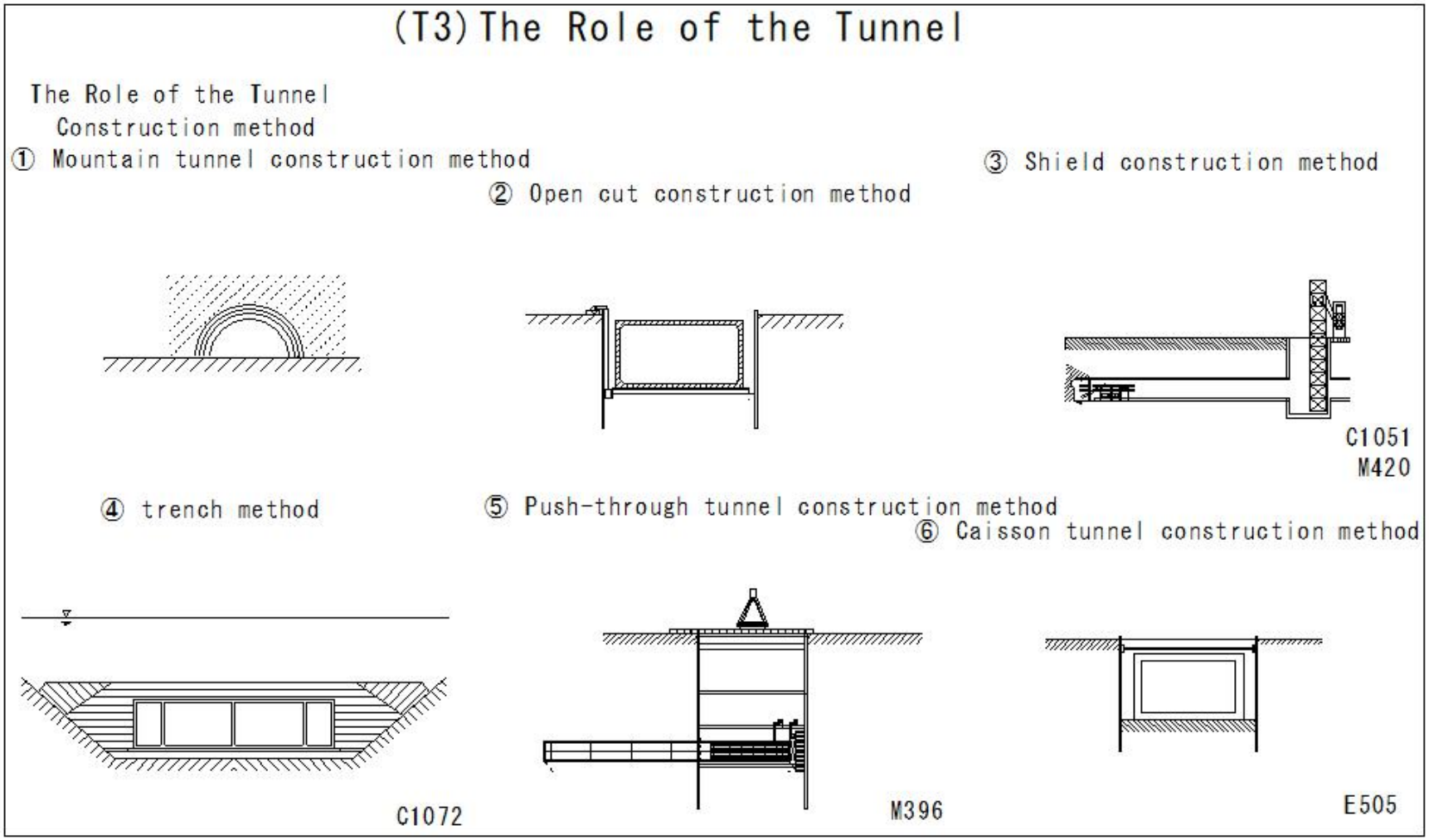
immersed tunnel



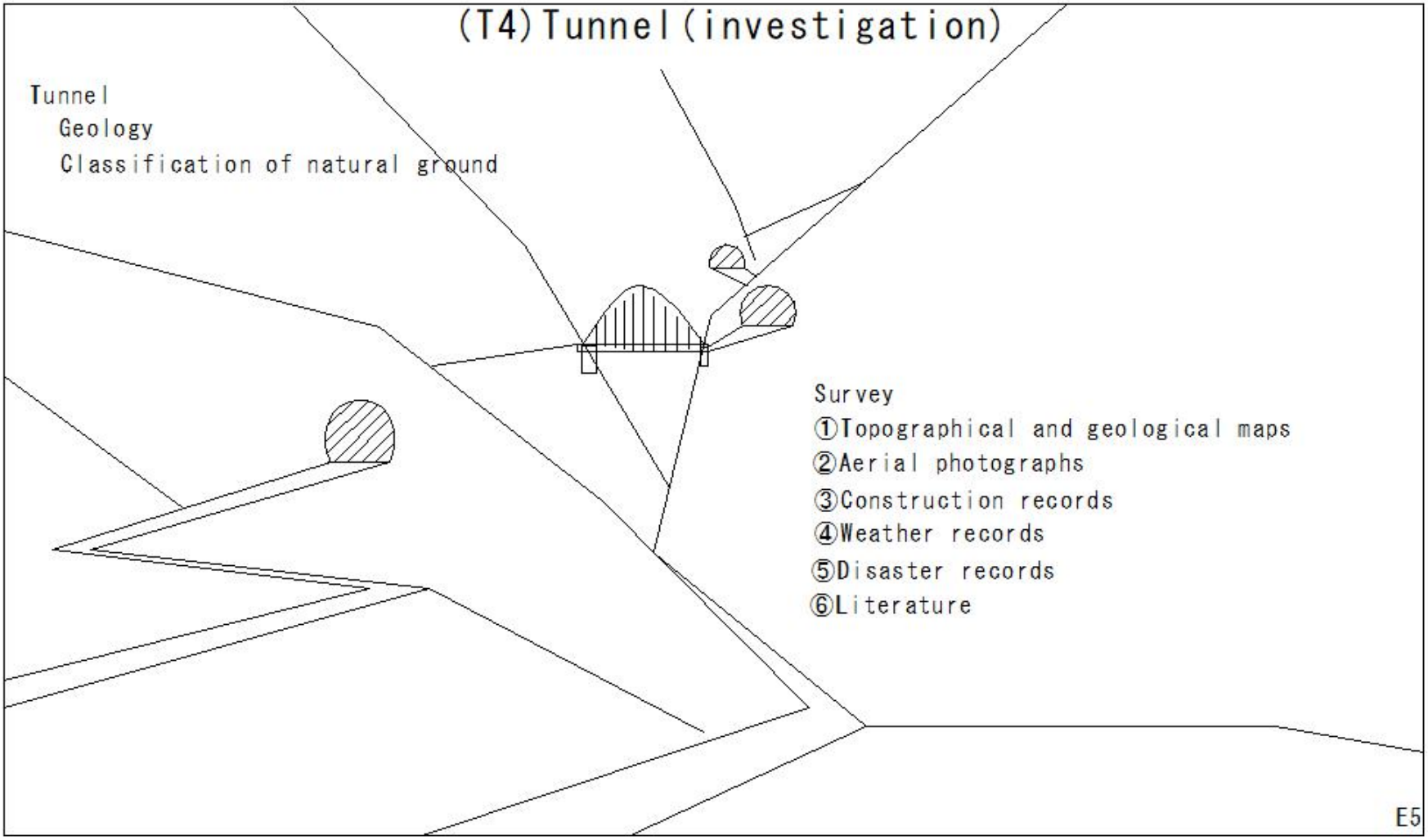
③ Undersea tunnels

C1072

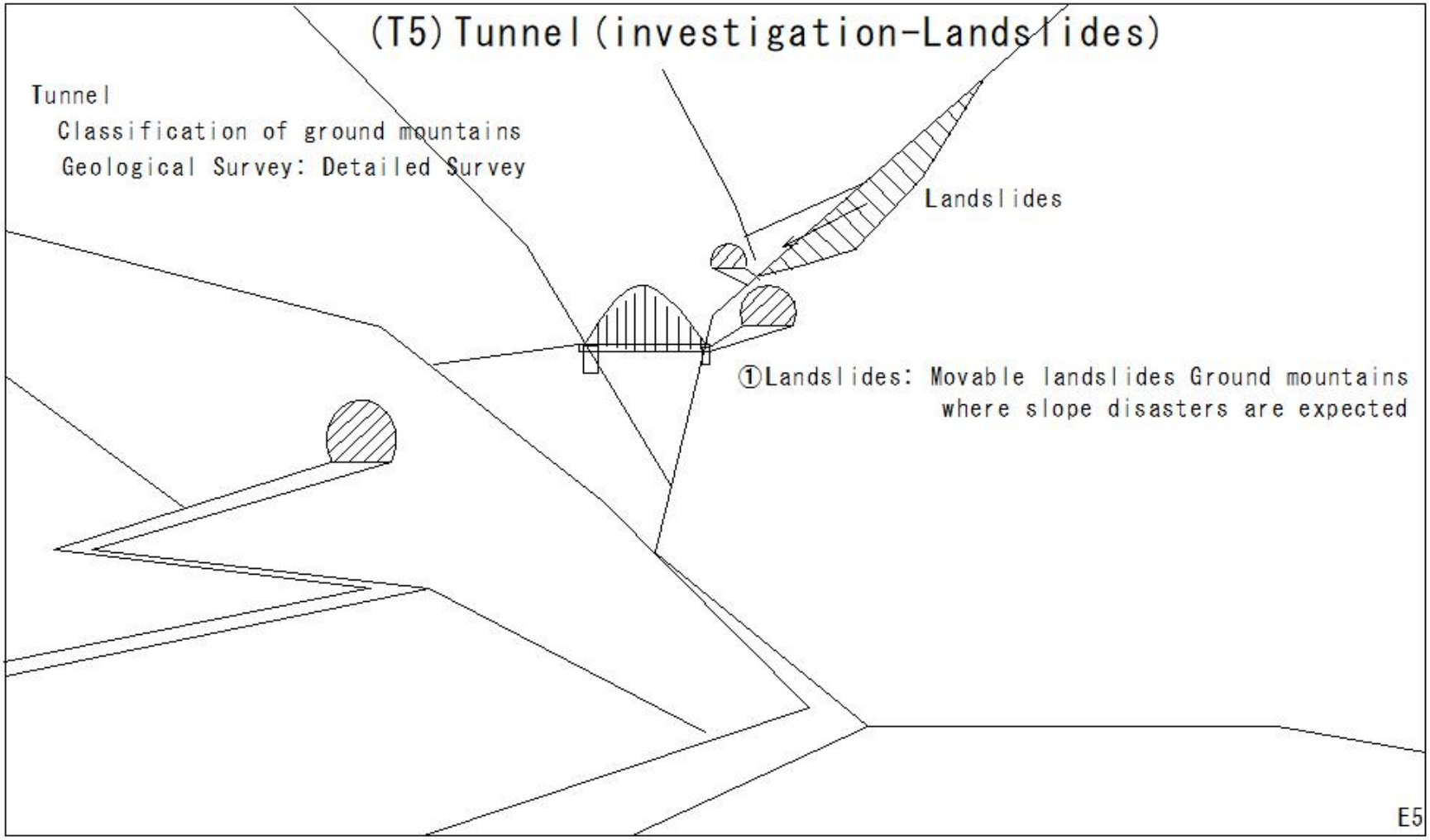
(T3)The Role of the Tunnel



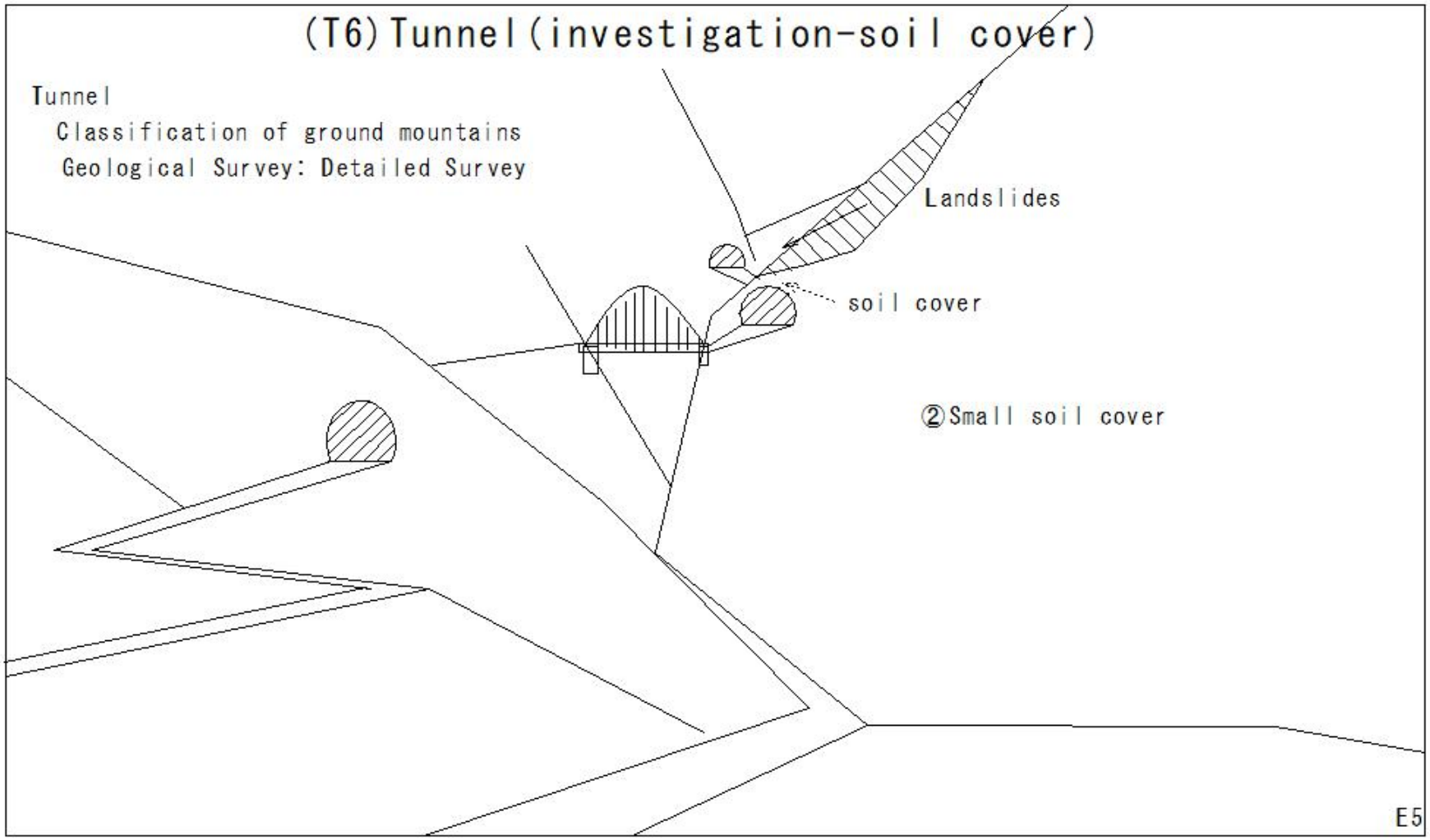
(T4)Tunnel(investigation)



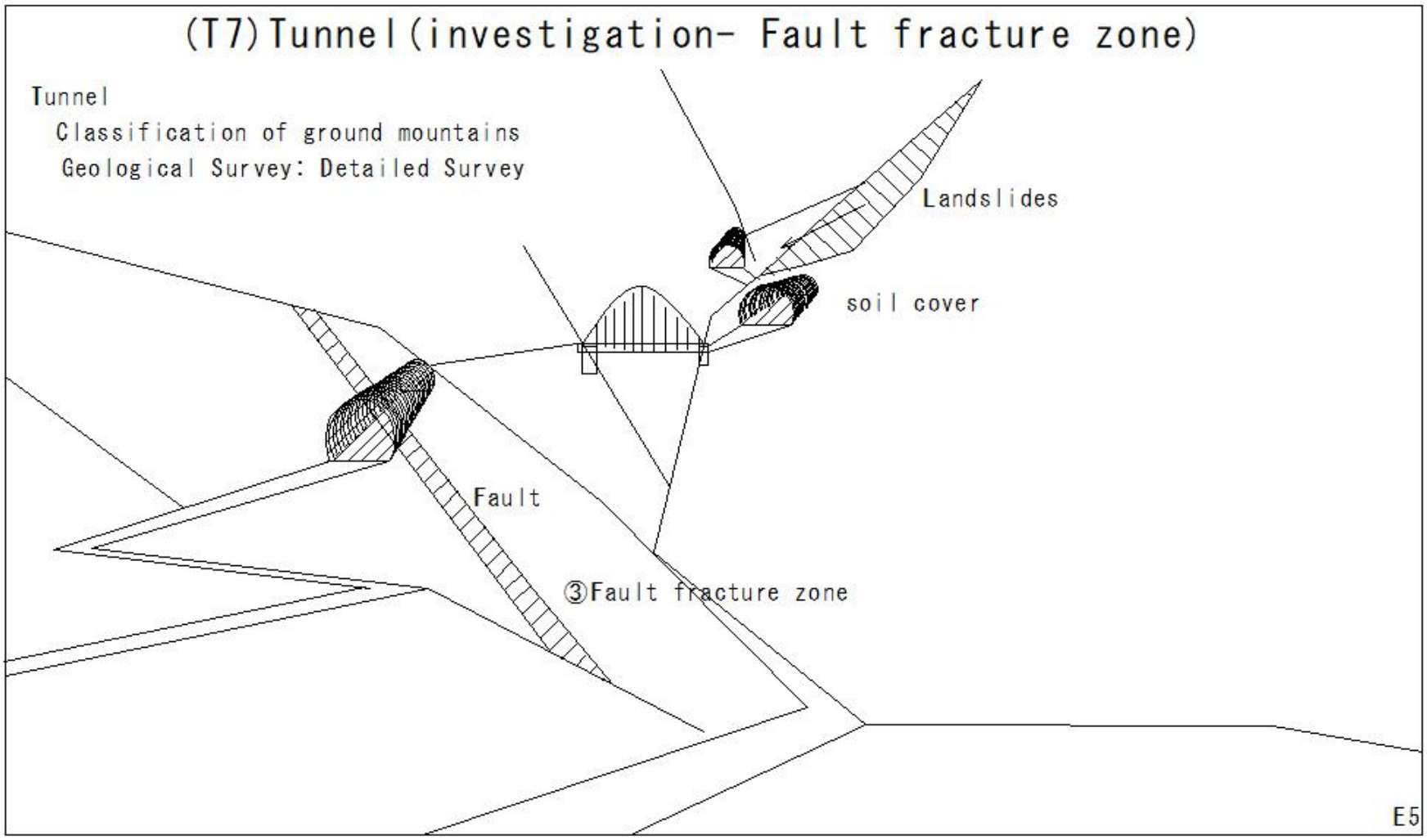
(T5)Tunnel(investigation-Landslides)



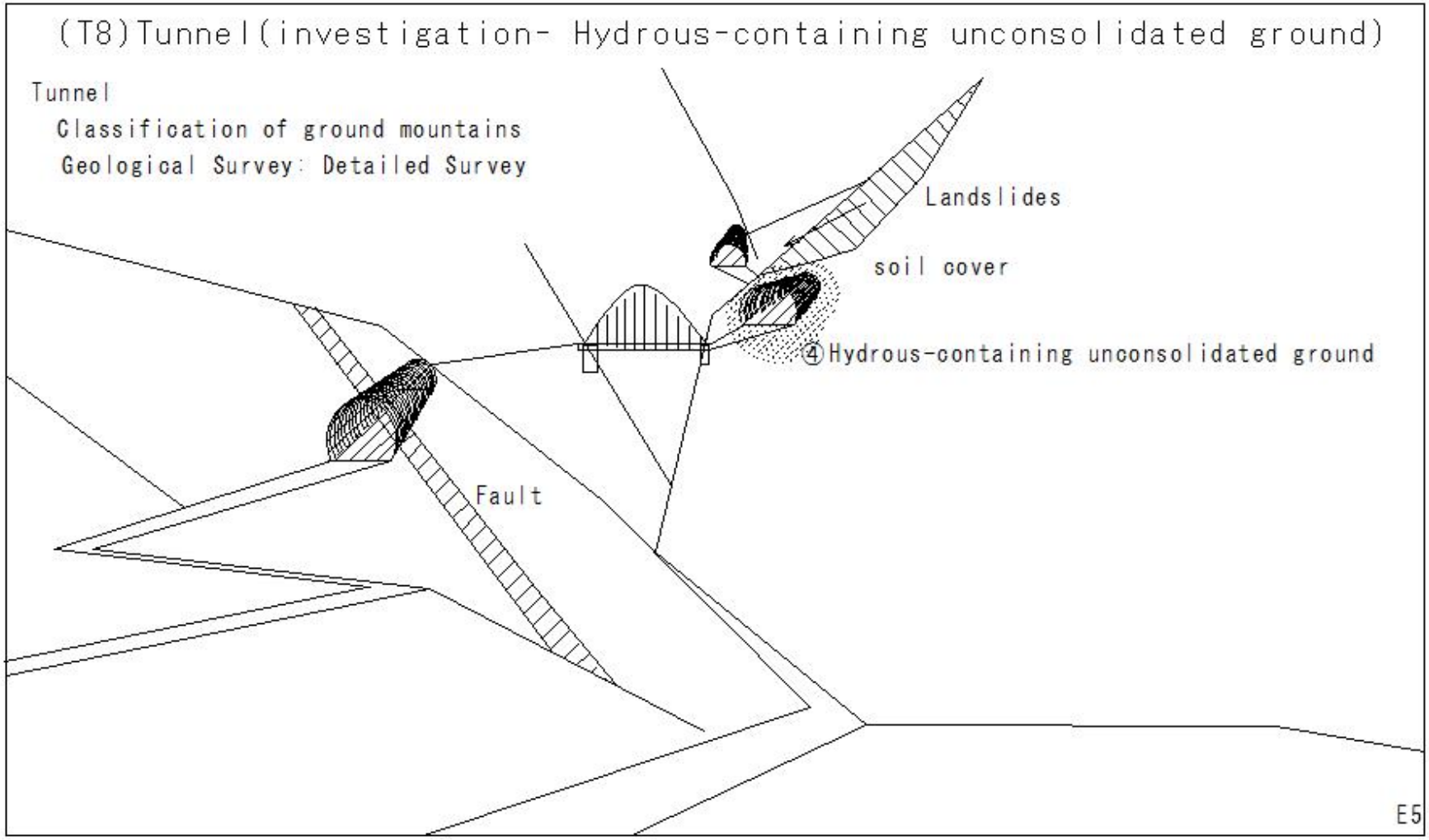
(T6)Tunnel(investigation-soil cover)



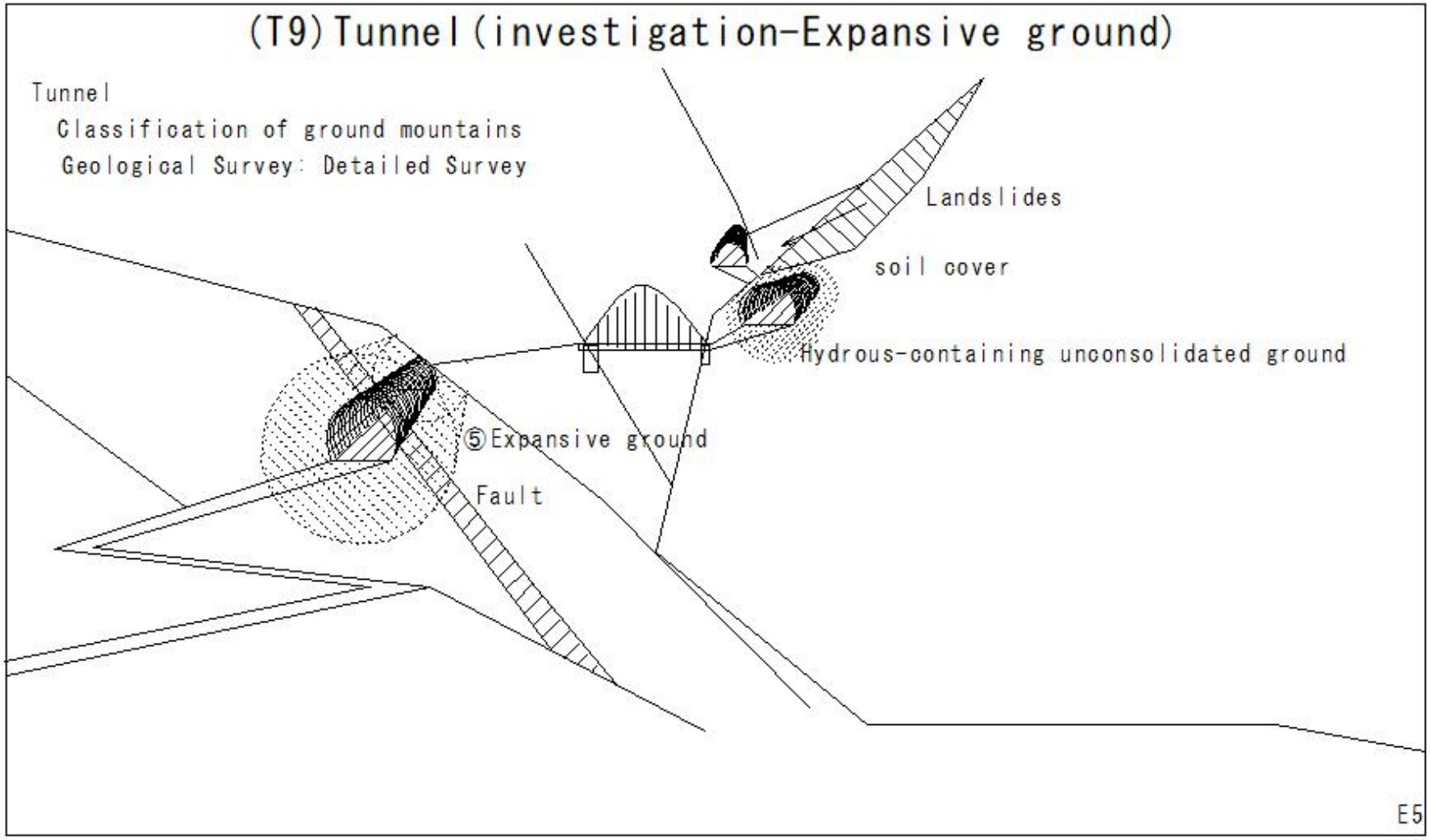
(T7)Tunnel(investigation- Fault fracture zone)



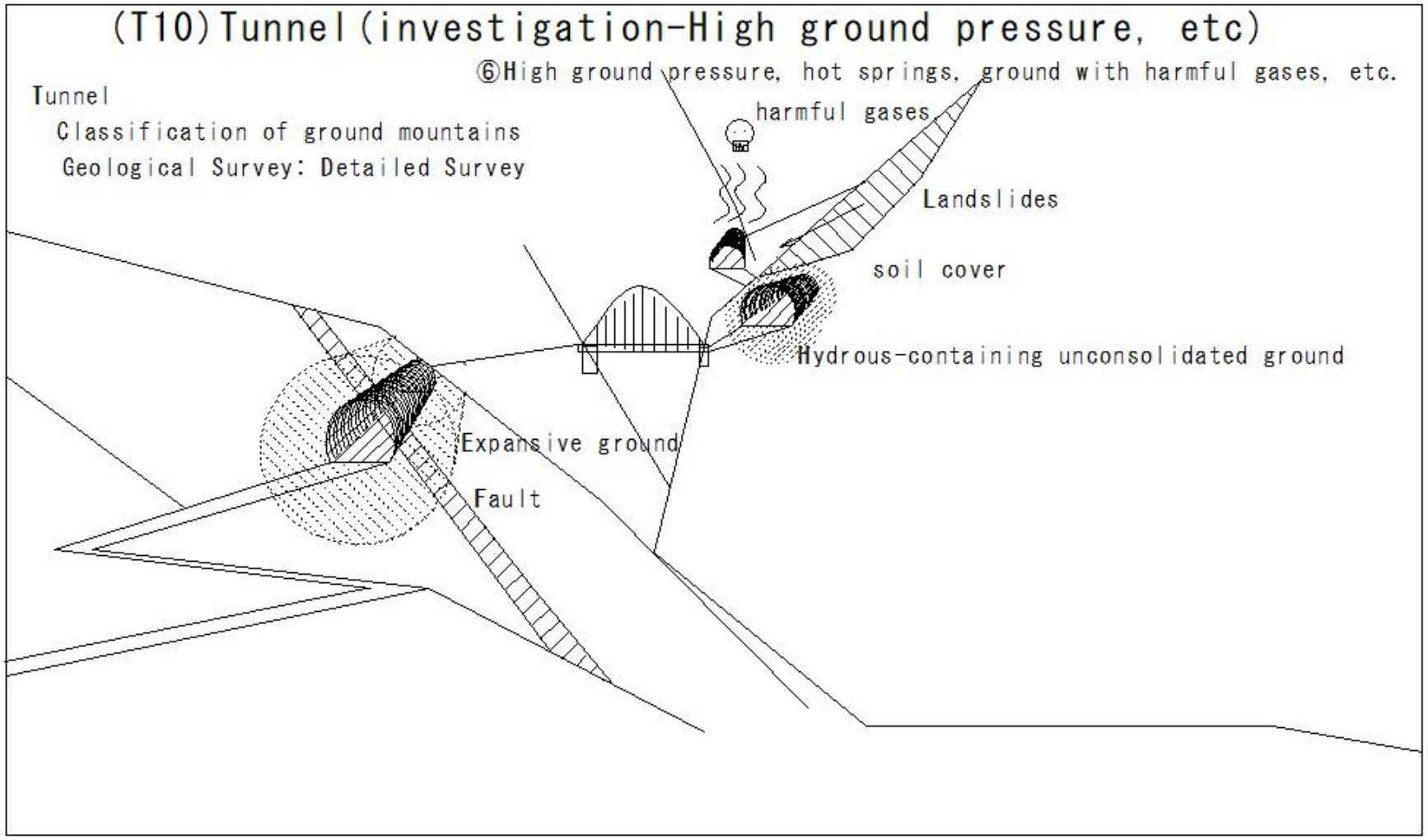
(T8)Tunnel(investigation- Hydrous-containing unconsolidated soil)



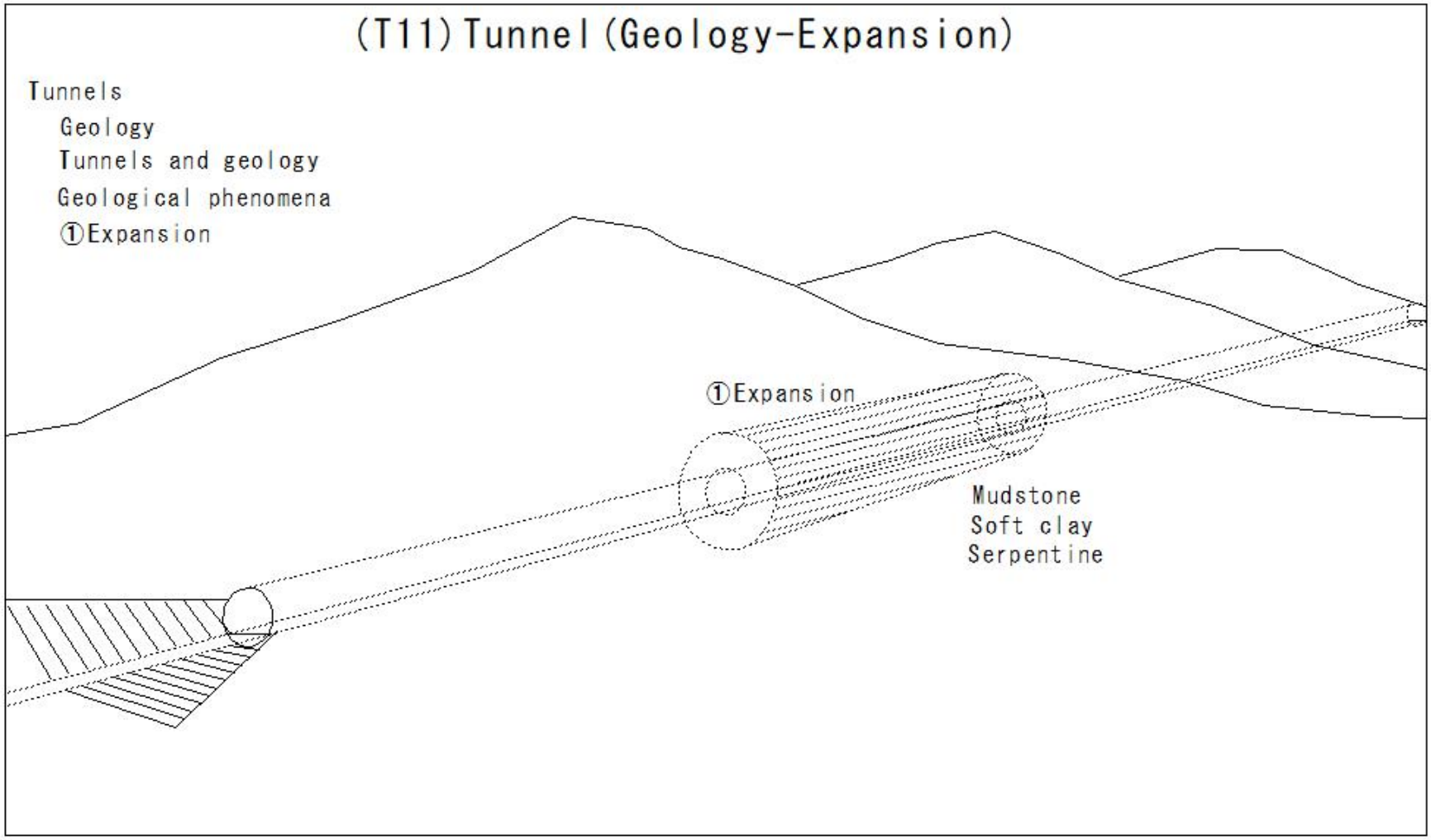
(T9)Tunnel(investigation-Expansive ground)



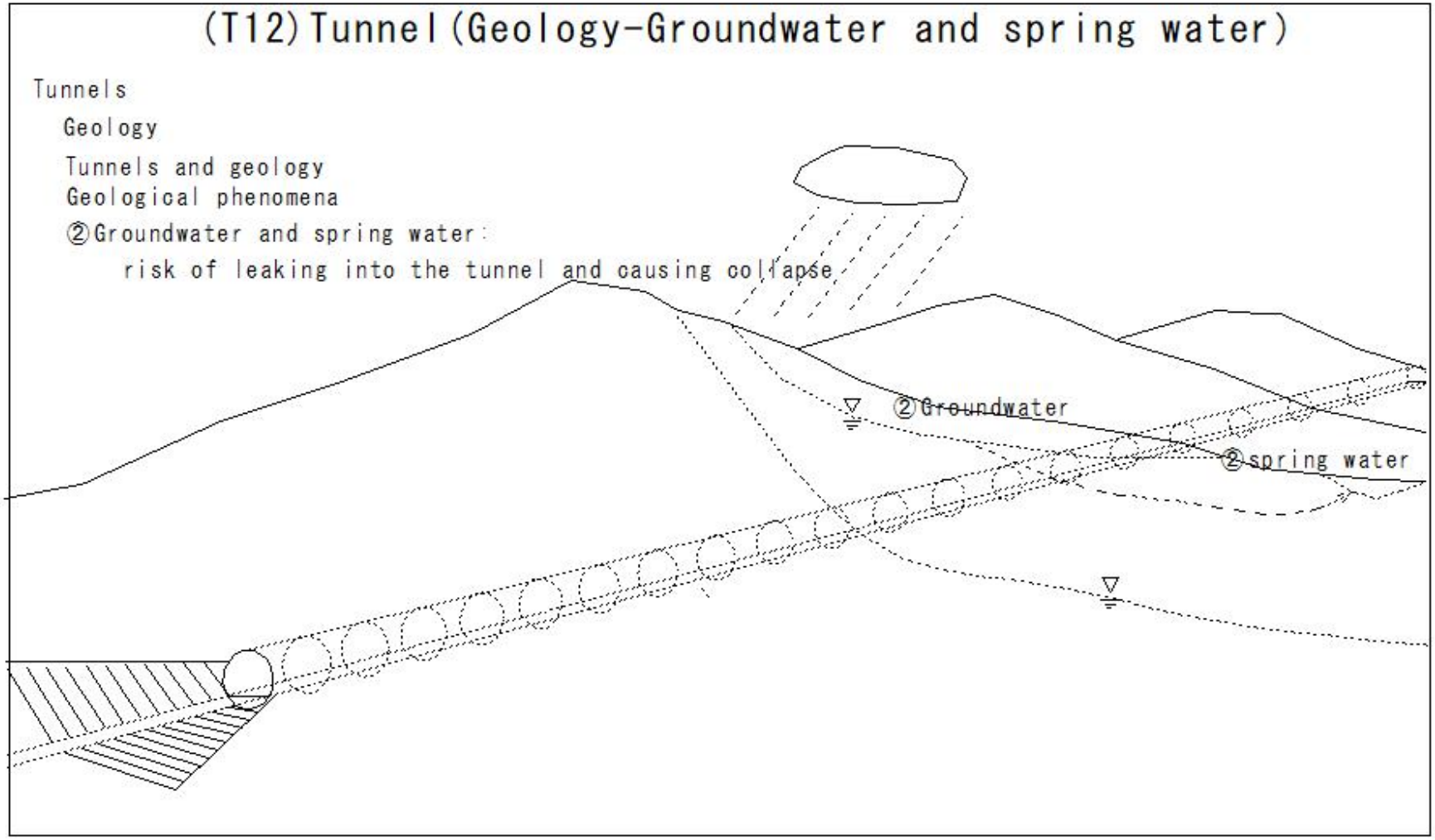
(T10)Tunnel(investigation-High ground pressure, etc)



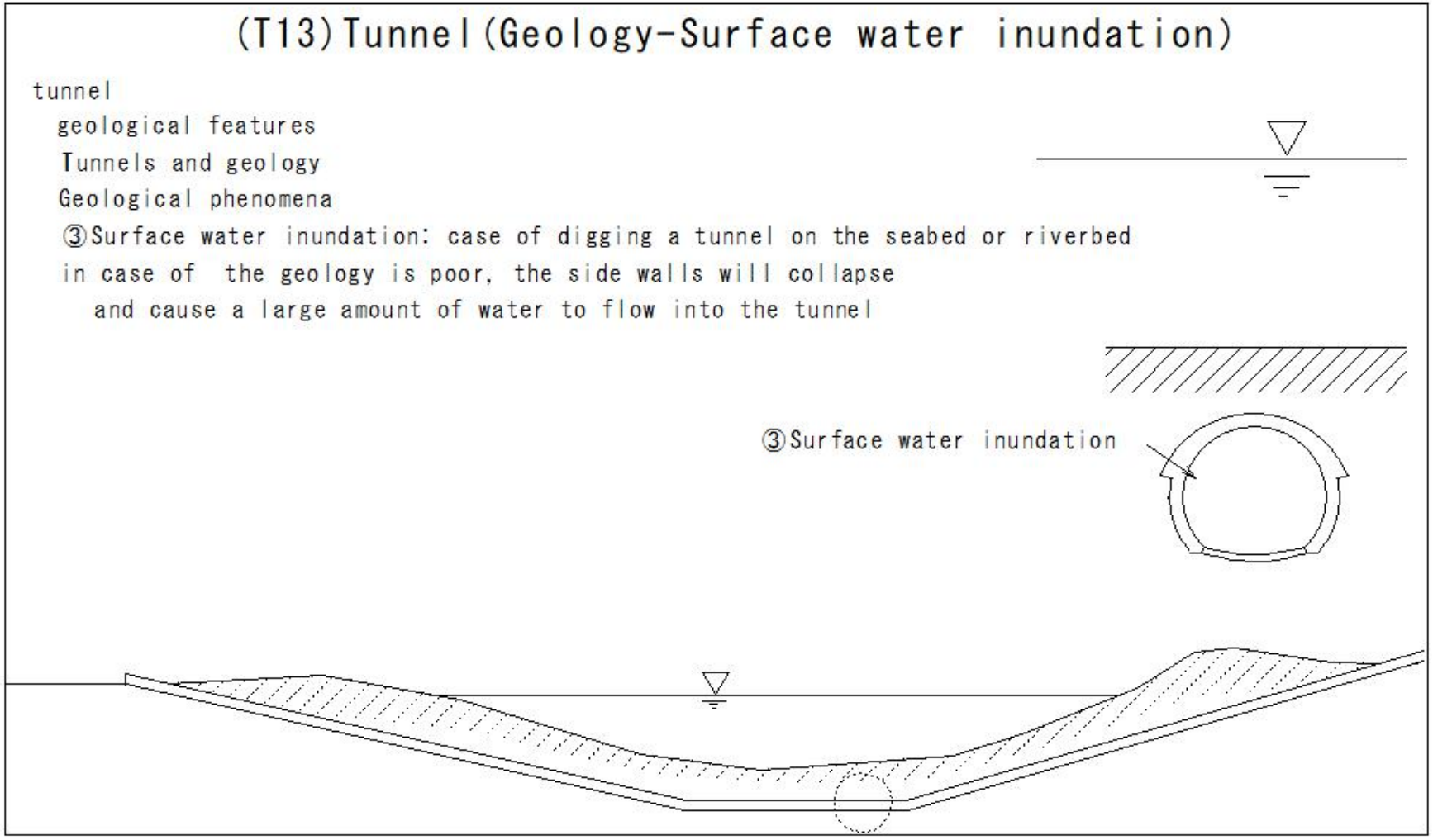
(T11)Tunnel(Geology-Expansion)



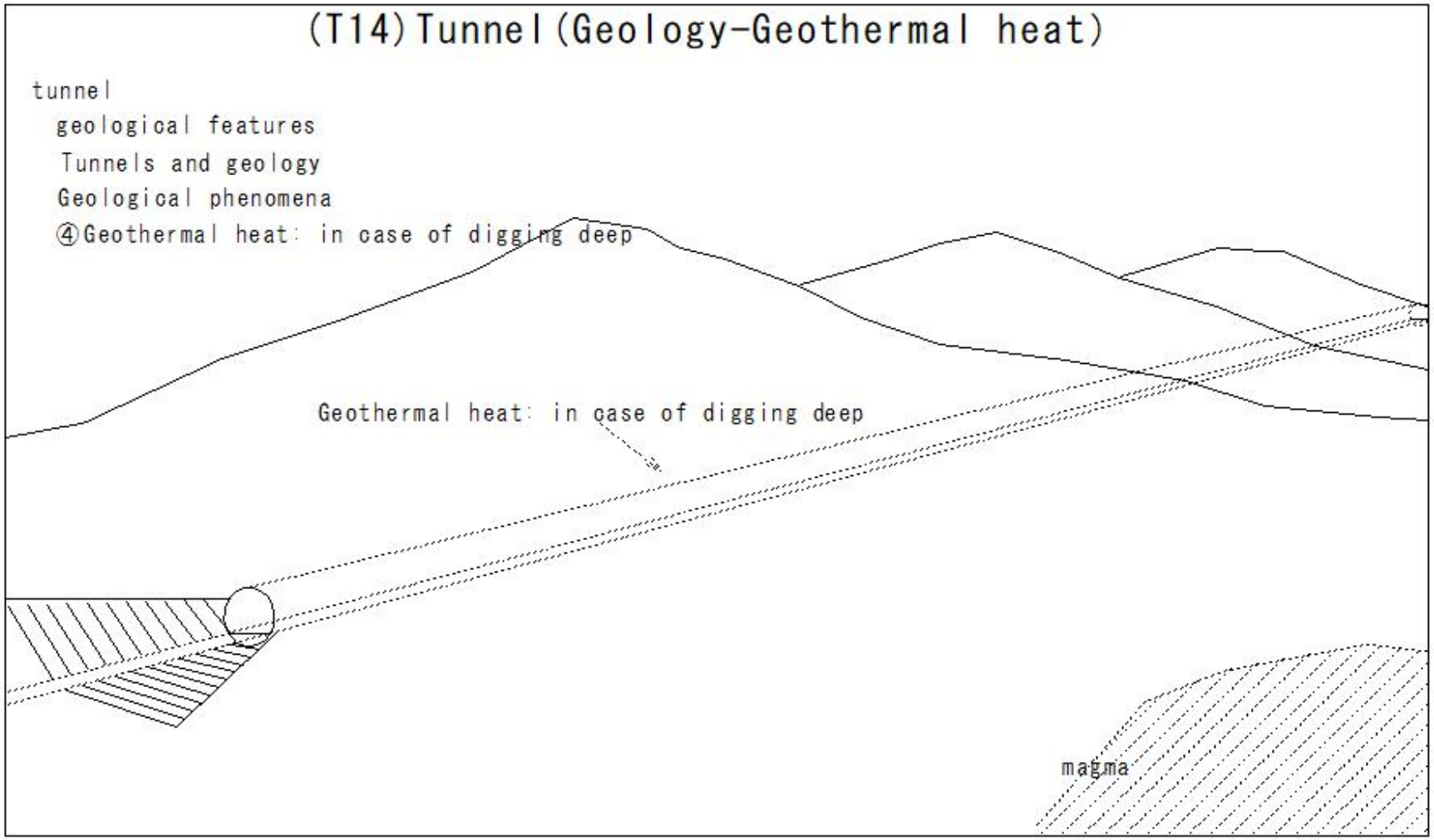
(T12)Tunnel(Geology-Groundwater and spring water)



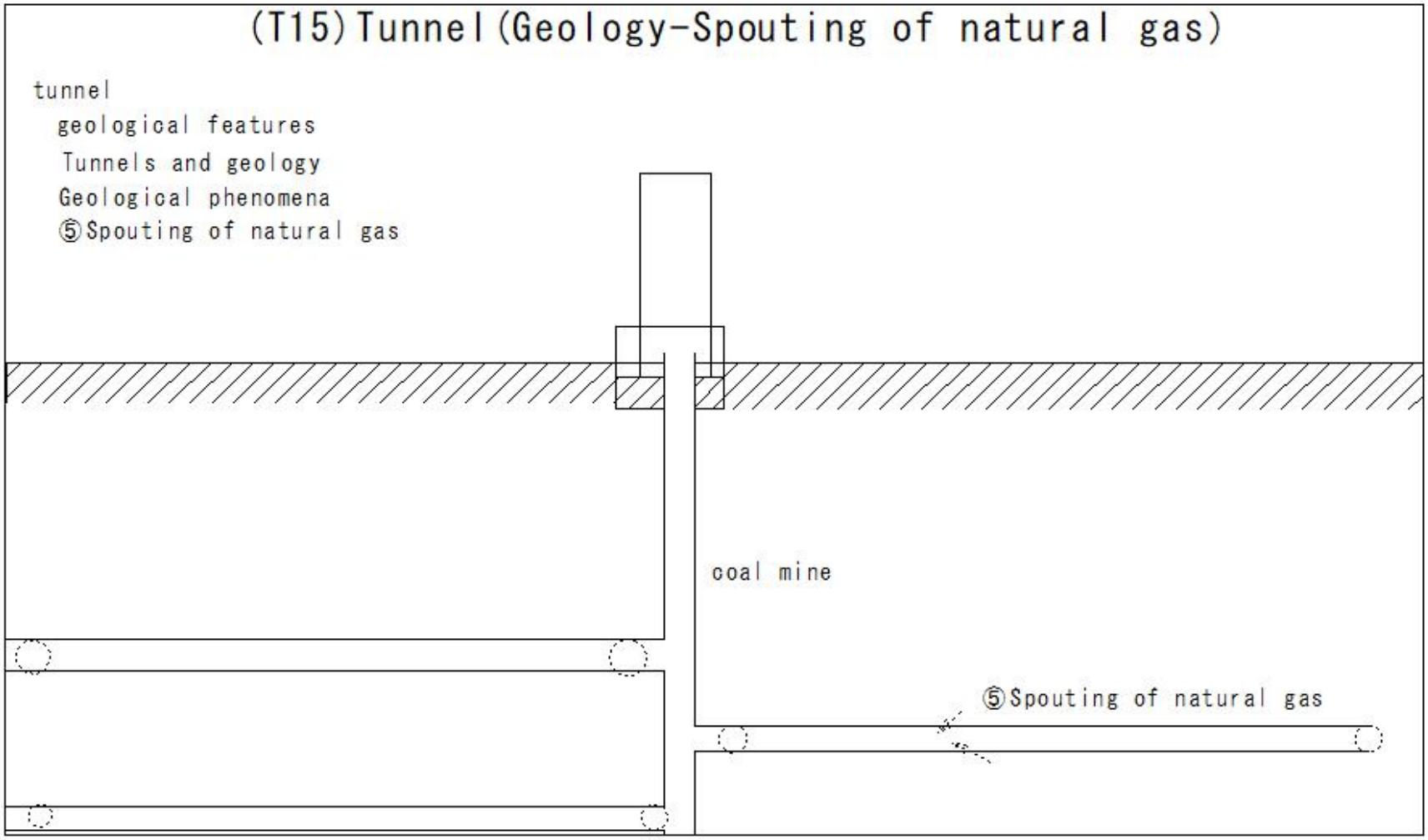
(T13)Tunnel(Geology-Surface water inundation）



(T14)Tunnel(Geology-Geothermal heat)



(T15)Tunnel(Geology-Spouting of natural gas）



(T16)Tunnel(Geology-Stress in the ground）

(T16)Tunnel(Geology-Stress in the ground)

tunnel

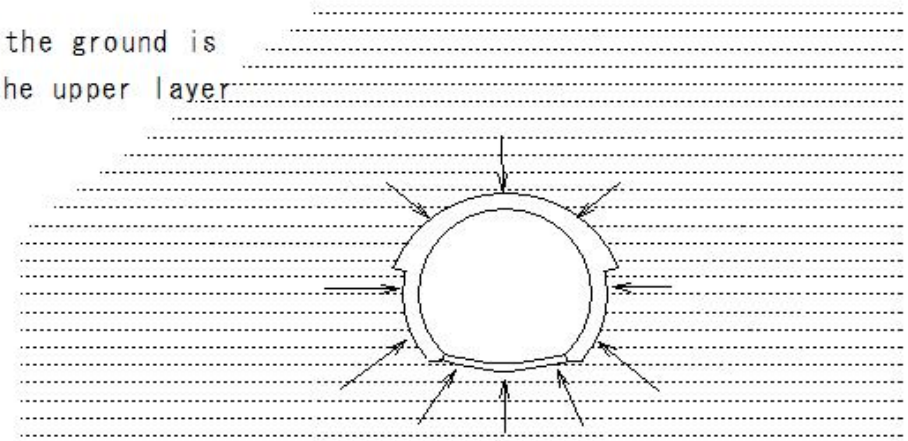
geological features

Tunnels and geology

Geological phenomena

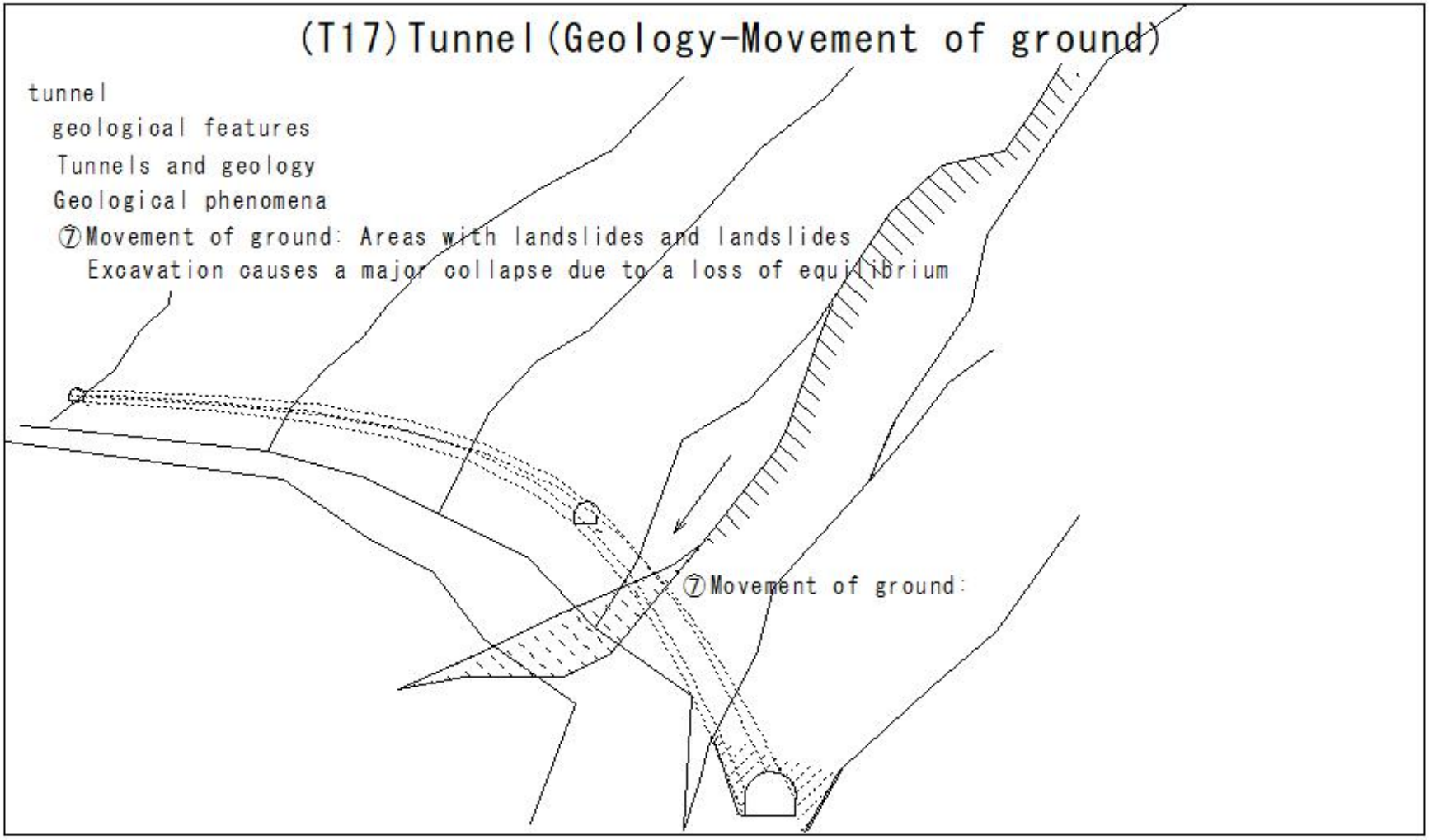
⑥Stress in the ground: The lower layer of the ground is subjected to pressure from the weight of the upper layer

Landburst phenomenon

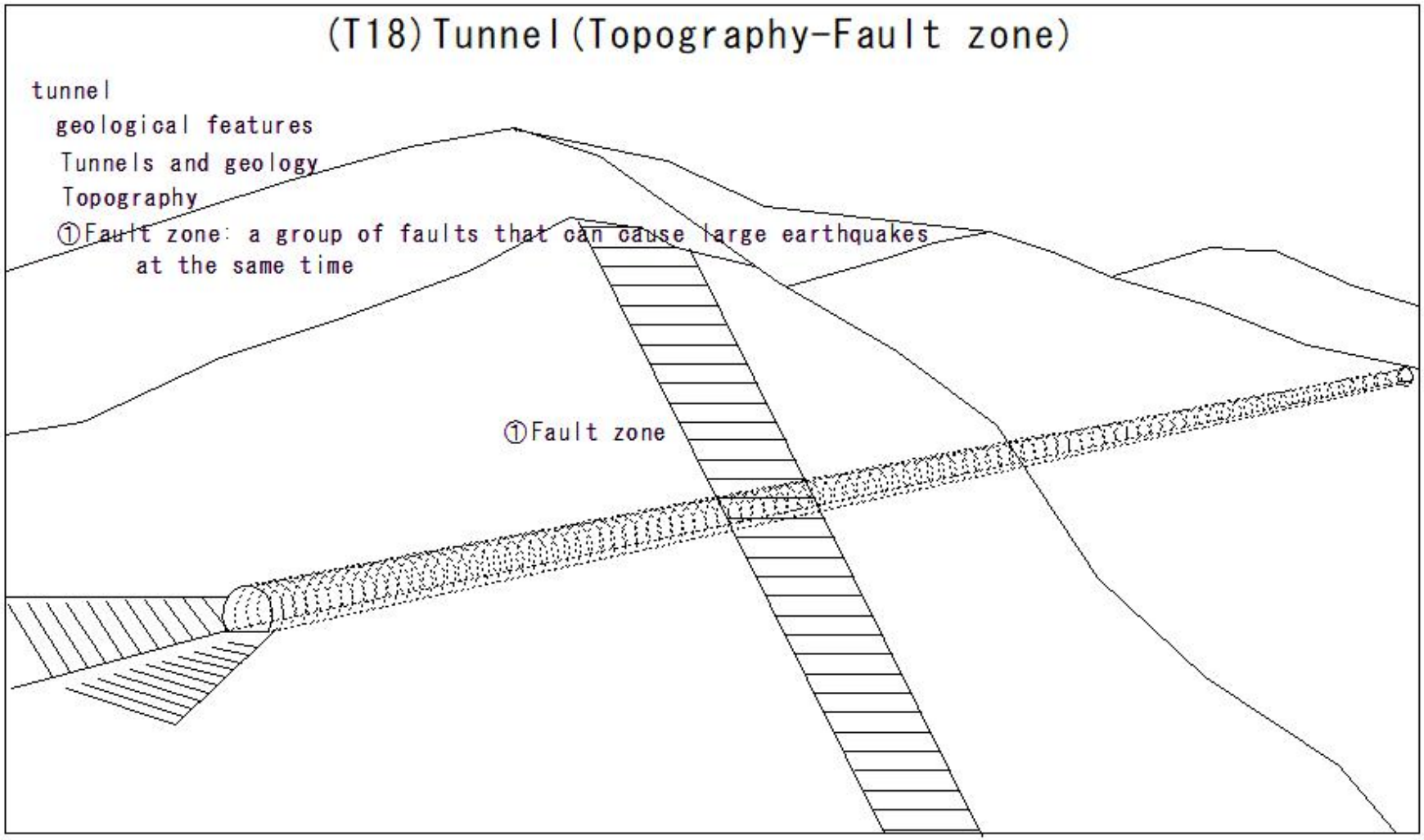


⑥Stress in the ground:

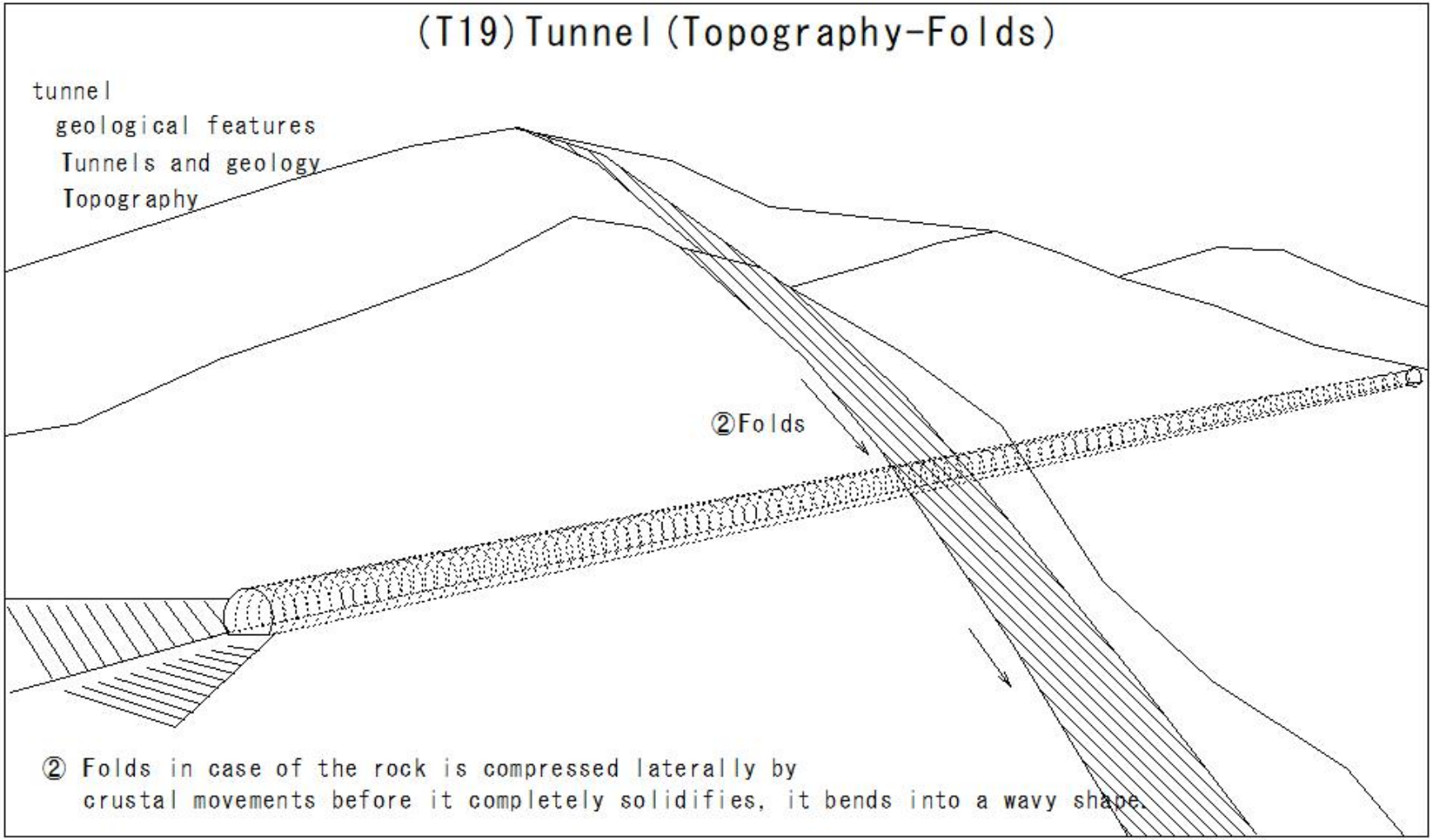
(T17)Tunnel(Geology-Movement of ground）



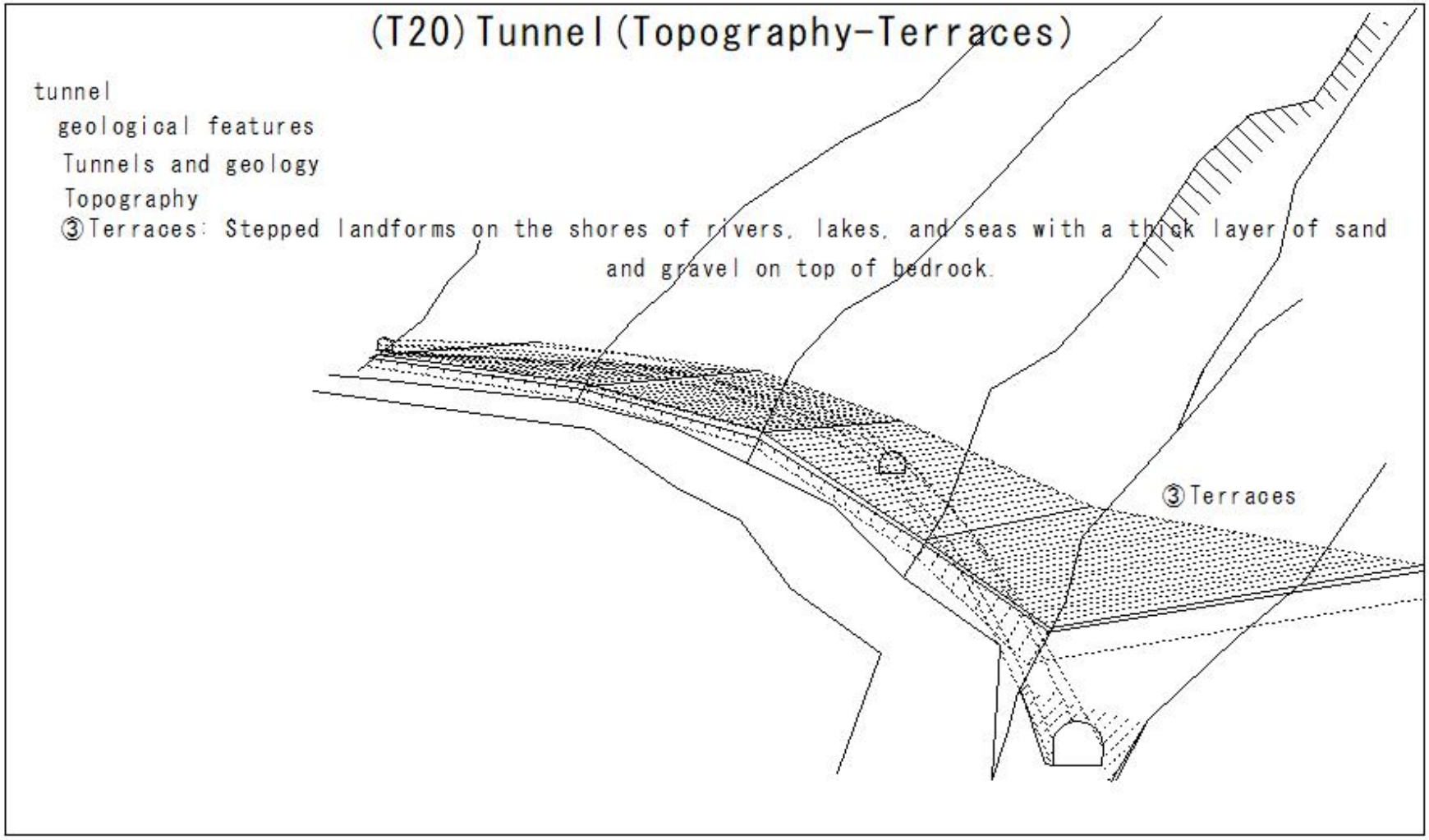
(T18)Tunnel(Topography-Fault zone）



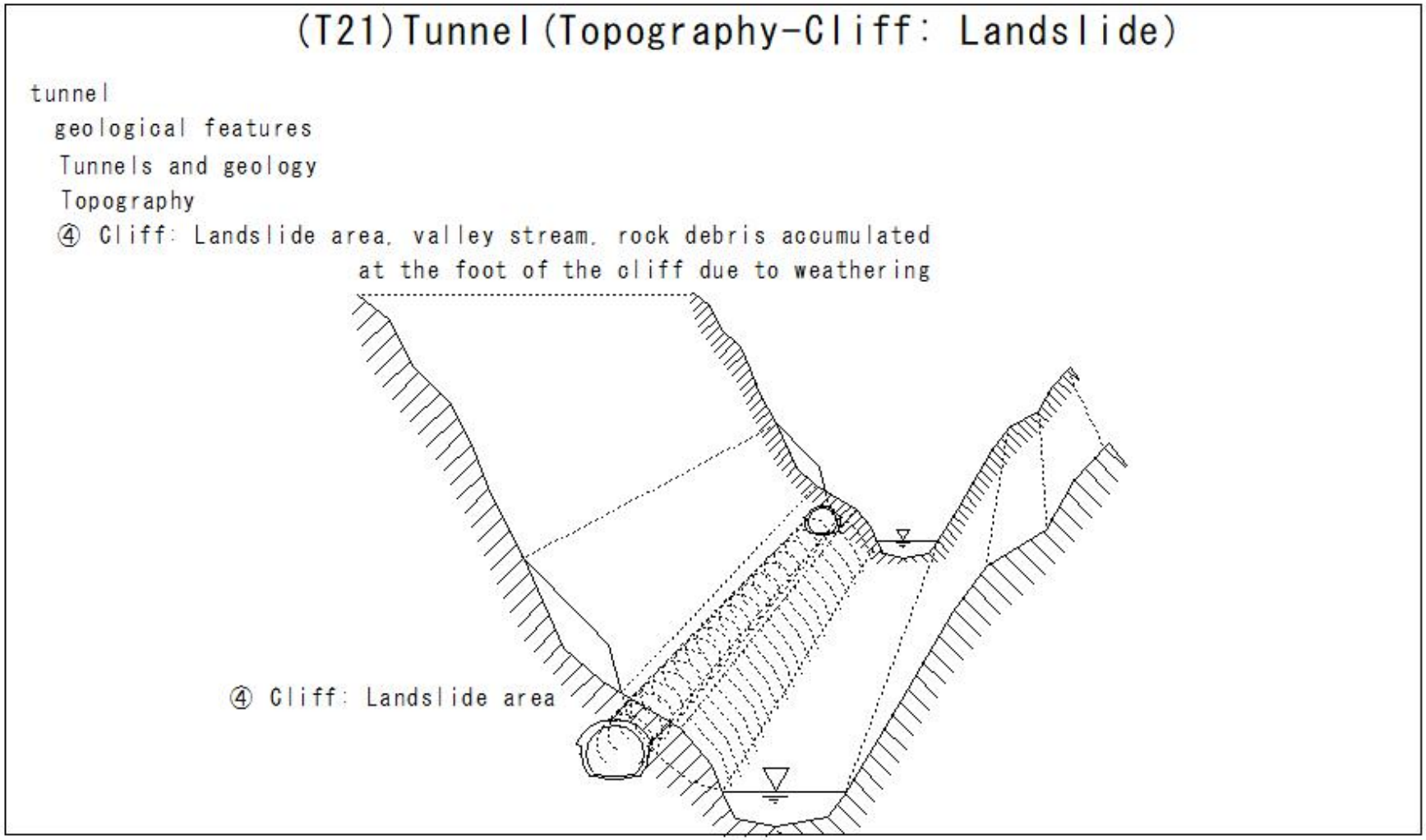
(T19)Tunnel(Topography-Folds）



(T20)Tunnel(Topography-Terraces)



(T21)Tunnel(Topography-Cliff: Landslide）



(T22)Tunnel(Topography-Landslide）

(T22) Tunnel (Topography-Landslide)

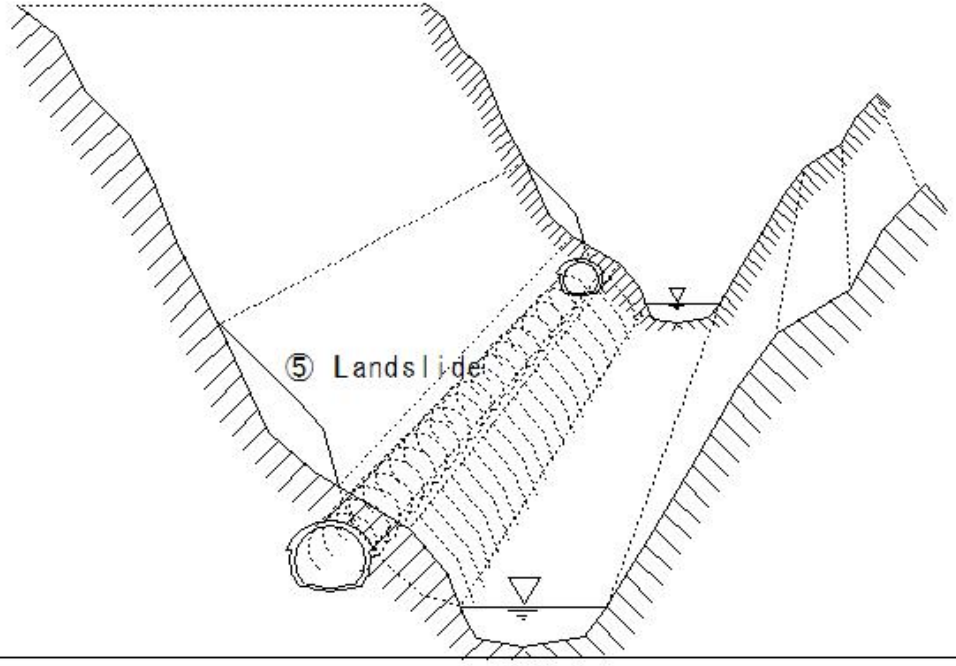
tunnel

geological features

Tunnels and geology

Topography

⑤ Landslide: Land that has moved due to a landslide or landslide in the past



(T23)Tunnel(Topography-design）

(T23)Tunnel(Topography-design)

Tunnel

Construction plan

① Tunnel design

・Support and Coverings (lining)

・Horizontal alignment - Straight line

・Curve radius - Large

・Drainage gradient: 0.3-0.5%

・Undersea tunnel, both entrances, downward gradient

・Width Height: 2m or more

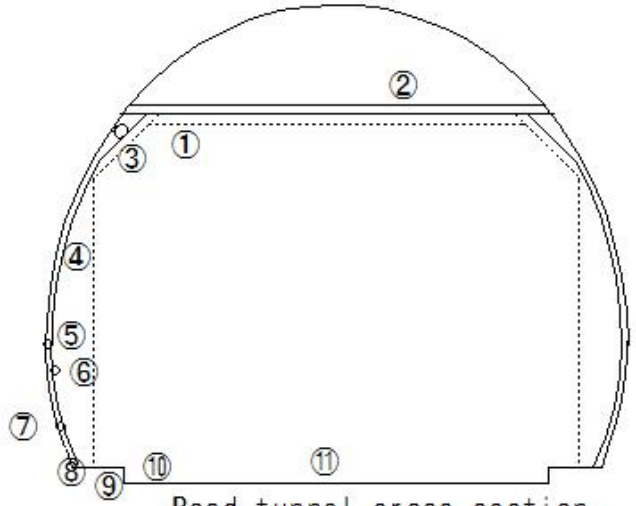
・Tunnel cross section: Construction limit,
cross-sectional area: Strong against earth pressure

・Economical

・Width Height: 2m or more

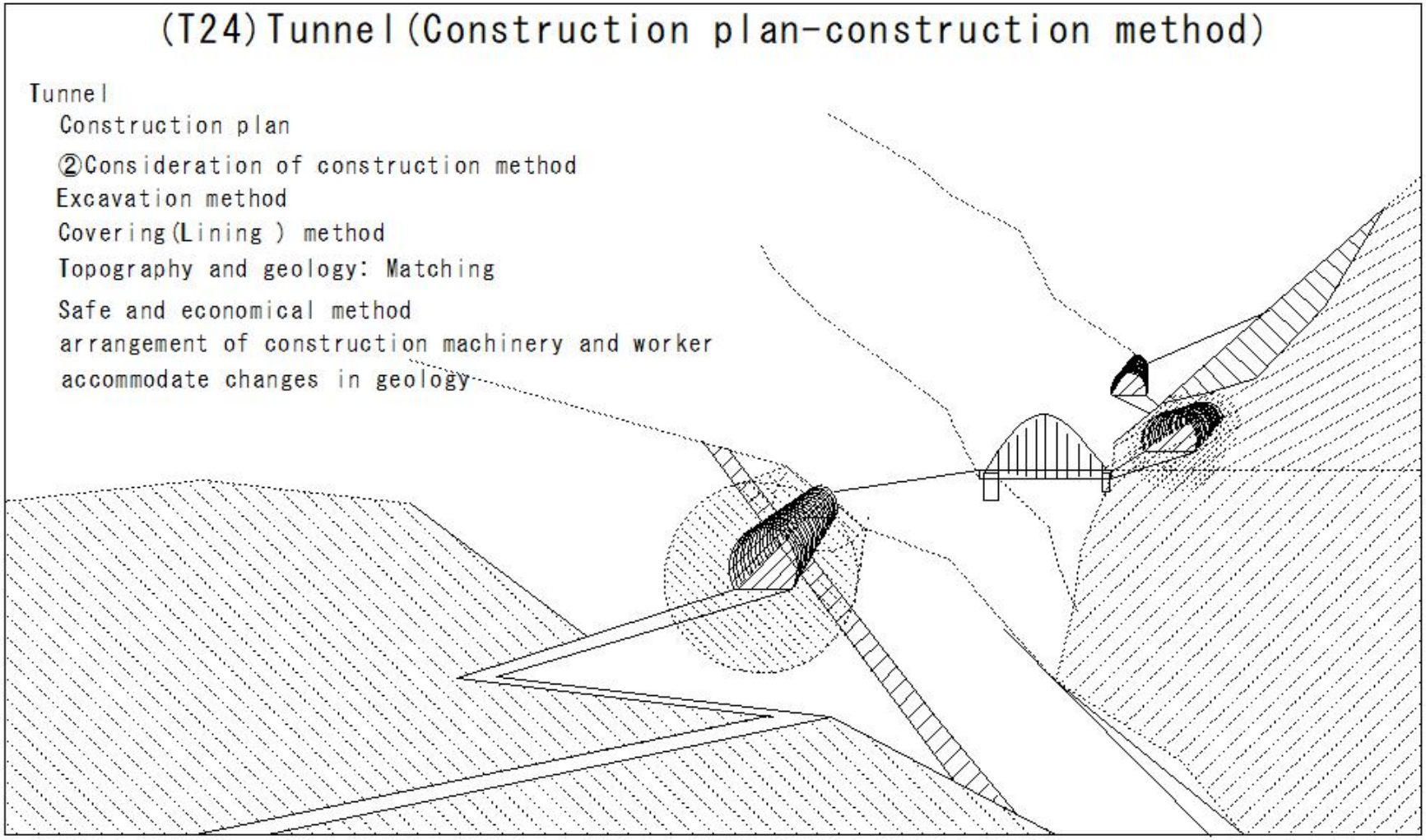
Ventilation, drainage, and communication equipment:
internal facilities

① Building limit
② Ceiling board
③ Lighting equipment
④ Interior materials
⑤ Fire detector
⑥ Emergency telephone
⑦ Fire hydrant box
⑧ Facility strip
⑨ Shoulder
⑩ Side strip
⑪ Roadway

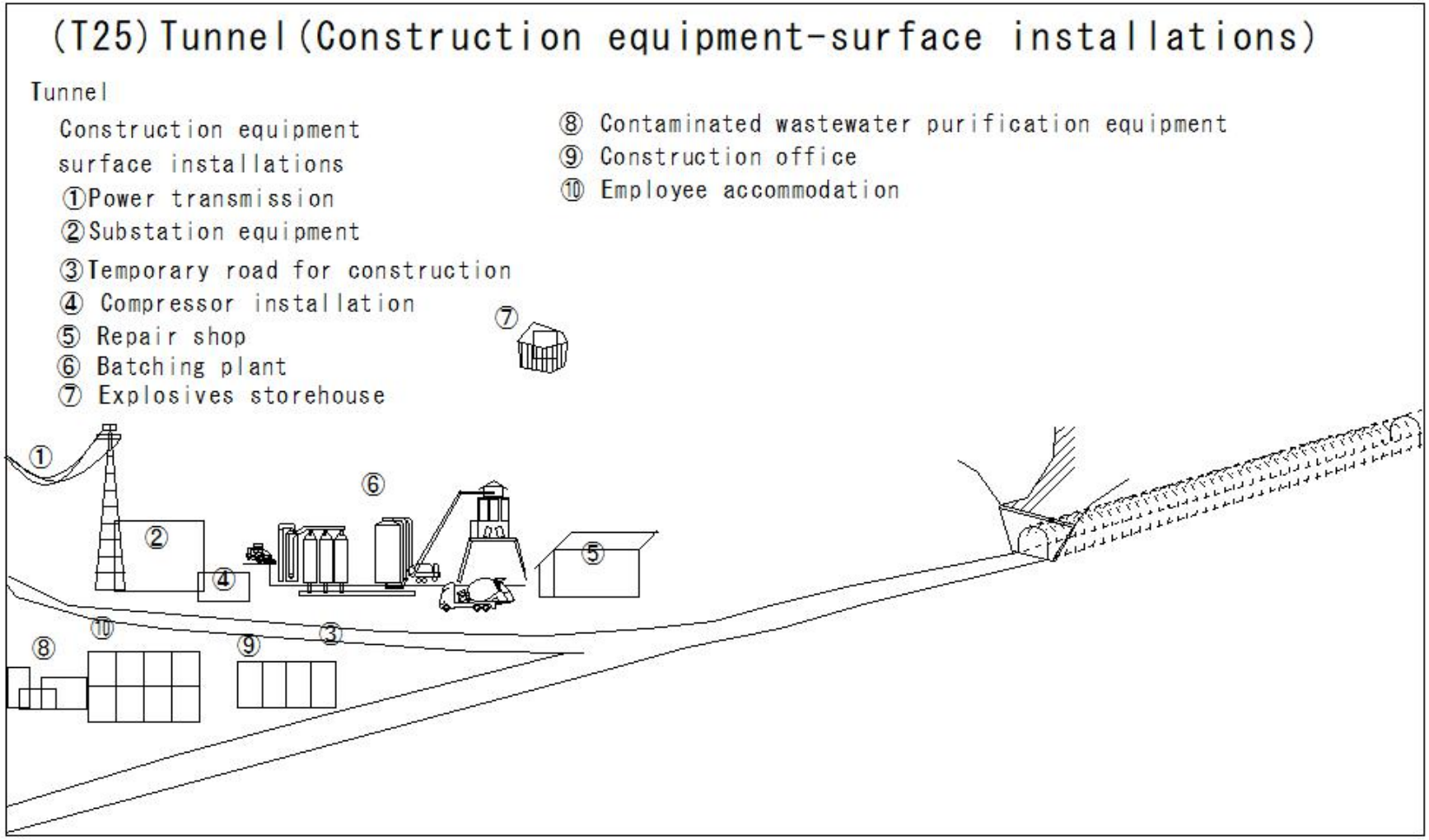


Road tunnel cross section

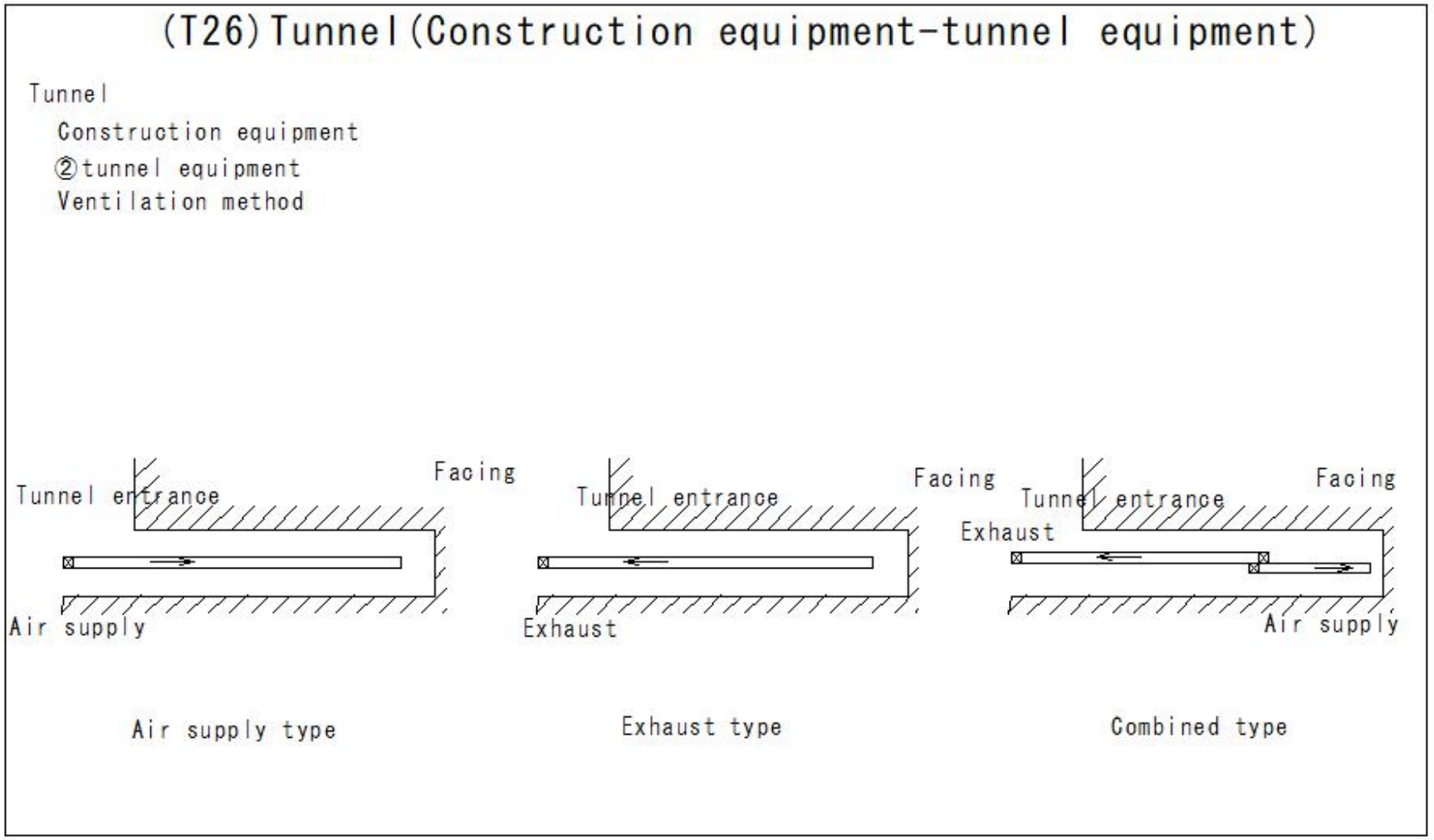
(T24)Tunnel(Construction plan-construction method)



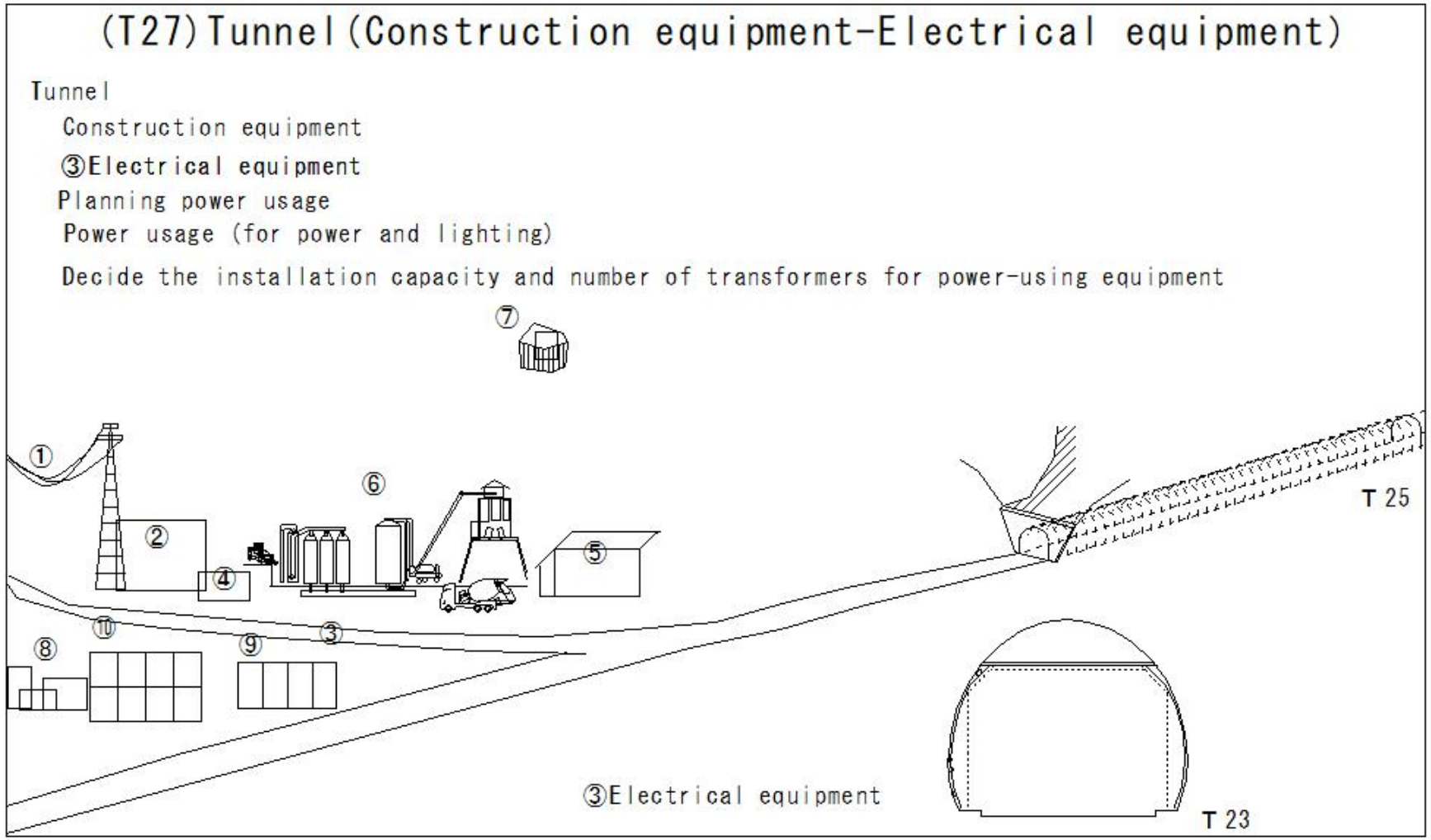
(T25)Tunnel(Construction equipment-surface installations）



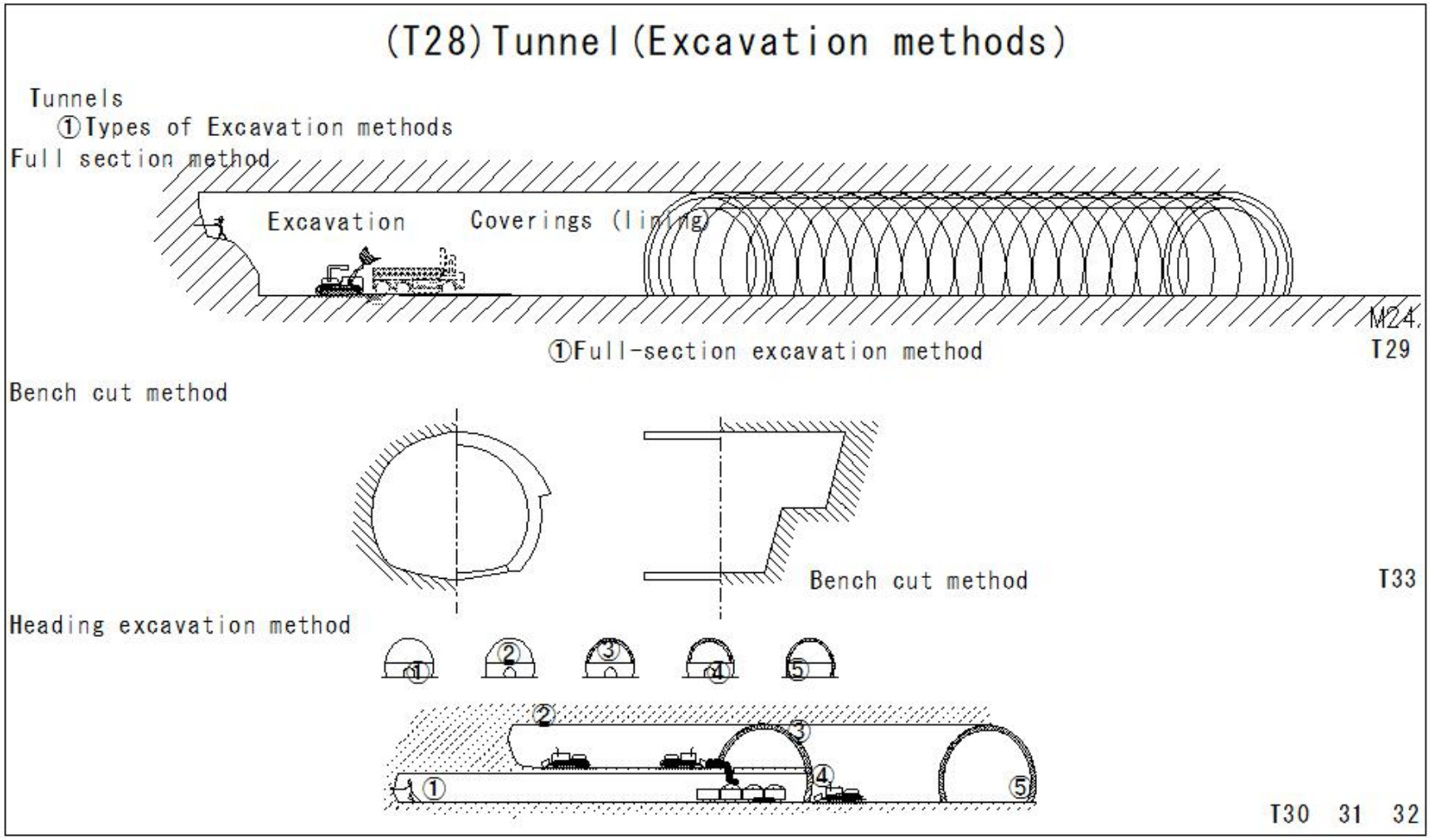
(T26)Tunnel(Construction equipment-tunnel equipment)



(T27)Tunnel(Construction equipment-Electrical equipment)



(T28)Tunnel(Excavation methods）



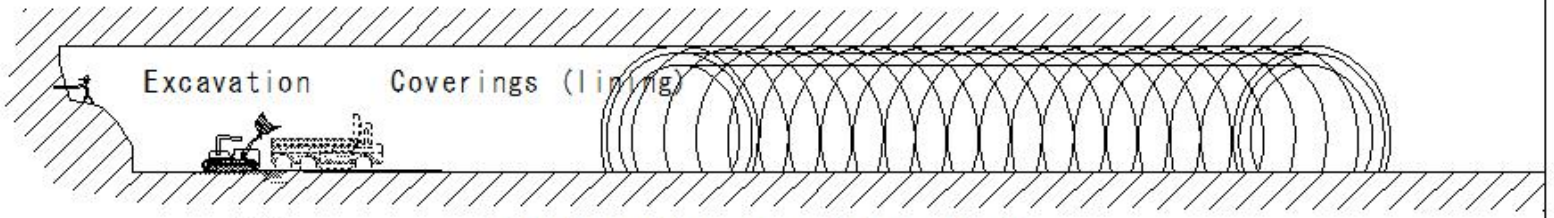
(T29)Tunnel(Excavation methods-Full-section excavation method）

(T29)Tunnel(Excavation methods-Full-section excavation method)

Tunnels

①Full-section excavation method

- Excavate the entire section of the tunnel at once
- Good rock base
- No spring water
- The Facing can be kept vertical until the next blast
- Large machinery can be used
- in case of work at the face stops, all work stops
- It is difficult to take measures in case of the rock quality deteriorates
- a certain amount of cross section is required
- Used for small and medium-sized cross-section tunnels of 30-40m2 or less
- Low adaptability to changes in ground conditions
- It is difficult to change the setup during construction



M24 ①Full-section excavation method

(T30)Tunnel(Excavation methods-heading excavation method)

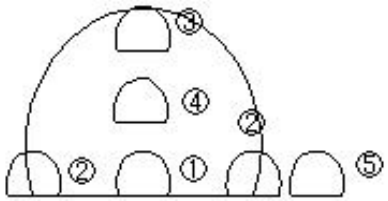
(T30)Tunnel(Excavation methods-heading excavation method)

Tunnels

① Types of excavation methods

② heading excavation method

- Geology - Soft
- Tunnel cross section - Excavate in sections
- Advanced excavation section - heading(Pilot)
- heading(Pilot) - Investigate geology and spring water conditions
- Set the center line of the tunnel
- Used to bring in materials and remove muck(rubble)
- in case of installed in the lower half, to treat spring water
- in case of installed in the upper half, to provide ventilation



Types of heading(pilot)

① Bottom heading(pilot) - Center bottom

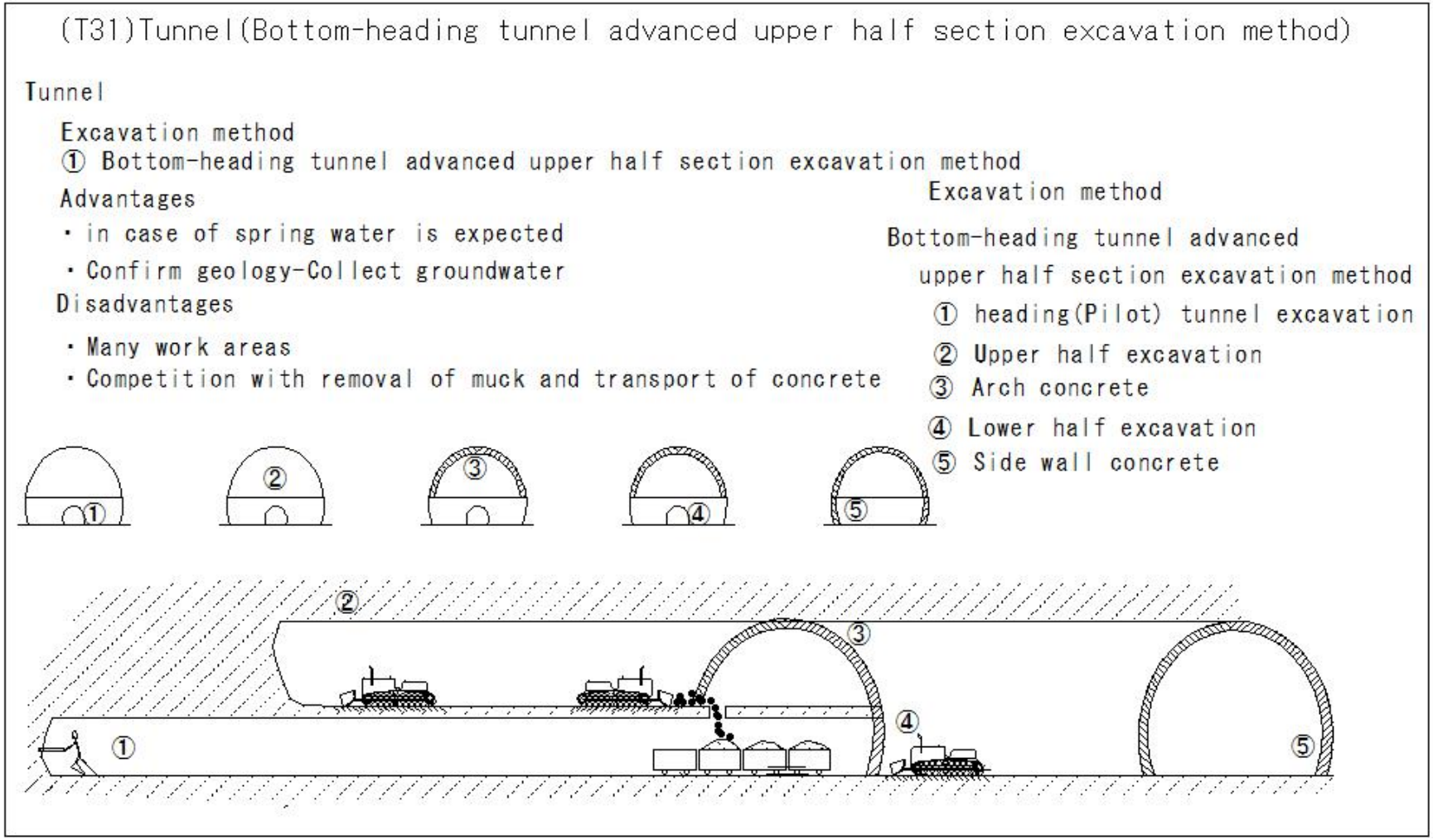
② Side wall heading(pilot) - Both sides of the bottom

③ Top heading(pilot) - Center top

④ Center heading(pilot) - Center of cross section

⑤ Parallel heading(pilot) - Parallel to the tunnel outside the cross section

(T31)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)



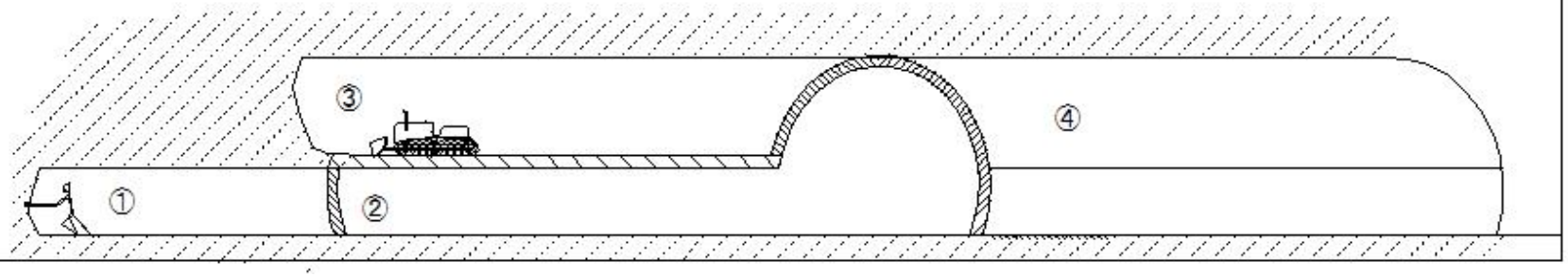
(T32)Tunnel(Side wall heading(pilot) tunnel advanced upper half section excavation method）

(T32)Tunnel(Side wall heading(pilot) tunnel advanced upper half section excavation method)
Tunnel

Excavation method

②Side wall heading(pilot) tunnel advanced upper half section excavation method

- Soft ground tunnel excavation method
- Width 10m - Effective
- Advance heading(pilot) tunnel excavation on both side walls of the tunnel
- After pouring side wall concrete
- Upper half and back excavation
- Side wall concrete is used as support ground for upper half support
- Suitable for soft ground
- 2 heading(pilot) tunnels - easy ground loosening
- Not economical



(T33)Tunnel(Excavation method-Bench cut method）

(T33)Tunnel(Excavation method-Bench cut method)

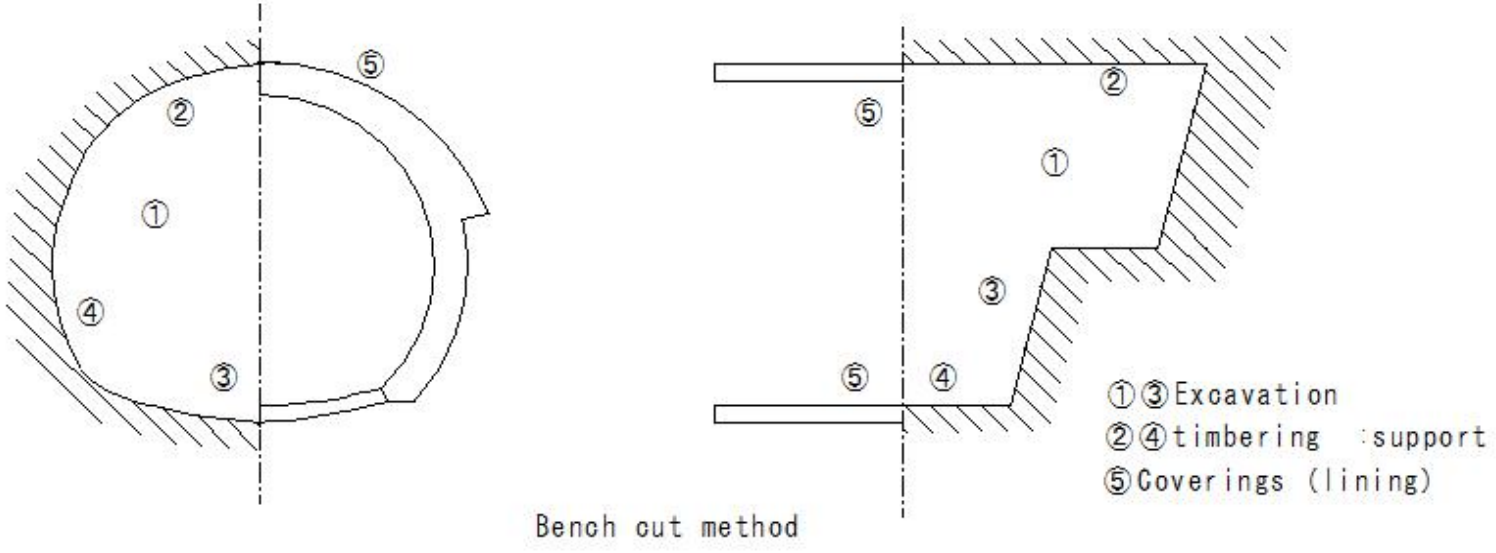
Tunnel

Excavation method

Bench cut method

Short bench cut method

Expansive geology - Quickly cover the entire cross section



Bench cut method

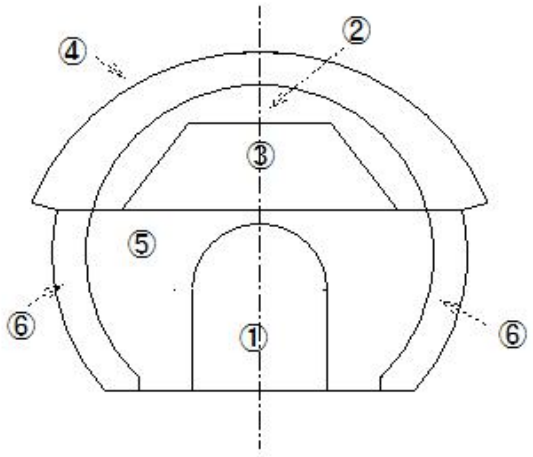
(T34)Tunnel(Excavation method-Ring cut method)

(T34)Tunnel(Excavation method-Ring cut method)

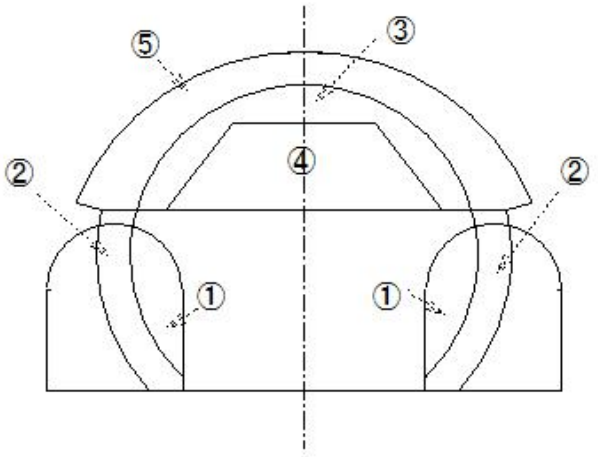
Tunnel

Excavation method

Ring cut method



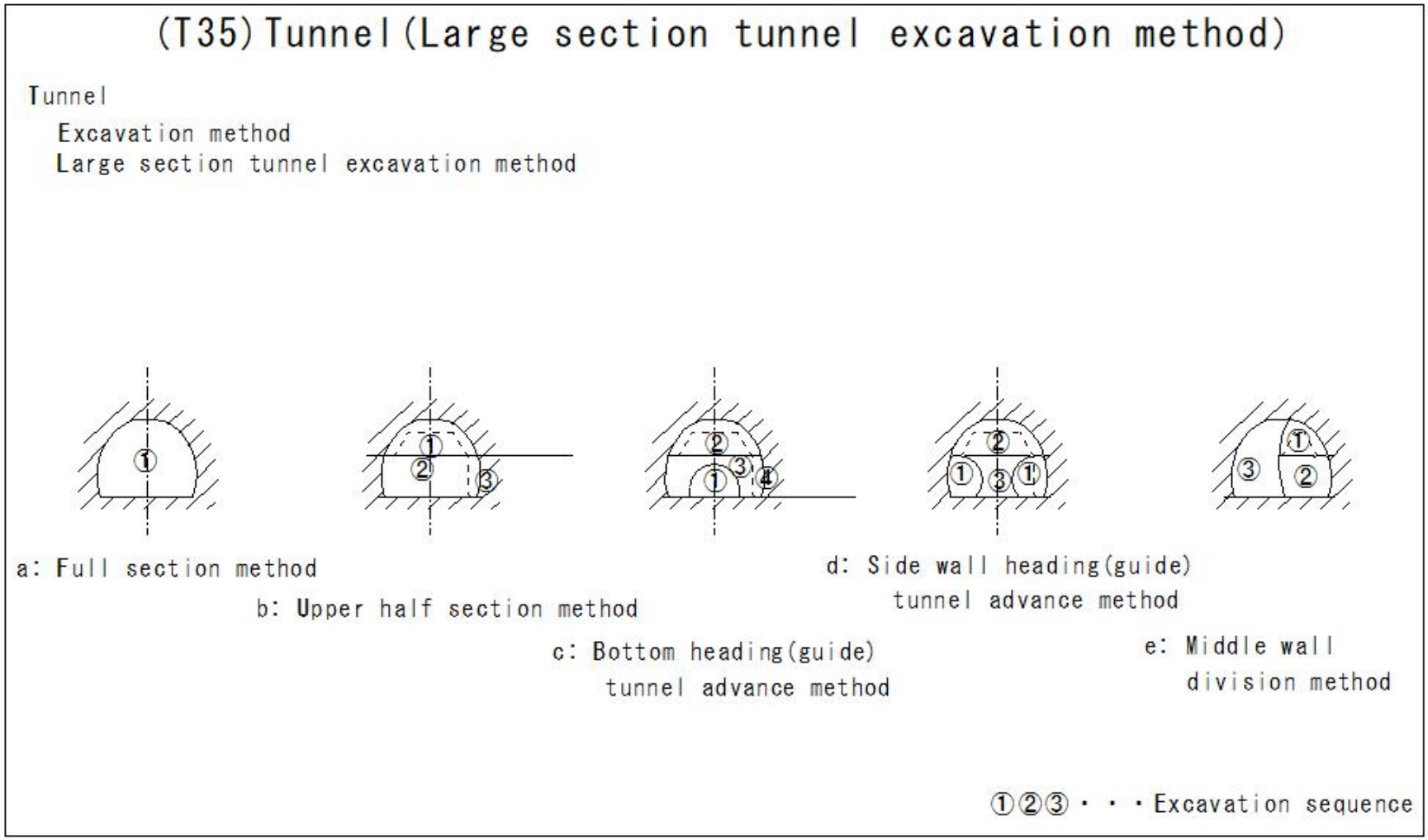
Bottom heading(pilot) tunnel advance ring cut method



Sidewall heading tunnel advanced ring cut construction method

Ring cut method

(T35)Tunnel(Large section tunnel excavation method)

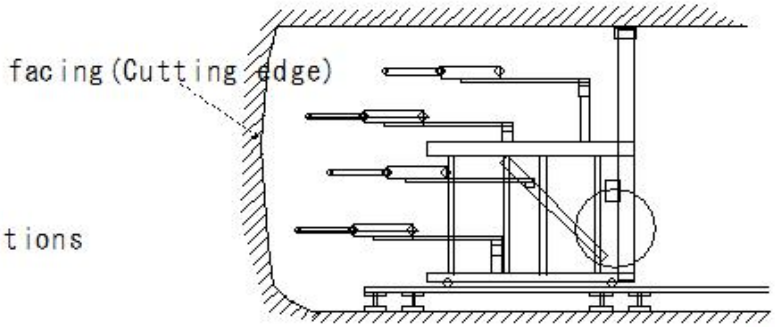


(T36)Tunnel(Rock drilling)

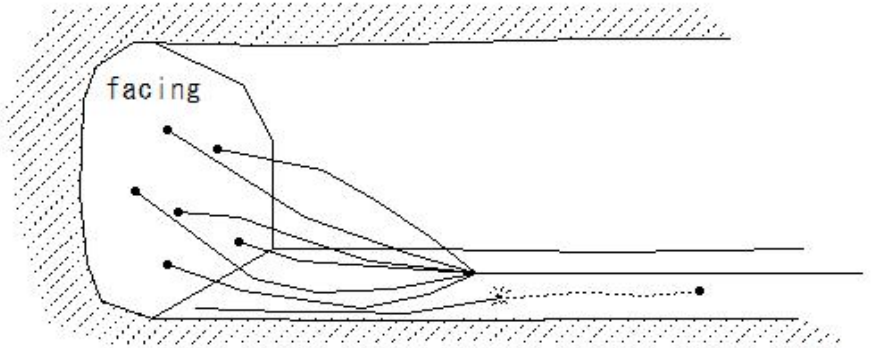
(T36)Tunnel(Rock drilling)

tunnel

- Rock drilling
  - ・Blasting drilling
  - ・Mechanical drilling
- Free-section excavator
- Full Section Excavator (TBM)
- Manual drilling: unfavorable construction conditions
  - The ground is unstable
  - Small Section Drilling



・Mechanical drilling T267



・Blasting drilling T143

(T37)Tunnel(Rock drilling)

(T37)Tunnel(Rock drilling)

tunnel

Rock drilling

①Types of rock drills

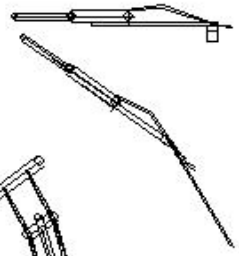
・Jackhammer

②Bit Rod

③Rock drilling jumbo: Collectively referred to as a moving scaffolding for drilling

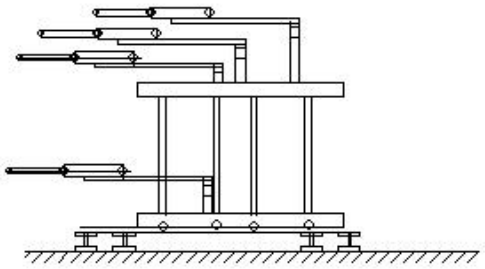
④Extra drilling: Excessive excavation of the part outside the design line of the tunnel cover concrete

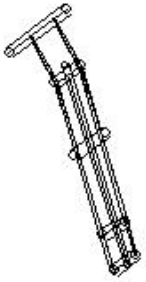
Drifter: horizontal hole



upward

Drill jumbo: excavate multiple holes at the same time





downward

T138

(T38)Tunnel(Rock drilling)

(T38)Tunnel(Rock drilling)

tunnel

blast

blasting plan

(1) Decide on one blast progress

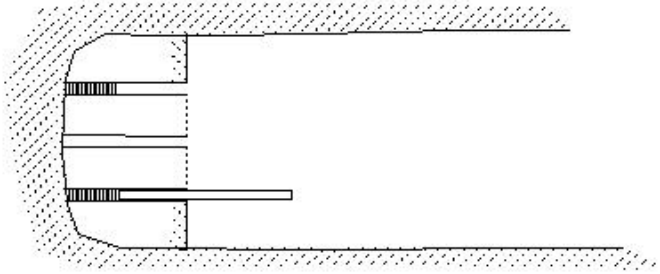
(2) How to get cut

(3) drill hole arrangement

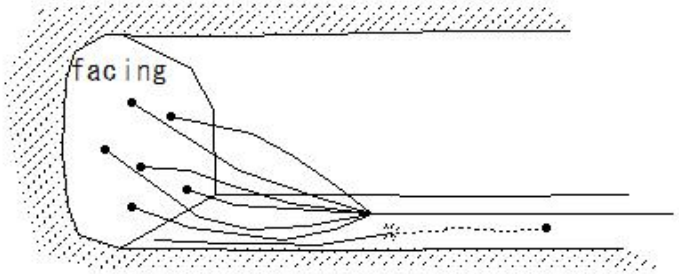
(4) Types of explosives

(5) Determination of the installing(explosives) amount

(6) Spacing of peripheral holes



T141



blasting

T143

(T39)Tunnel(cut)

(T39)Tunnel(cut)

tunnel

blast

cut

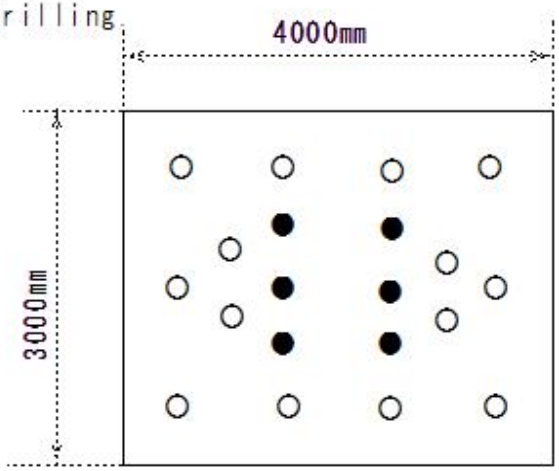
(1) V-cut: Wedge cut

● cut

○ side hole

Average hole depth: 1.2 m, hard sandstone

・It is difficult to apply small-section drilling



(1) V-cut: Wedge cut

(T40)Tunnel(cut)

(T40)Tunnel(cut)

tunnel

blast

(2) Pyramid cut

●cut

○side hole

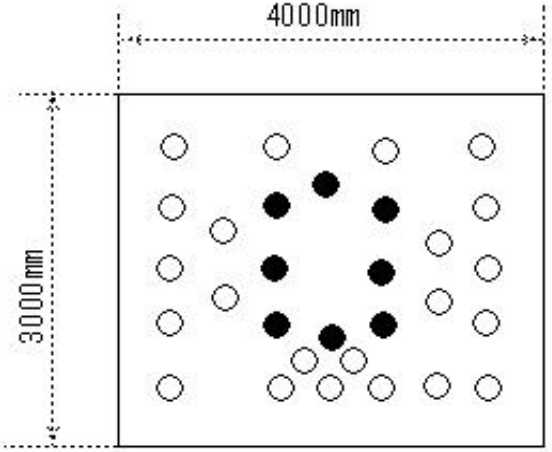
Average hole depth 1.5m hard quartz diorite

4000mm

3000mm

・Drilling - Difficult

・ Explosion effect - large



(2) Pyramid cut

(2) Pyramid cut

(T41)Tunnel(Burn cut)

(T41) Tunnel (Burn cut)

Tunnel

Blast

③Burn cut

Burn cut method hole boring

・Used for small cross sections

Characteristics

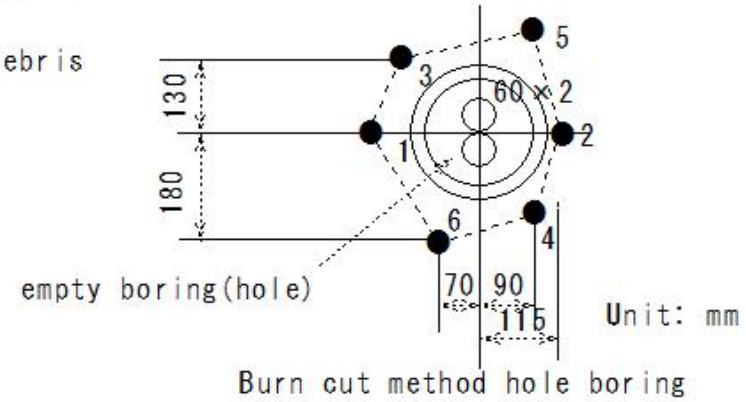
①Horizontal hole: Easy to drill deep drill holes

②No skill required

③Good drilling efficiency - no hole edges left

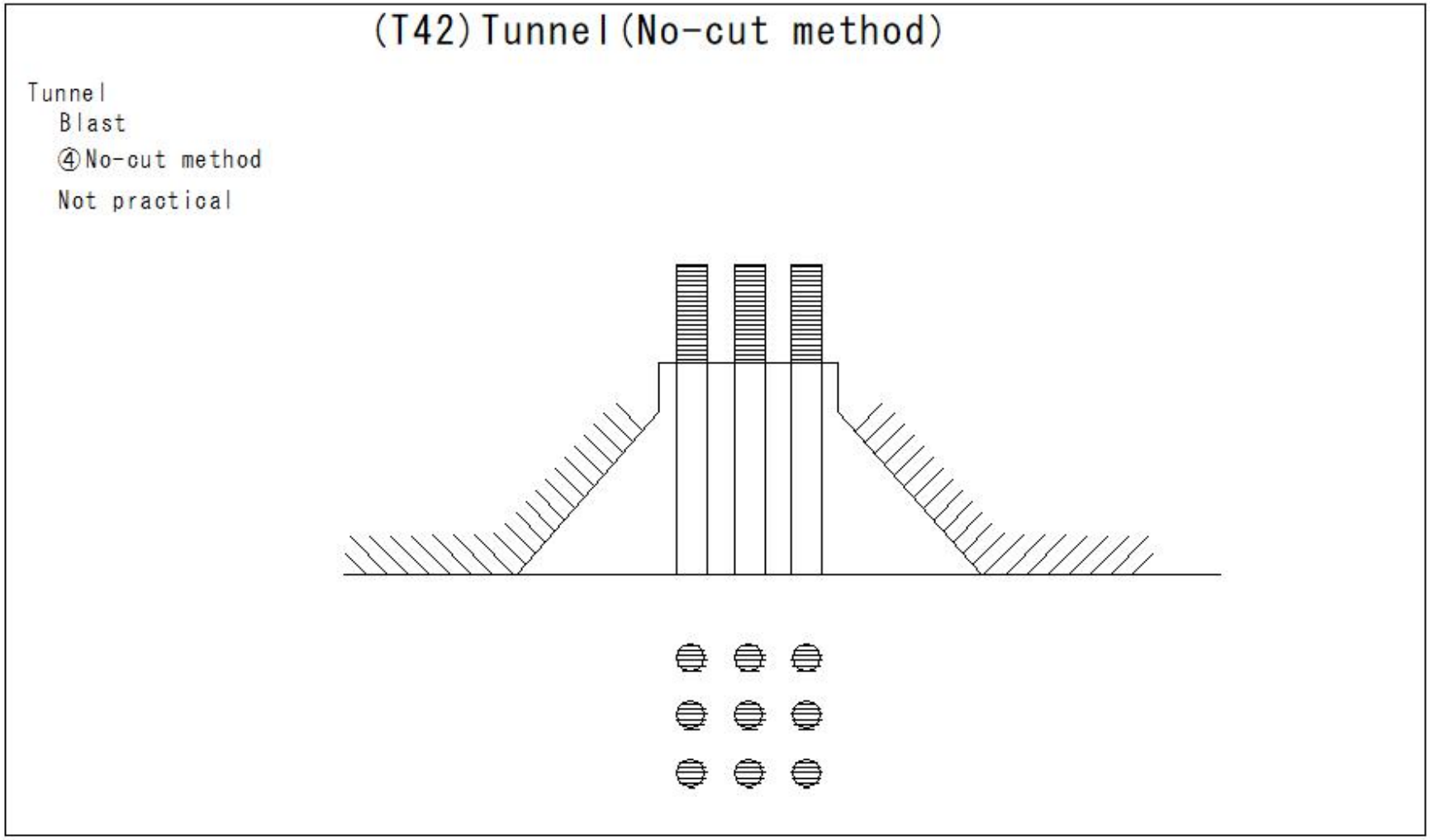
④Explosives are saved

⑤Less flying stones - easy to remove debris



Burn cut method hole boring

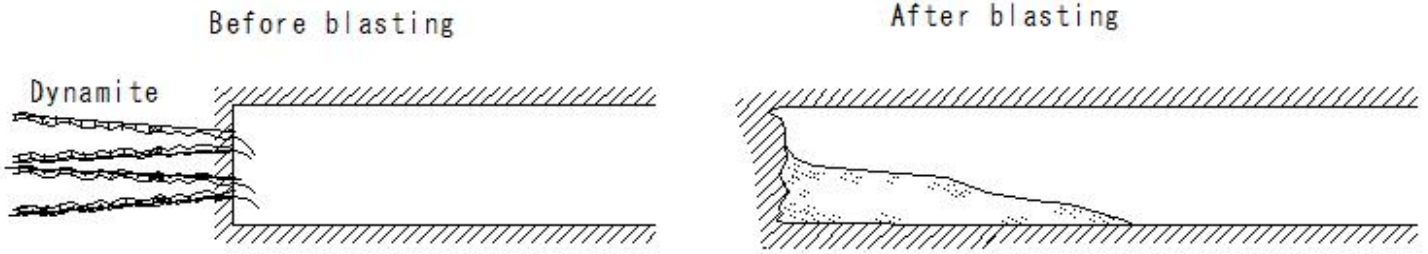
(T42)Tunnel(No-cut method）



(T43)Tunnel(Precautions for blasting)

(T43)Tunnel(Precautions for blasting)

Tunnels
Blasting
Precautions for blasting
① In the case of electrical blasting, be careful of stray and leaking currents
② In the case of fuse blasting, ensure time for ignition and evacuation
③ in case of blasting, protect the supports and coverings and ensure that workers have evacuated
④ After blasting, gas remains; unexploded explosives - wait an appropriate amount of time before approaching the cutting edge
Electrical blasting: 5 minutes or more
Fuse blasting: 15 minutes or more
⑤ Residual explosives: Remove with compressed air and water; sympathetic detonation
⑥ After blasting, carefully remove loose stones



T232

(T44)Tunnel(Loading machines)

(T44) Tunnel (Loading machines)

Tunnels

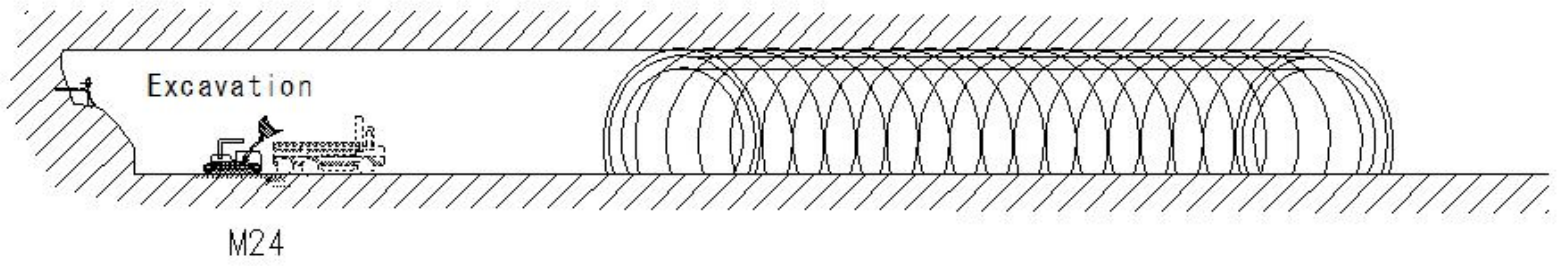
Muck disposal

Loading machines, Muck transport methods, Transport machines, Muck dumping equipment

① Classification by power source: Compressed air drive, Electric drive, Diesel engine drive

② Travel method: Rail type, Crawler type, Wheel type

③ Loading method: Overshot type, Side dump type, Front end type



T29

(T45)Tunnel(Muck transport method）

(T45)Tunnel(Muck transport method)

Tunnel

Muck disposal

Muck transport method

Rail type

Tire type

①Rail type

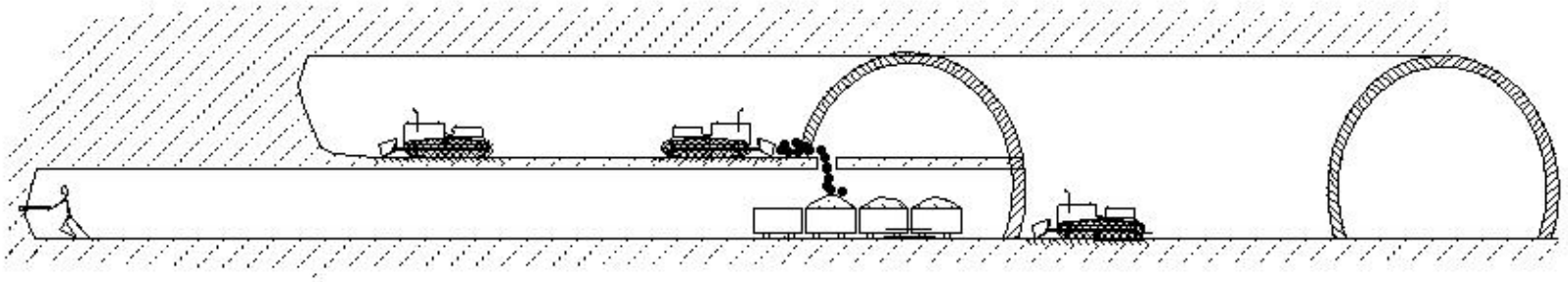
Muck trolley connection - towed by locomotive

①Muck trolley

②Locomotive:

Battery locomotive: needs to be charged

Diesel locomotive: gas generation, prevents air pollution inside the mine



T31

(T46)Tunnel(Muck Handling-Rails and turnouts）

(T46)Tunnel(Muck Handling-Rails and turnouts)

tunnel

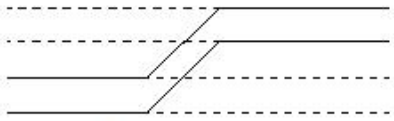
Muck Handling

(3) Rails and turnouts

・muck locomotives

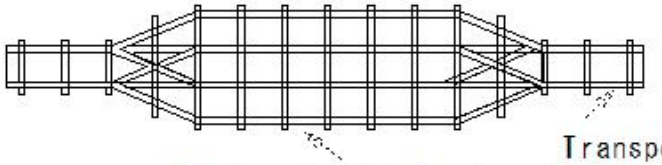
・Mobile writing equipment

(3) Rails and turnouts



S-shaped

N-type

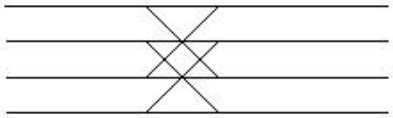


Transportation Main Line

Moving double-track rails

Y-shaped

California Switch



X-shaped

(T47)Tunnel(Muck Handling-Tire method）

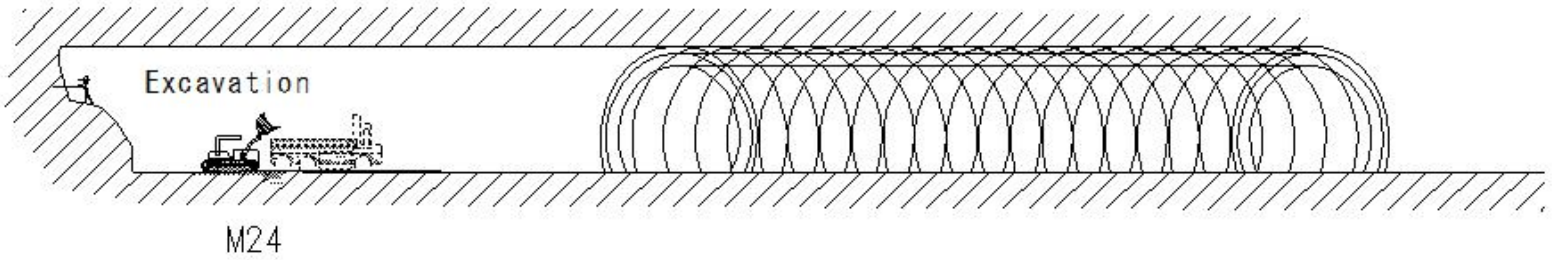
(T47)Tunnel(Muck Handling-Tire method)

tunnel

muck handling

(2) Tire method

- Use of dump trucks
- muck and discarding - do it consistently
- Good work efficiency
- in case of the geology is poor, if the work space is narrow - unsuitable
- The transportation distance increases as the progress of the cut face progresses.
- The backing of the dump truck becomes longer
- Efficiency - Reduced
- Safety aspect - Bad



T29
T44

(T48)Tunnel(Muck Handling-Tire method）

(T48)Tunnel(Muck Handling-Tire method)

tunnel

muck Handling

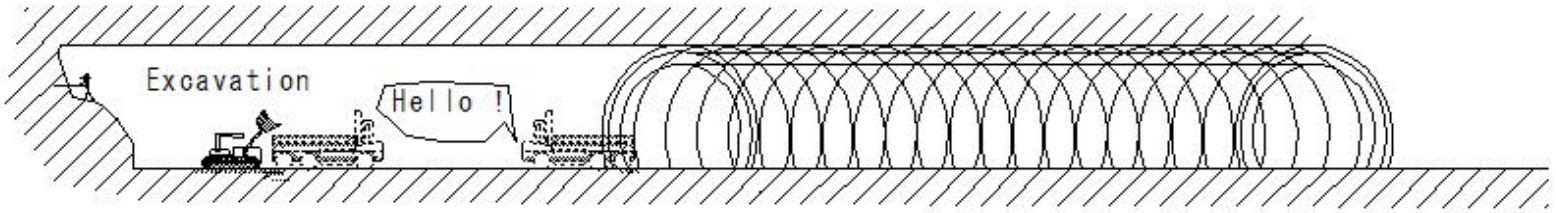
(2) Tire method

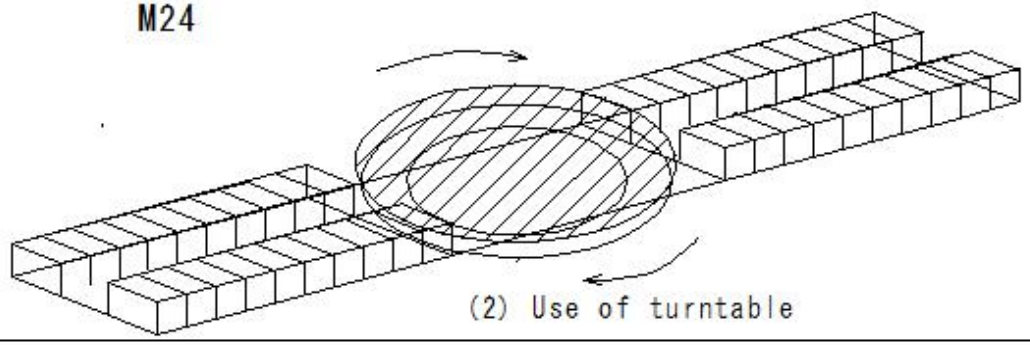
Direction change method

(1) Uses a special truck (dumper) that can reverse in both front and rear directions

(2) Use of turntable

・Diesel dump truck is used to ensure exhaust gas ventilation.

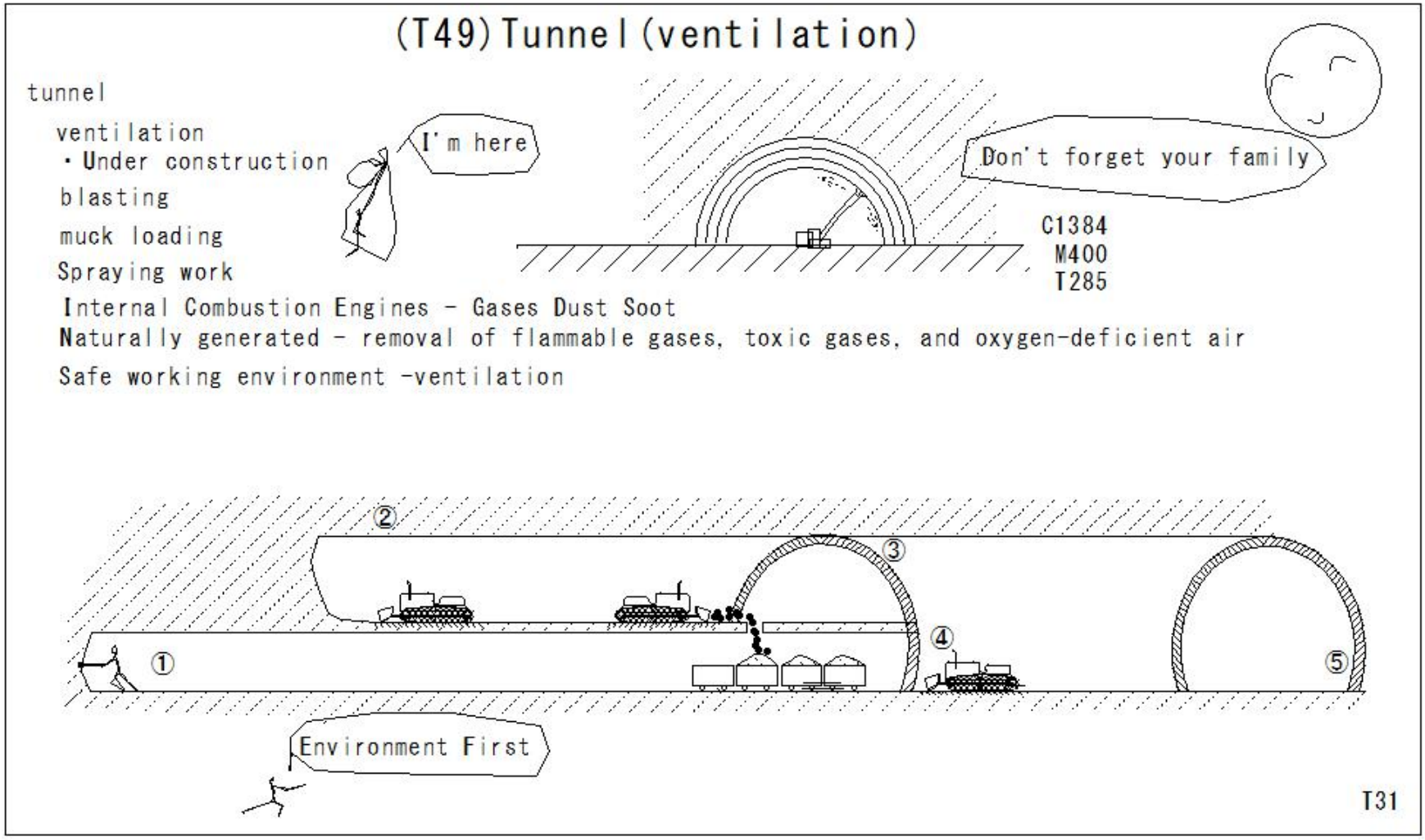




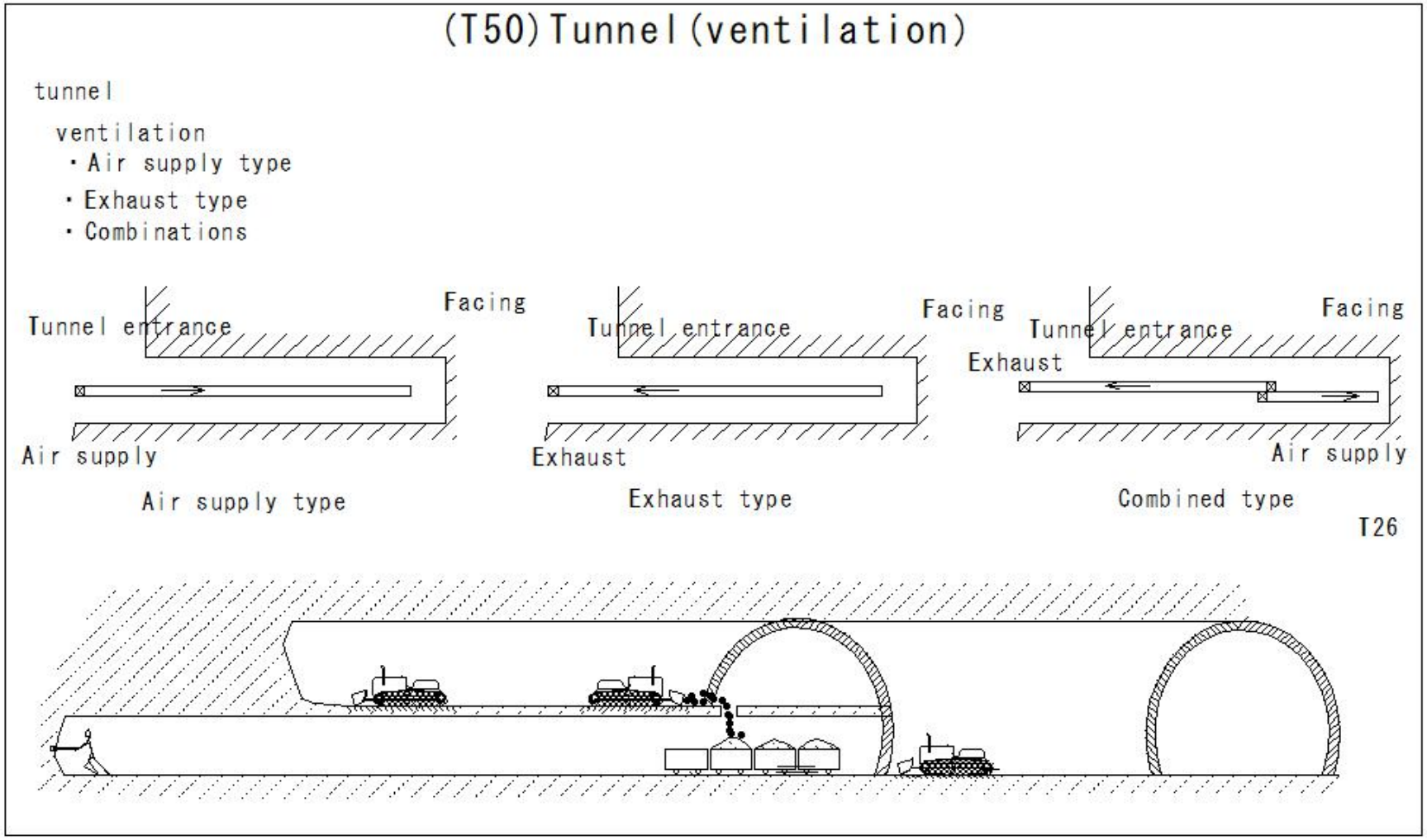
(2) Use of turntable

T44

(T49)Tunnel(ventilation）



(T50)Tunnel(ventilation）



(T51)Tunnel(timbering(support))

(T51)Tunnel(timbering(support))

tunnel

timbering(support)

Construction order of timbering(support)

・in case of the ground is good

(1) Shotcrete

(2) Rock bolt

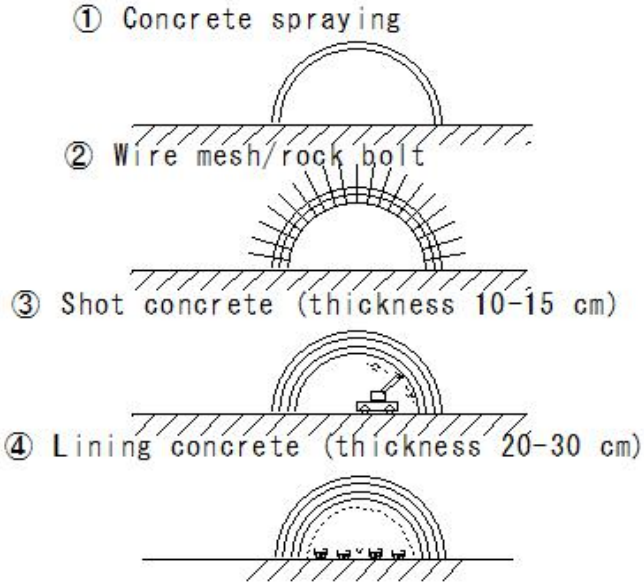
・ in case of the ground conditions are bad

(1) Primary shotcrete

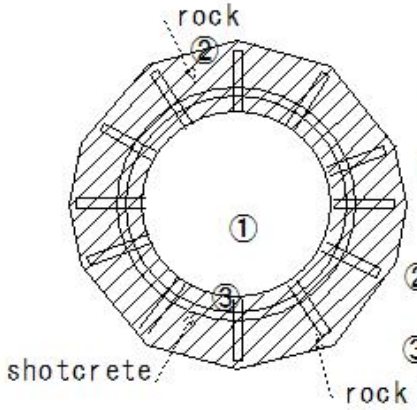
(2) Steel timbering(support)

(3) Rock bolt

(4) Secondary shotcrete



C955



C931

Mountain tunnel

Lining concrete

①Side wall: Supports arch and horizontal earth pressure

②Arch section: Supports the ground near the ceiling

③Inverted part: becomes ring-shaped and becomes firm

(T52)Tunnel(timbering(support))

(T52)Tunnel(timbering(support))

Tunnels

timbering(support)

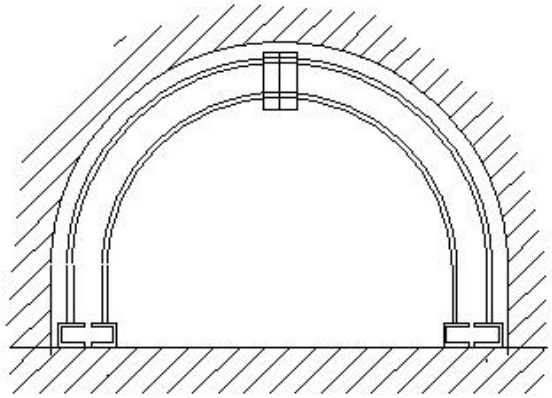
Types of supports

1. Pillar-type supports

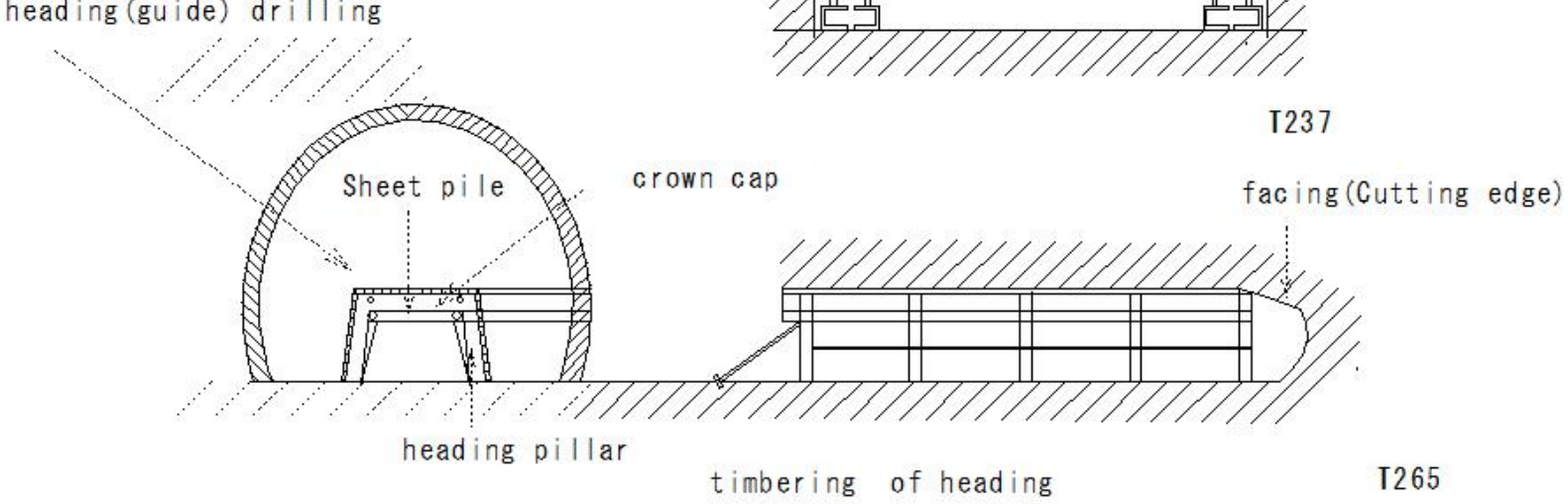
・principal rafter type: Arched section only

・Branch-type

Wall plate type support(timbering)



T237



T265

(T53)Tunnel(Steel arch supports)

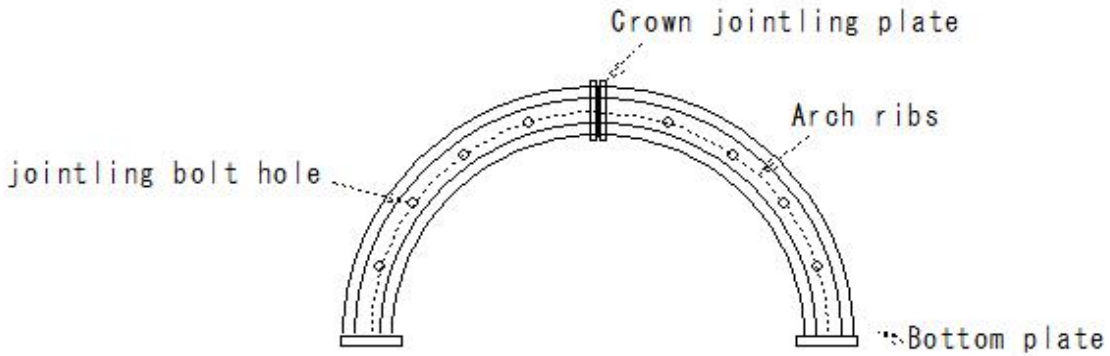
(T53)Tunnel(Steel arch supports)

Tunnels

Supports

Types of supports

②Steel arch supports



a: Half-section type

(T54)Tunnel(supports)

(T54)Tunnel(Steel arch supports)

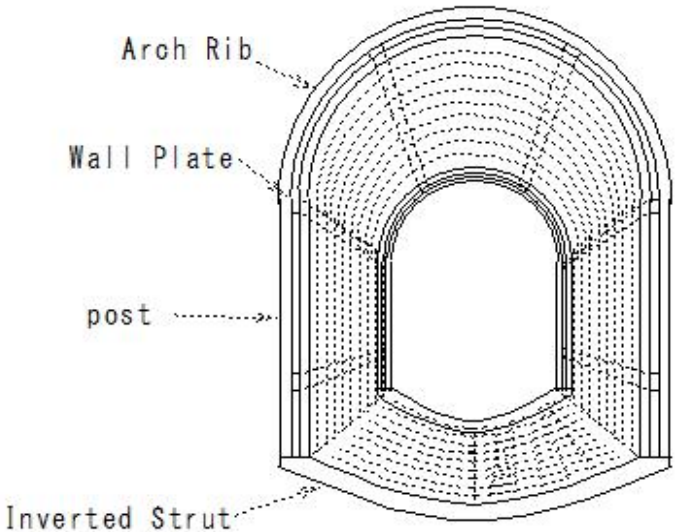
tunnel

support

Types of support

②Steel arch supports

b: Full-section type

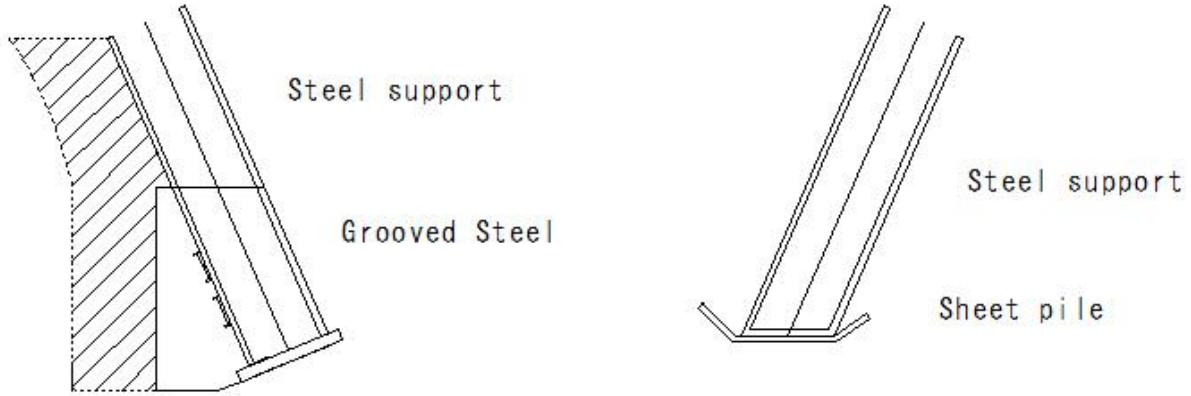


b: Full-section type

(T55)Tunnel(Steel arch supports)

(T55)Tunnel(Steel arch supports)

tunnel
support
Types of support
②Steel arch supports
Measures to prevent settlement of support



Measures to prevent settlement of support

(T56)Tunnel(Rock Bolt)

(T56)Tunnel(Rock Bolt)

tunnel

Rock Bolt

Rock masses that are likely to fall off

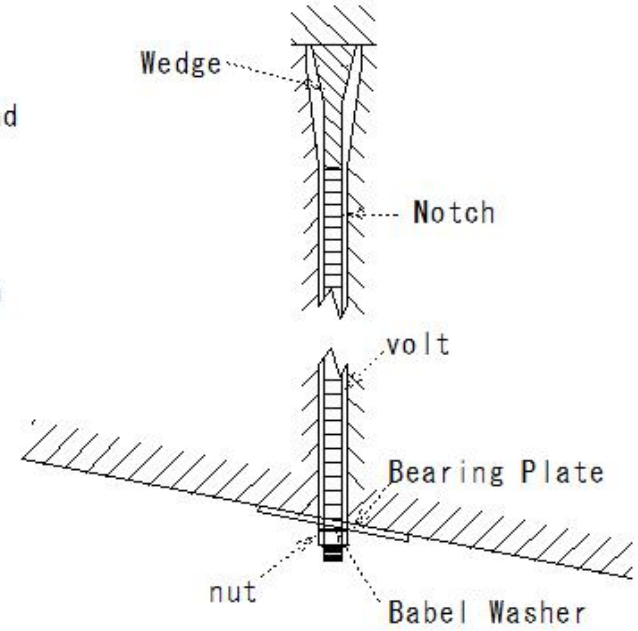
Tighten it with a rock bolt on the ground

Rock mass-arching action

Construction method

(1) Drop floating stones

(2) Prompt construction after excavation



Wedge shape

Rock Bolt

(T57)Tunnel(Rock Bolt)

(T57)Tunnel(Rock Bolt)

tunnel

Rock Bolt

Rock masses that are likely to fall off

Tighten it with a rock bolt on the ground

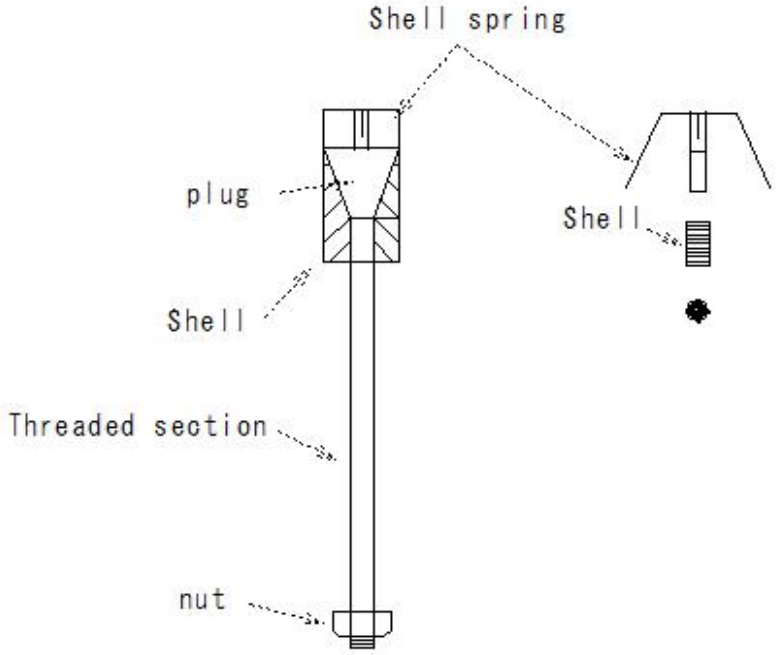
Rock mass-arching action

Construction method

(1) Drop floating stones

(2) Prompt construction after excavation

Expansion method



Expansion method

(T58)Tunnel(Rock Bolt)

(T58)Tunnel(Rock Bolt)

tunnel

Rock Bolt

Rock masses that are likely to fall off

Tighten it with a rock bolt on the ground

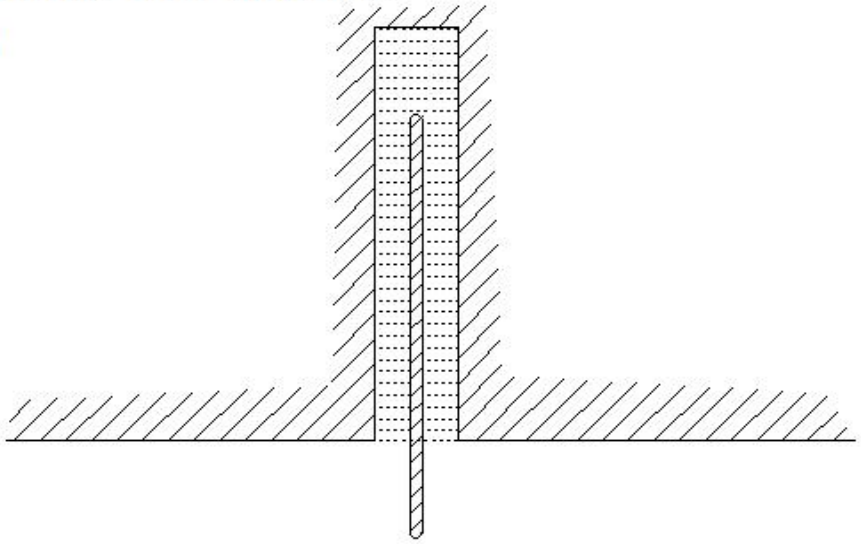
Rock mass-arching action

Construction method

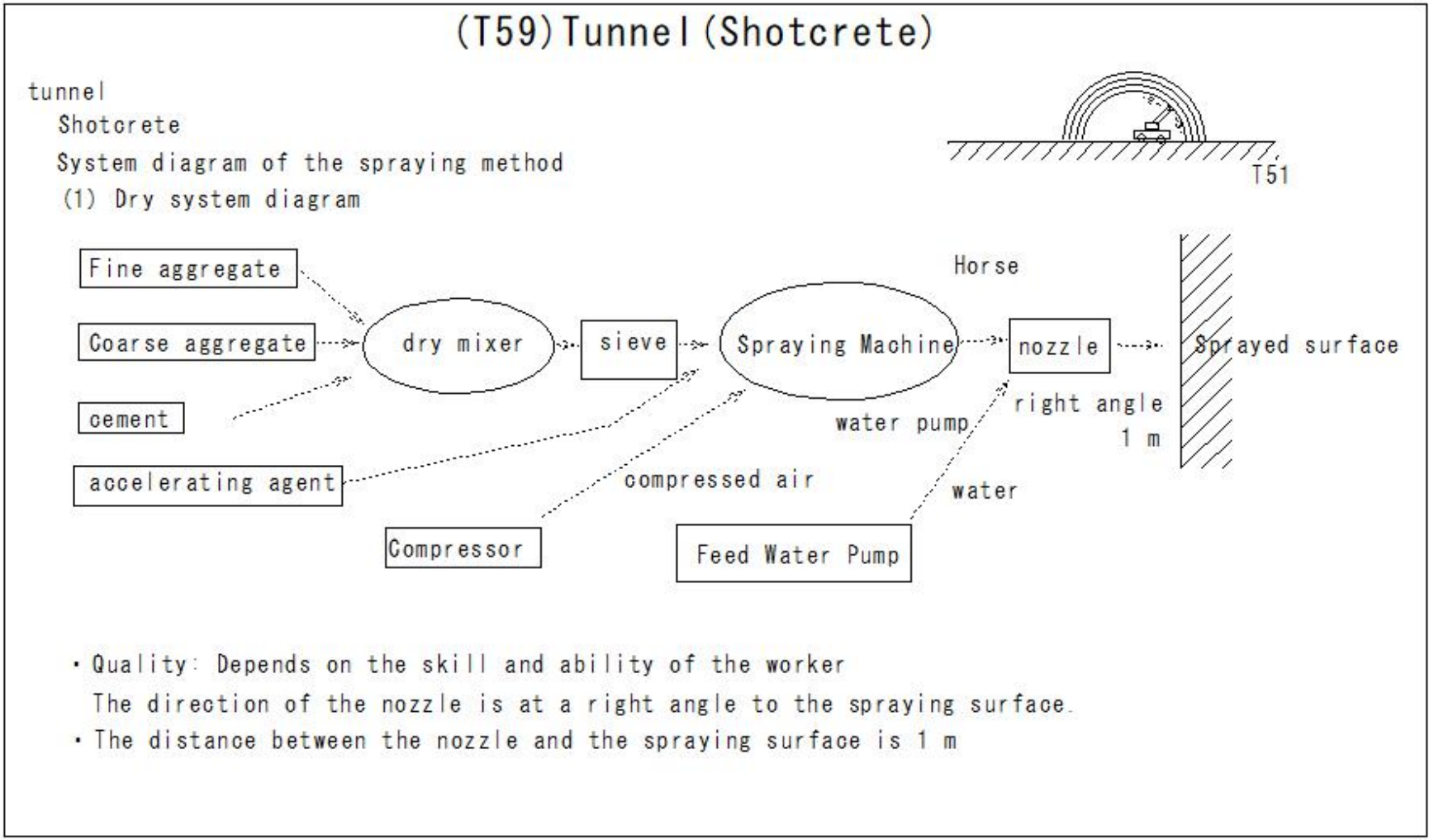
(1) Drop floating stones

(2) Prompt construction after excavation

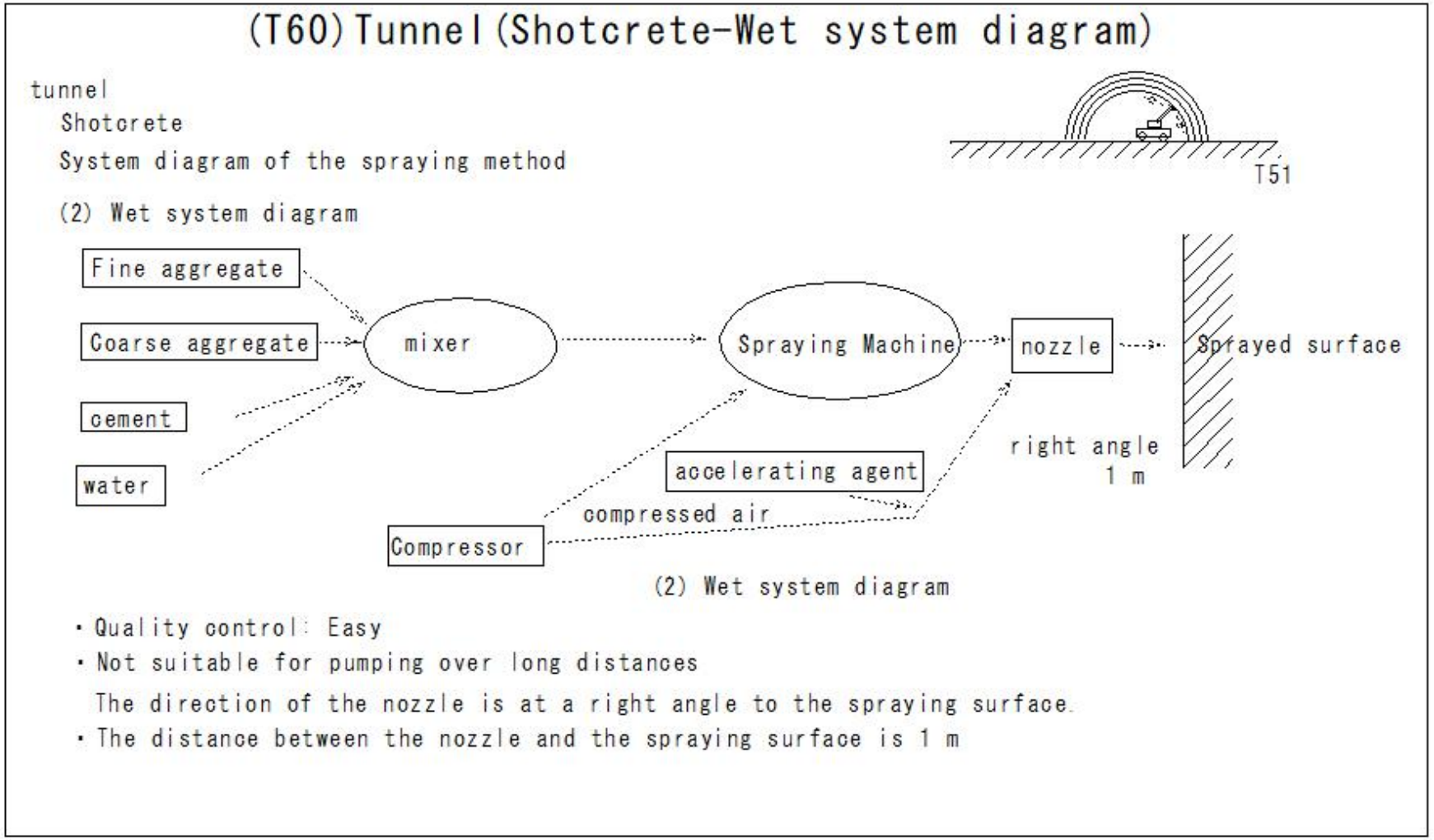
Expansion method



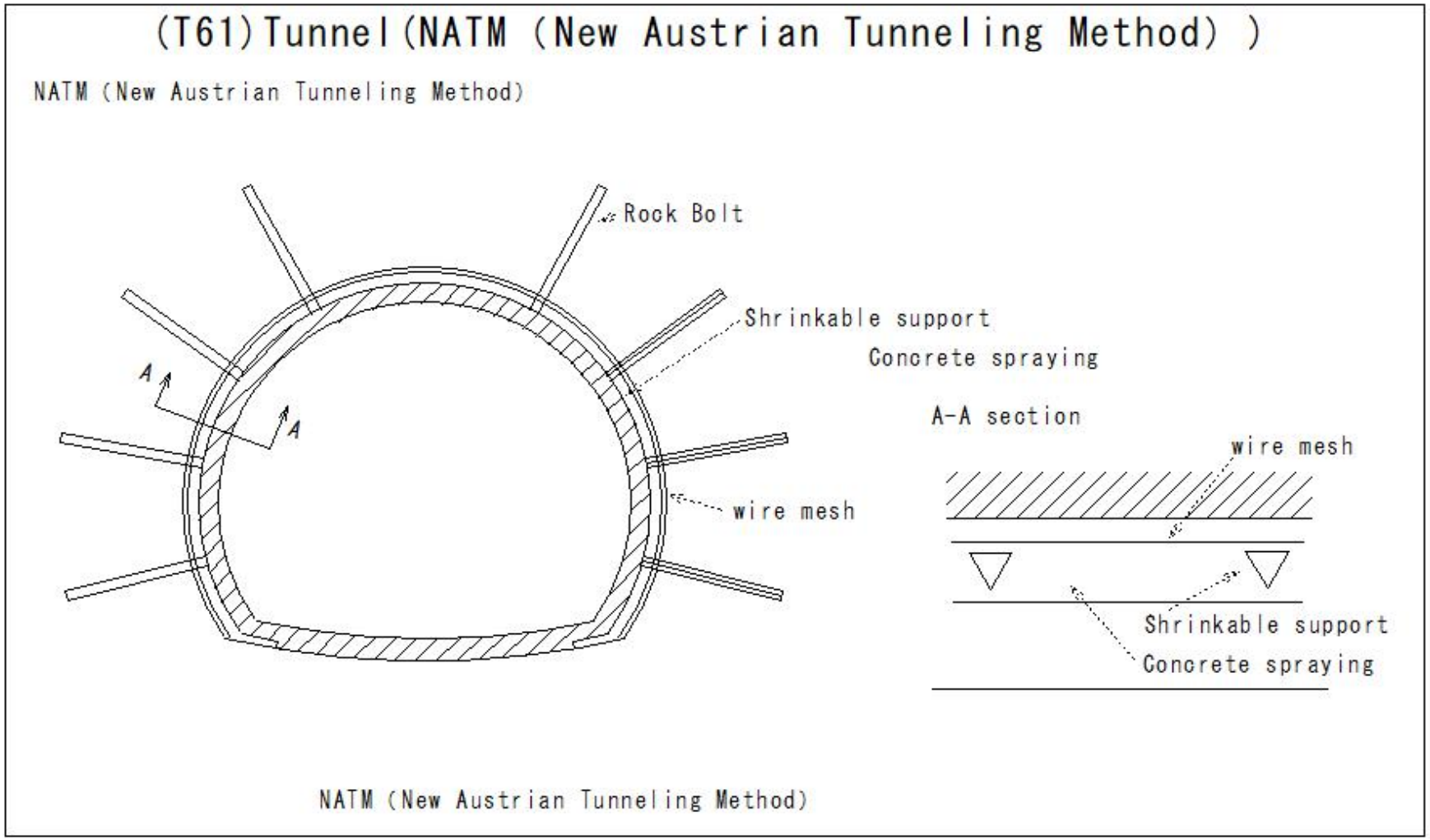
(T59)Tunnel(Shotcrete)



(T60)Tunnel(Shotcrete-Wet system diagram)



(T61)Tunnel(NATM（New Austrian Tunneling Method）)



(T62)Tunnel(NATM（New Austrian Tunneling Method）)

(T62)Tunnel(NATM (New Austrian Tunneling Method))

NATM (New Austrian Tunneling Method)

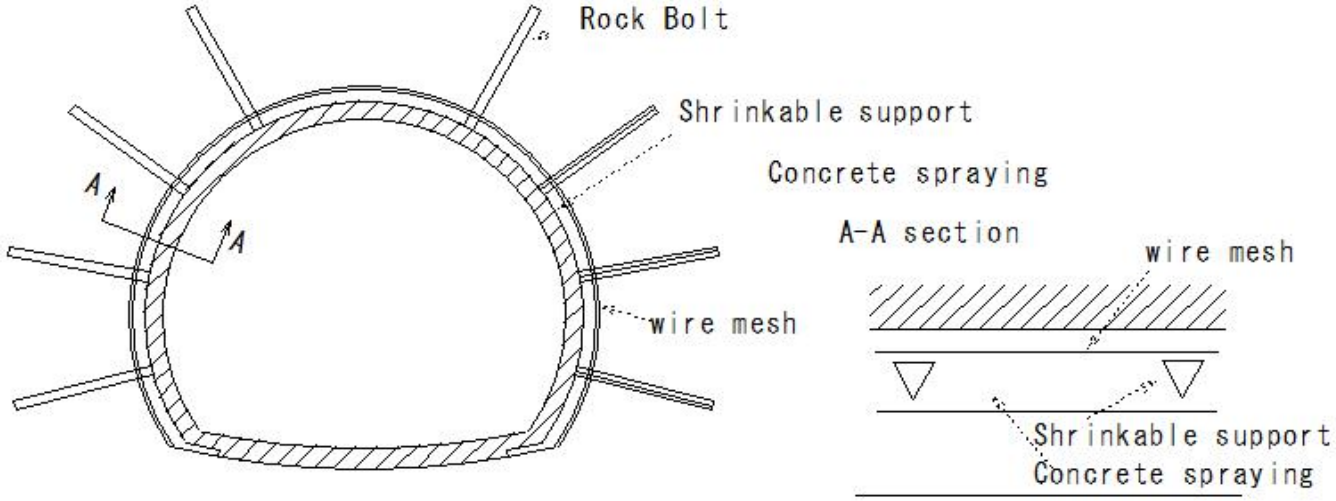
(1) Prevent the generation of excessive soil pressure by allowing deformation of the inside and void of the tunnel to some extent.

(2) Spraying is carried out at an early stage after excavation

(3) Formation of a bedrock arch around the tunnel
Utilizing the inherent bearing capacity of the ground

(4) During construction, soil pressure and deformation are measured, and the ground is monitored.

(5) Secondary Coverings (lining): Future maintenance and water shut-off



(T63)Tunnel(Coverings (lining))

(T63)Tunnel(Coverings (lining))

tunnel

Coverings (lining)

・Prevention of collapse and spring water

・Ensuring the safety of the ground

(1) Make a structure with good watertightness with little groundwater and spring water

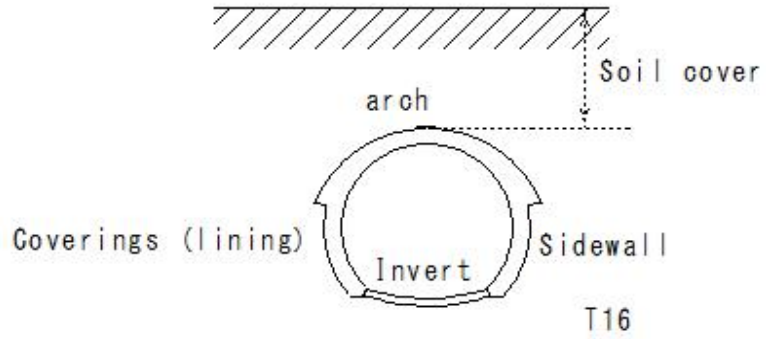
(2) Improve workability such as inspection and maintenance during use

(3) Maintain facilities such as erection, lighting, and ventilation in the tunnel

Required strength of concrete: Unreinforced concrete: 160-210kgf/cm2

Reinforced concrete: 210-240kgf/cm2

Coverings (lining) thickness: 20-40cm



T16

(T64)Tunnel(Coverings (lining)-shrinkage cracking (strain))

(T64)Tunnel(Coverings (lining)-shrinkage cracking (strain))

tunnel

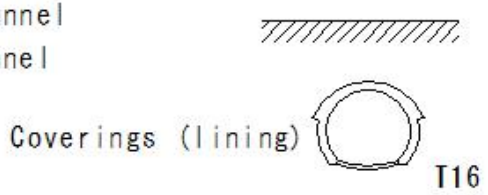
Coverings (lining)

Causes of shrinkage cracking (strain)

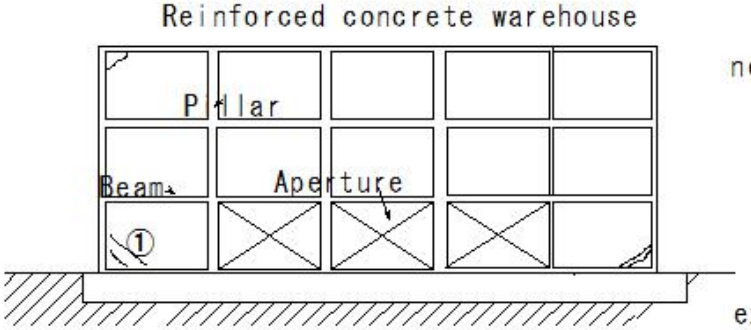
(1) Temperature shrinkage due to a drop in the curing temperature of concrete

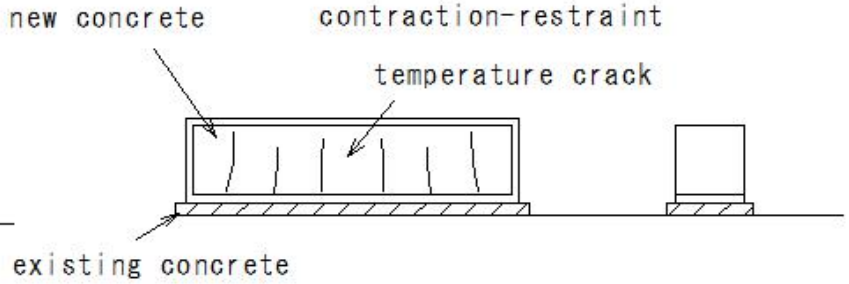
(2) Temperature shrinkage due to temperature drop in the tunnel

(3) Drying shrinkage due to decrease in humidity in the tunnel



T16





①Temperature shrinkage・Drying shrinkage -

- due to restraint

C326

C1433

(T65)Tunnel(Coverings (lining)-Crack protection)

(T65)Tunnel(Coverings (lining)-Crack protection)

tunnel

Coverings (lining)

Crack prevention

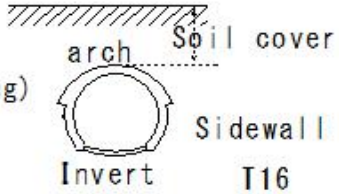
①Cutting edges with shotcrete (reduction of external constraints)

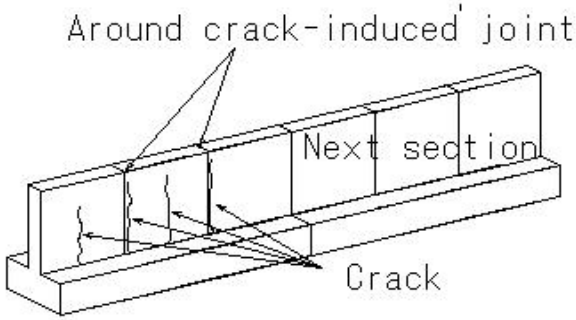
②Improvement of the quality of concrete (reduction of shrinkage strain, increase of tensile strength)

③Setting of crack-inducing joints (crack occurrence control)

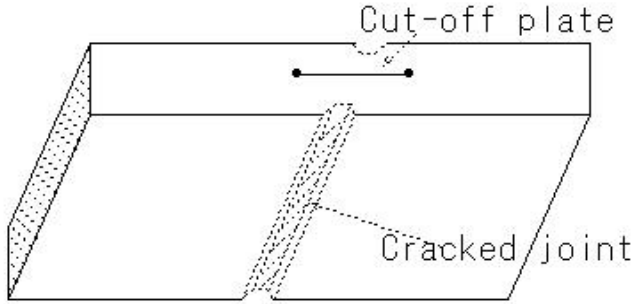
Covering: 160-200kgf/cm2 unreinforced concrete

Tunnel entrance: Areas with thin soil cover and soft geology: Reinforced concrete





C363



C826

(T66)Tunnel(Shape of the Coverings (lining))

(T66)Tunnel(Shape of the Coverings (lining))

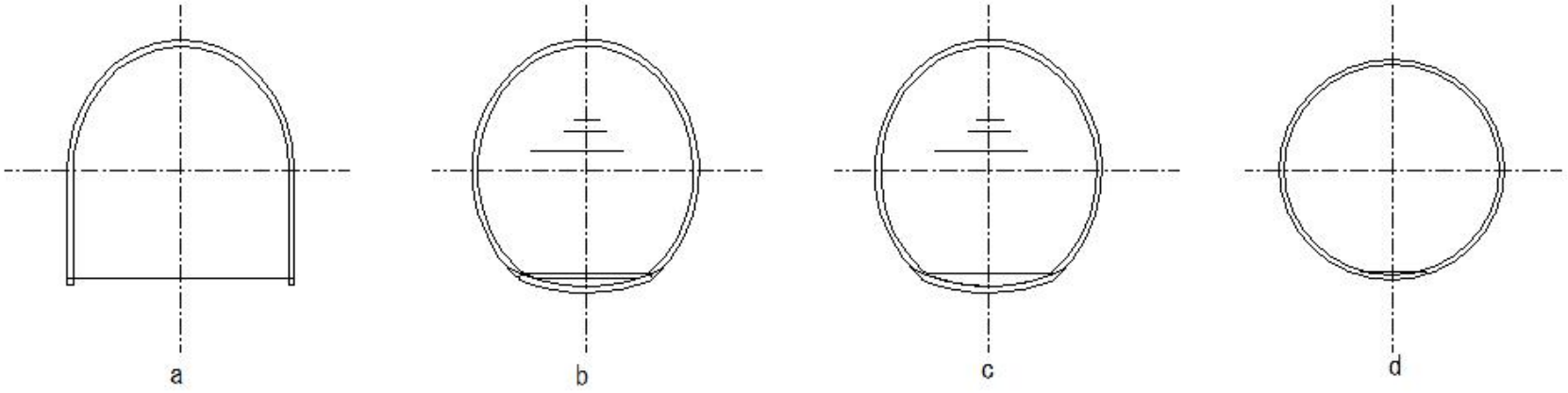
tunnel

Shape of the Coverings (lining)

Cross-sectional shape according to geology

Soft geology - invert

Cross-sectional - closed cross-section



(T67)Tunnel(Enlarged sidewall concrete)

(T67)Tunnel(Enlarged sidewall concrete)

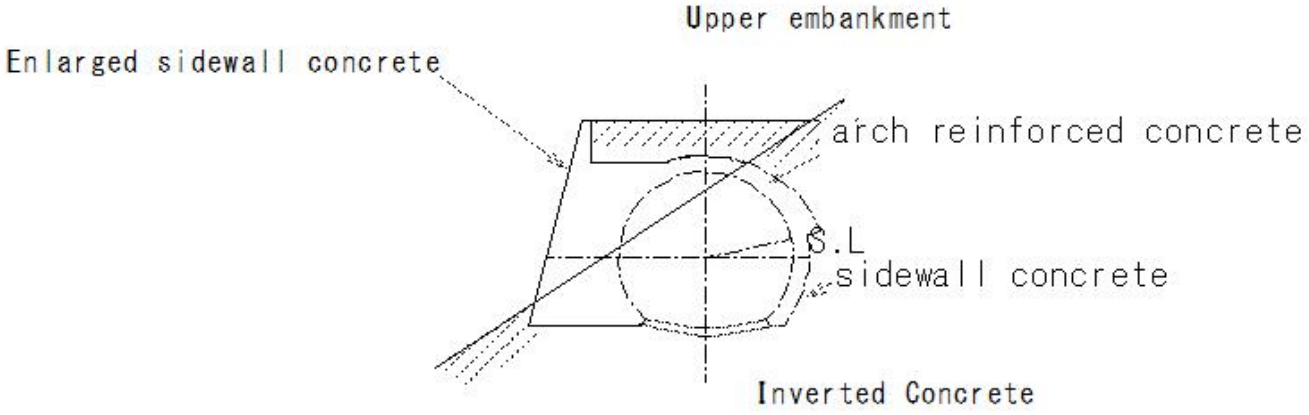
tunnel

Shape of the Coverings (lining)

Enlarged sidewall concrete

Near the Tunnel entrance

Soil Cover - Shallow Pressure - Enlarged sidewall concrete



Enlarged sidewall concrete

C1061

(T68)Tunnel(Shape of the cover)

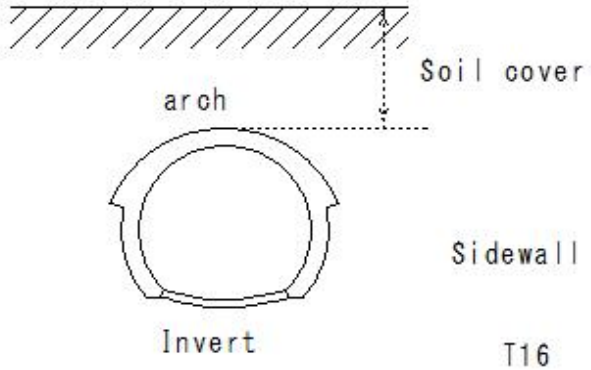
(T68) Tunnel (Shape of the cover)

tunnel

Shape of the cover

Design Thickness Standards

Width of the inner cross-section (m)	Design thickness of concrete coverings (lining) (cm)
2	20－30
5	30－50
10	40－70



T16

(T69)Tunnel(coverings (lining))

(T69)Tunnel(coverings (lining))

tunnel

The order of construction of the coverings (lining)

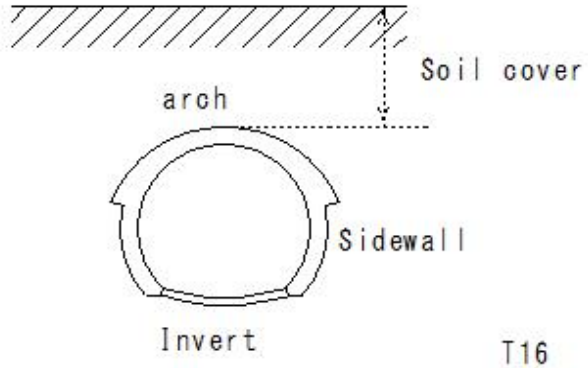
case of steel arch support is used for supporting

(1) After placing the arch and side wall, the invert is placed

(2) place the arch first, and while excavating, place the side wall and then place the invert

(3) The side wall is placed first, and the invert is placed on it after the arch is placed.

(4) Cast all cross-sections at once



T16

(T70)Tunnel(coverings (lining)-formwork)

(T70)Tunnel(coverings (lining)-formwork)

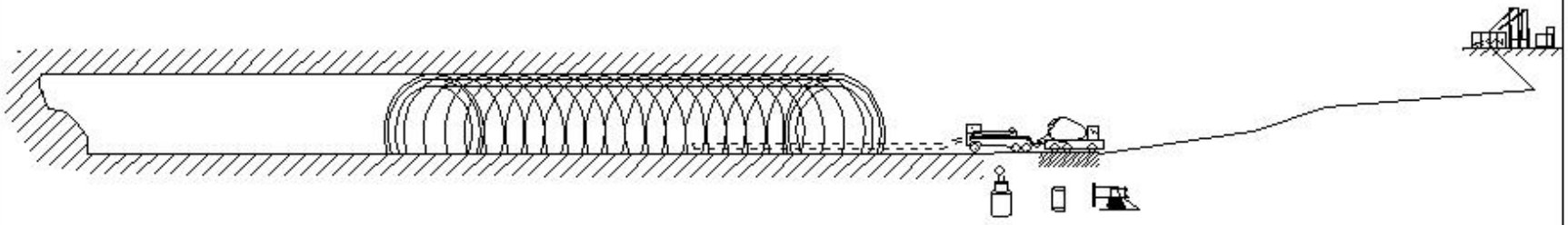
tunnel

cover formwork

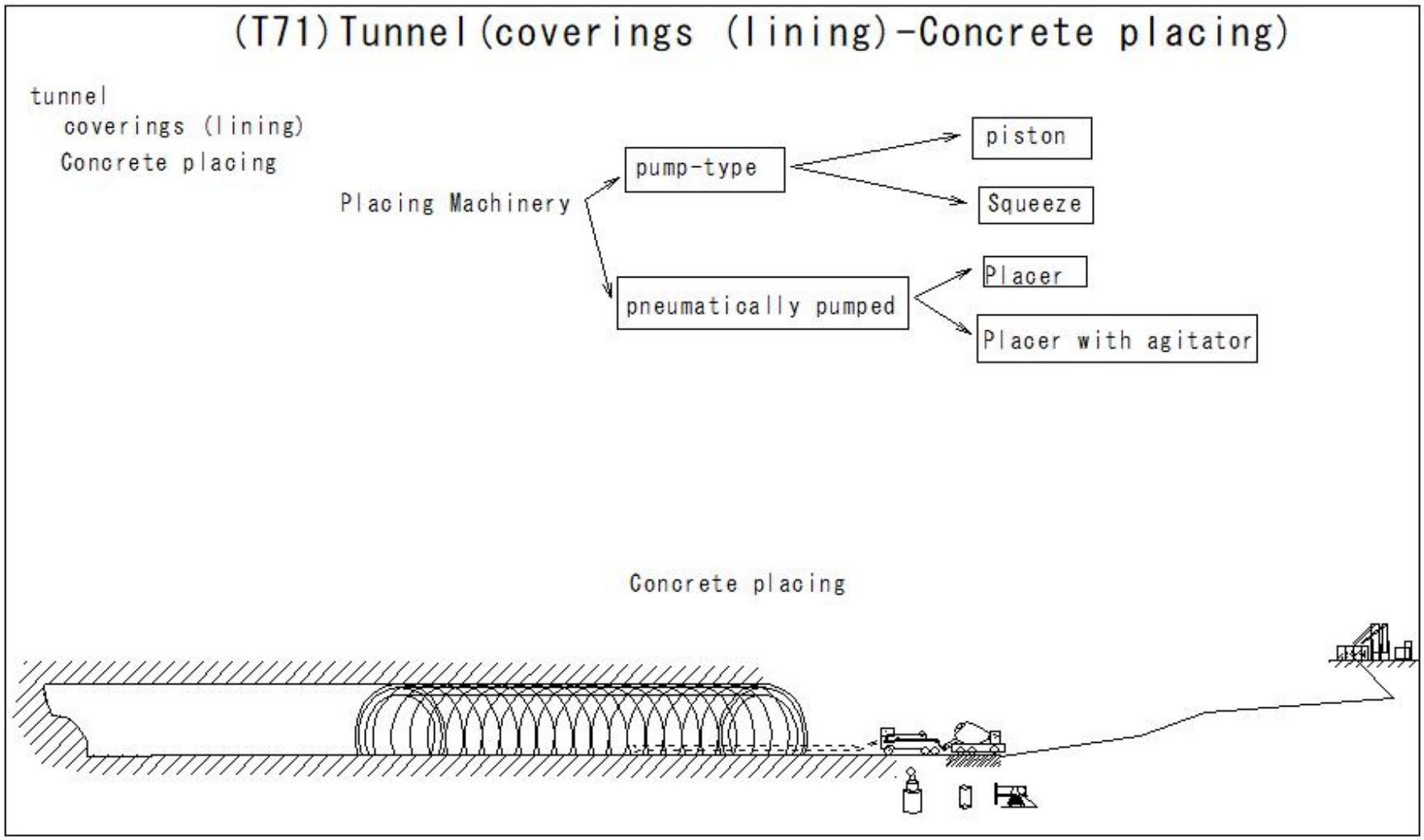
- Mobile formwork
- Prefabricated formwork
- Concrete placing for covering: Presser with concrete pump and agitator
- Slump 12-18cm
- Concrete: high temperature, drying, 1 hour

Low temperature wet - 2 hours

Concrete placing



(T71)Tunnel(coverings (lining)-Concrete placing)



(T72)Tunnel(coverings (lining)-Concrete placing)

(T72)Tunnel(coverings (lining)-Concrete placing)

tunnel

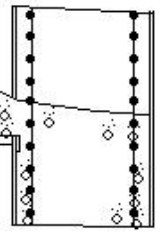
coverings (lining)

Precautions in case of placing concrete

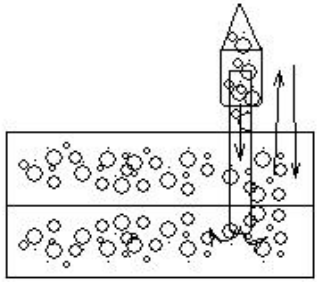
(1)Prevention of segregation : Embedding the discharge port in concrete

Concrete placement

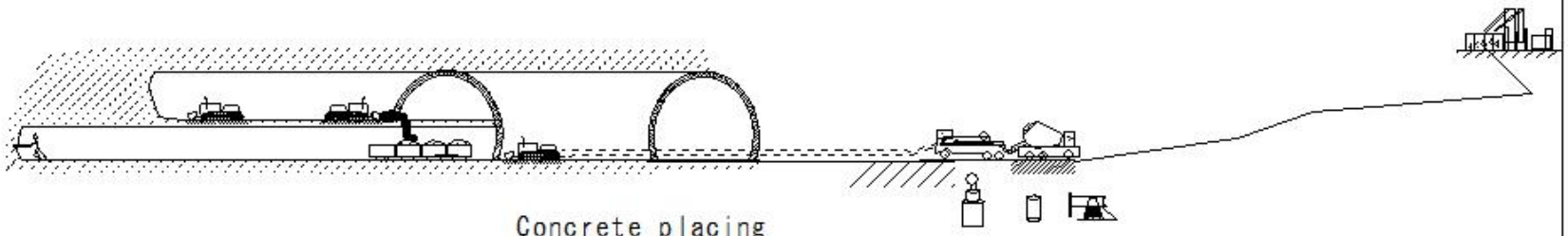
Concrete injection input



C1271

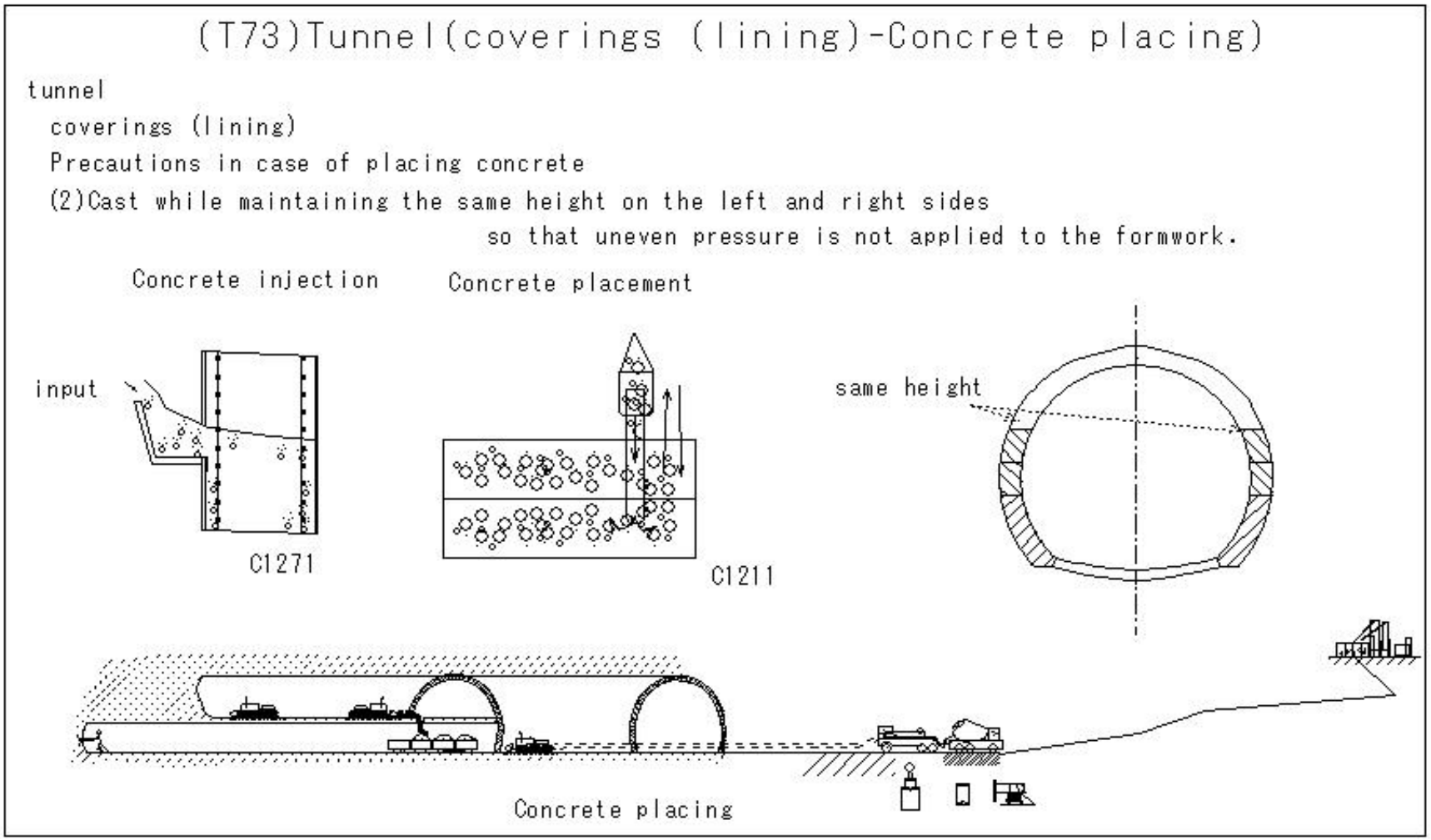


C1211

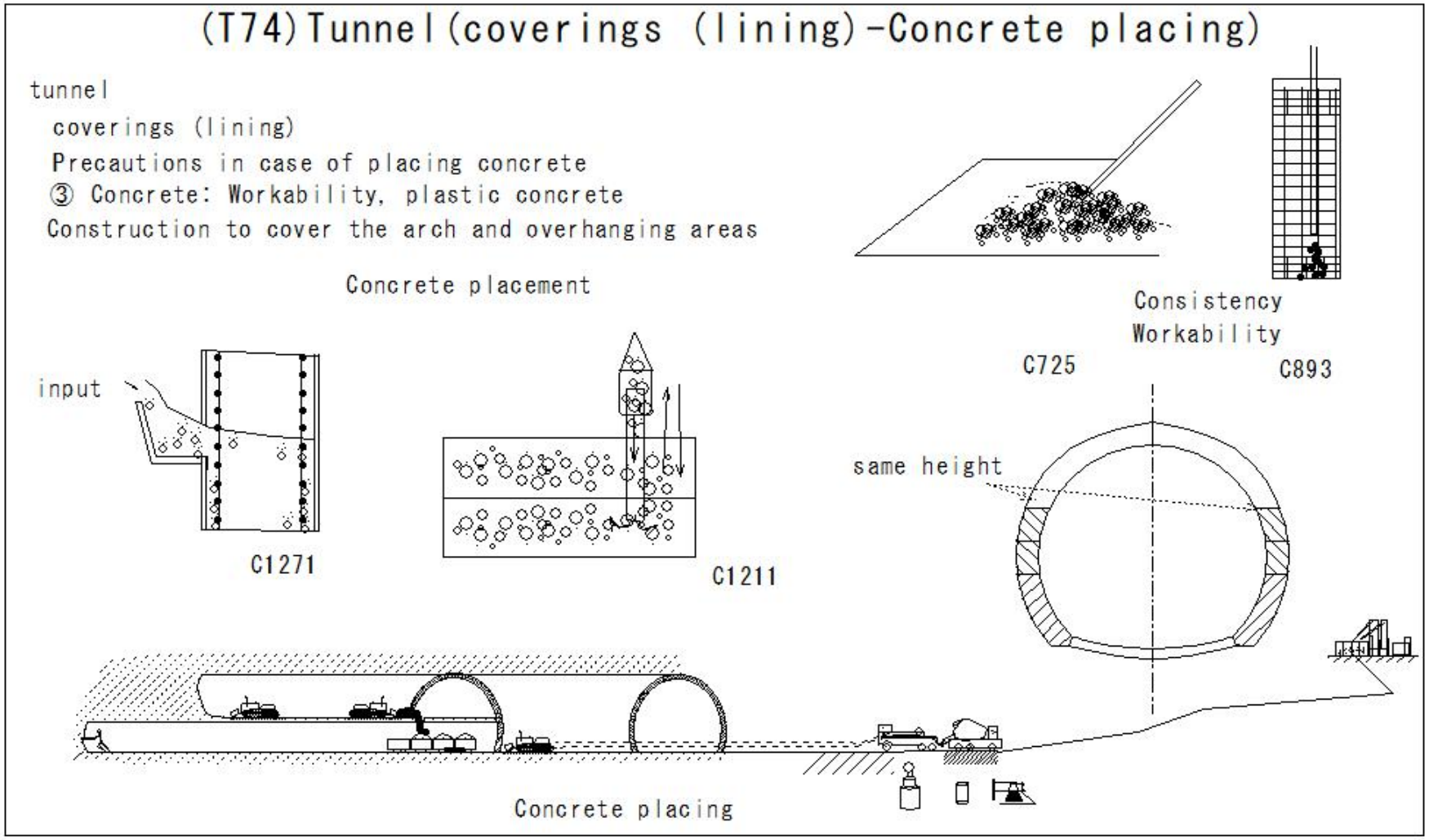


Concrete placing

(T73)Tunnel(coverings (lining)-Concrete placing)



(T74)Tunnel(coverings (lining)-Concrete placing)



(T75)Tunnel(coverings (lining)-Concrete placing)

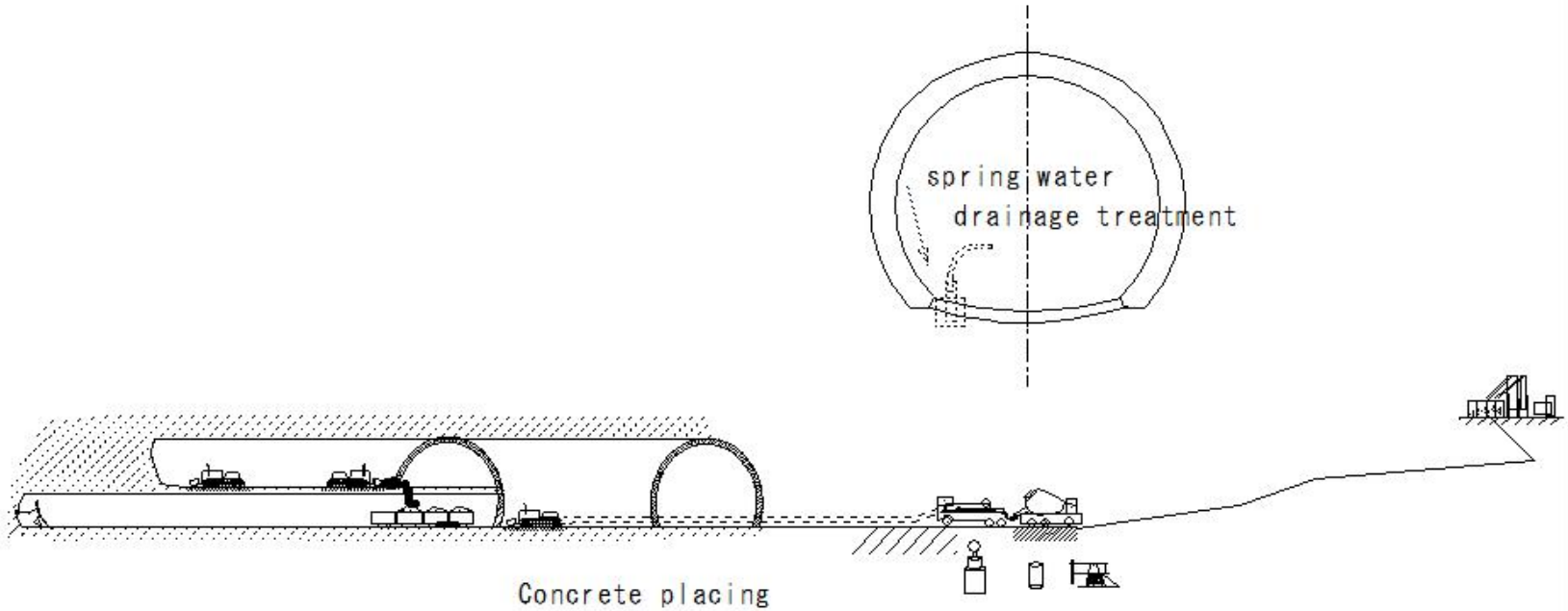
(T75)Tunnel(coverings (lining)-Concrete placing)

tunnel

coverings (lining)

Precautions in case of placing concrete

④in case of spring water is, use appropriate drainage treatment and place high-quality concrete



(T76)Tunnel(coverings (lining)-Concrete placing)

(T76)Tunnel(coverings (lining)-Concrete placing)

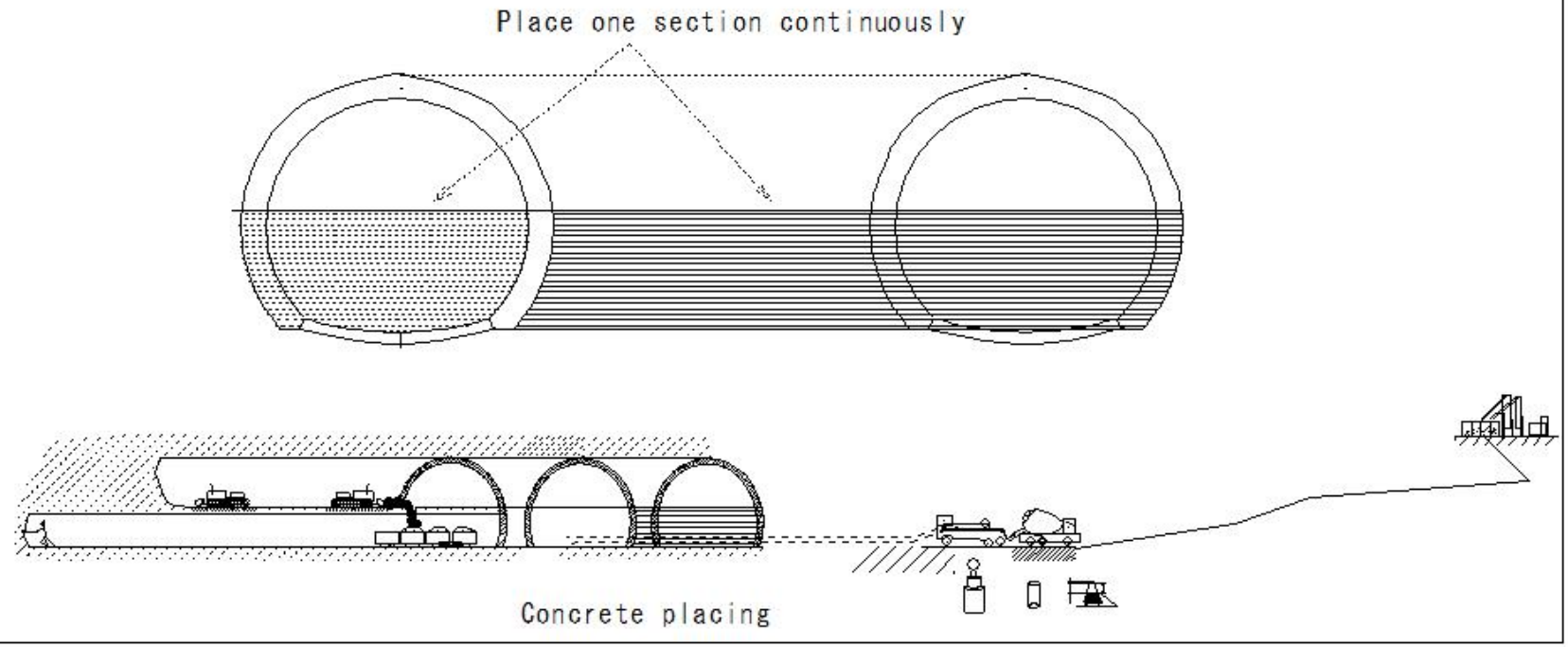
tunnel

coverings (lining)

Precautions in case of placing concrete

⑤Place concrete quickly after mixing

Place one section continuously



(T77)Tunnel(coverings (lining)-Concrete placing)

(T77)Tunnel(coverings (lining)-Concrete placing)

tunnel

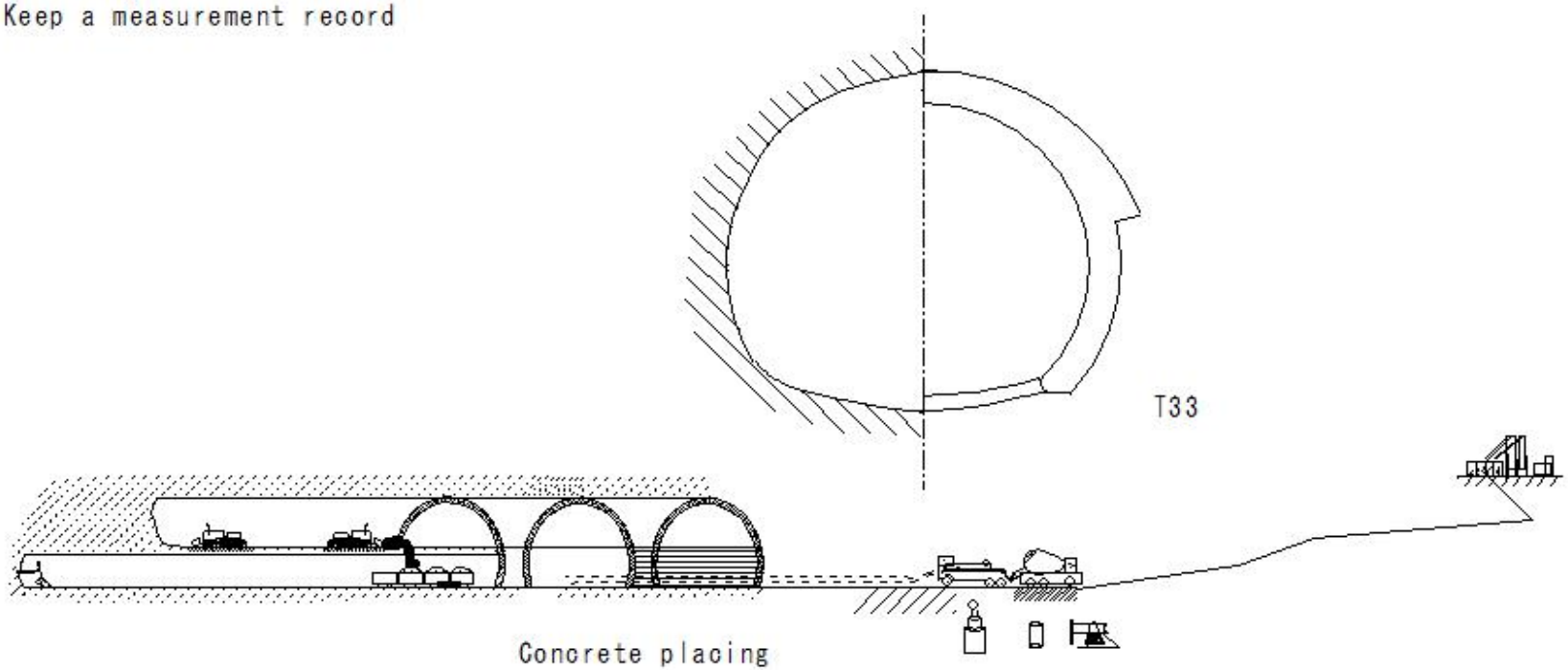
coverings (lining)

Precautions in case of placing concrete

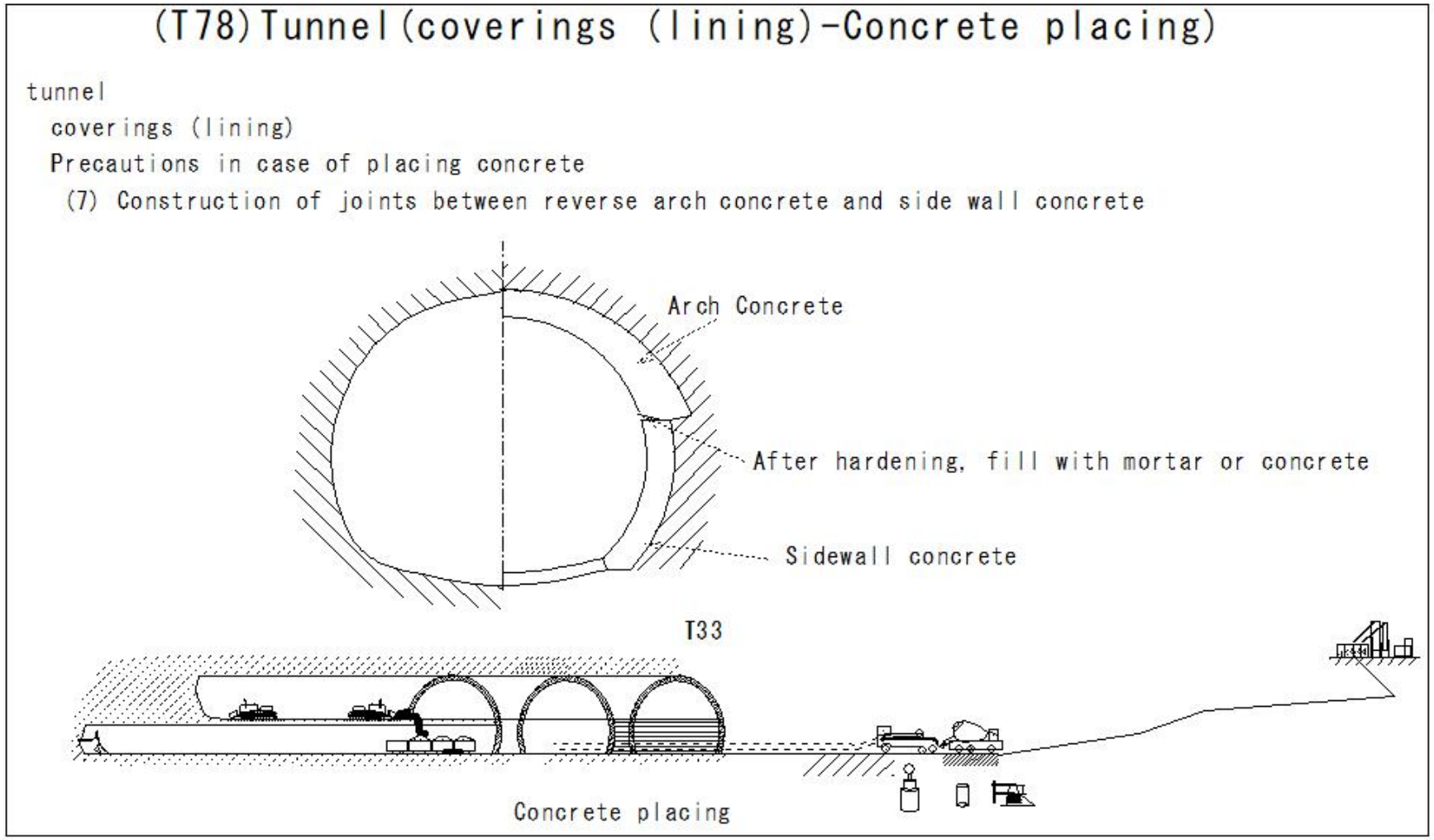
⑥check the design thickness of the concrete

Stability of the thickness of the concrete

Keep a measurement record



(T78)Tunnel(coverings (lining)-Concrete placing)



(T79)Tunnel(coverings (lining)-Concrete placing)

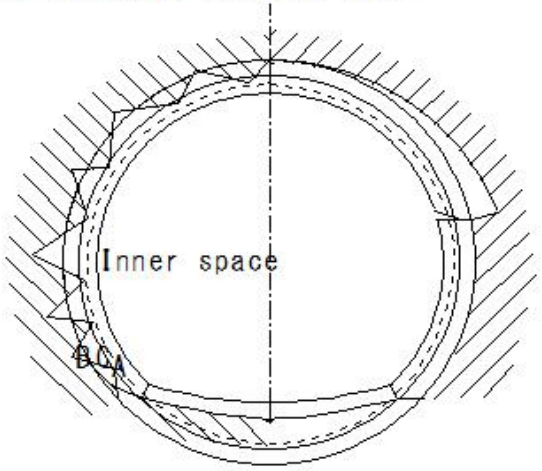
(T79)Tunnel(coverings (lining)-Concrete placing)

tunnel

coverings (lining)

Precautions in case of placing concrete

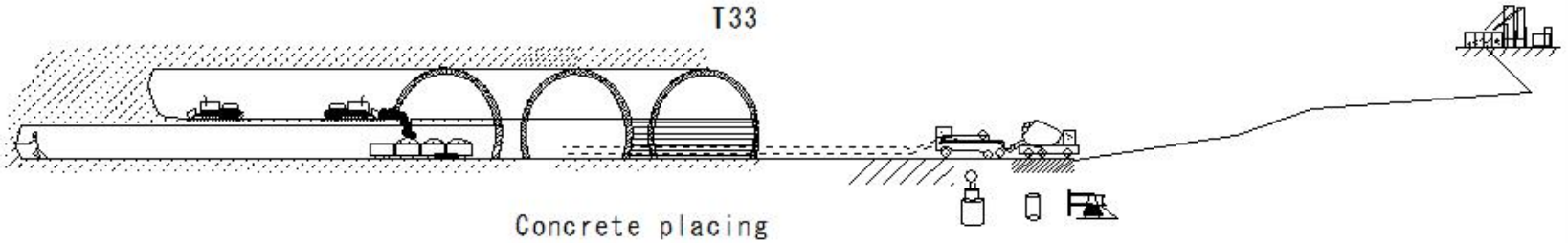
(8) Concrete payment line



A: Minimum winding thickness: Concrete completely inside the line

B: Payment line: The line subject to construction cost payment

C: Design coverings (lining) thickness: Rocks and iron materials may be placed between lines A and C, but do not enter wood, etc.



Concrete placing

(T80)Tunnel(Grouting)

(T80)Tunnel(Grouting)

tunnel

Grouting

coverings (lining): There is an air gap between the arch crown and the ground.

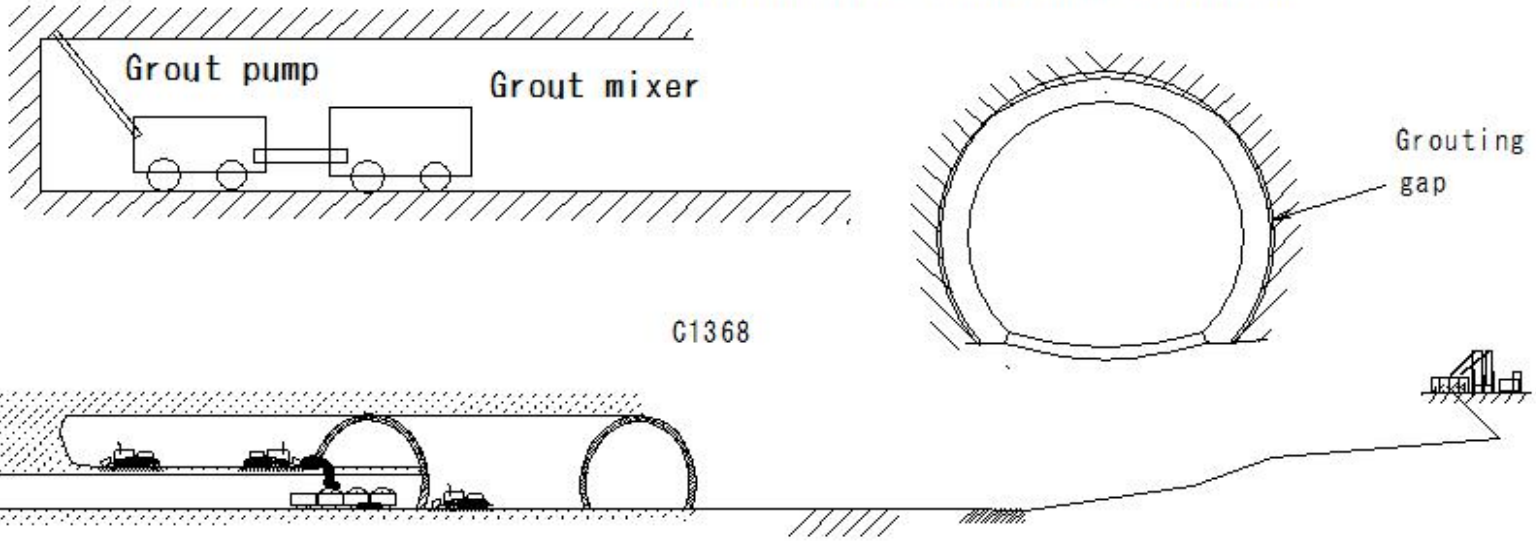
injection: do it early

Pressure Tunnel: Backing Injection

Injection is based on the injection material, the machine used, and the injection pressure.

The condition of the ground behind Selecting the appropriate one according to

the construction conditions of injection



(T81)Tunnel(Grouting)

(T81)Tunnel(Grouting)

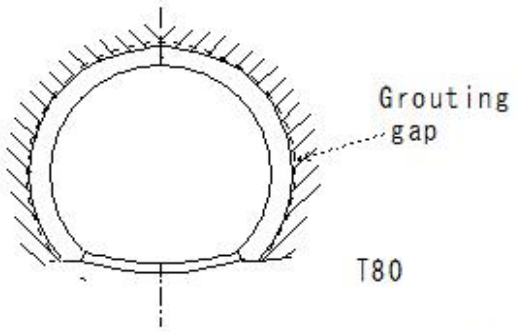
Tunnels

Grouting
Injection material: Mortar

No segregation

Minimal settling and minimal volumetric shrinkage

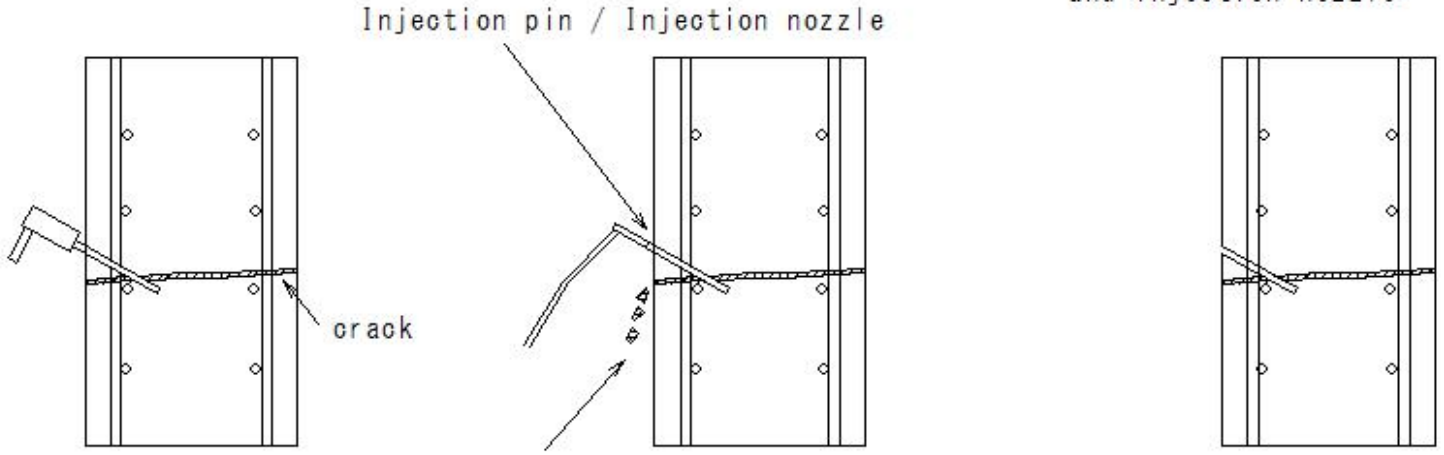
Injection material strength: 10kgf/cm2



①Drilling

②Injection

③ Removal of injection pin
and injection nozzle



Cracks - grouting material - outflow

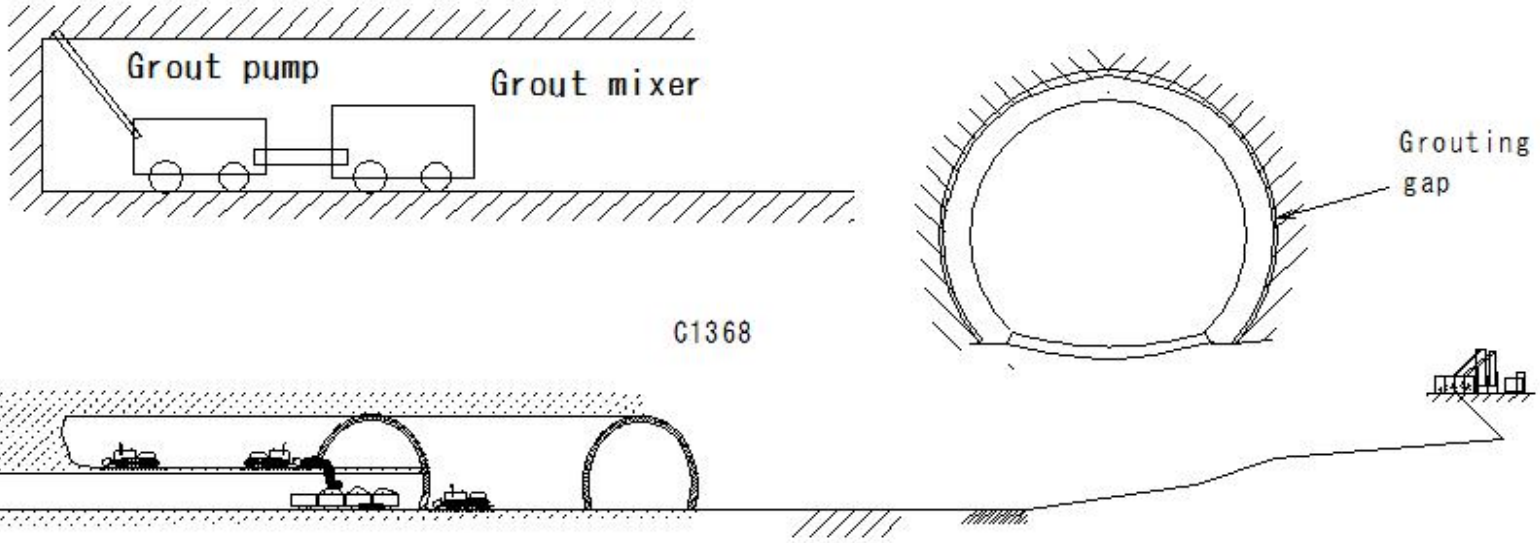
C1500

(T82)Tunnel(Grouting)

(T82) Tunnel (Grouting)

Tunnel

Grouting
Injection machine: Grout mixer + grout pump combination
Concrete mixer and concrete pump
Install a device to measure injection pressure (pressure gauge) of 1kgf/cm2 or more



(T83)Tunnel(Grouting（injection mix proportion）)

(T83)Tunnel(Grouting (injection mix proportion))

Tunnels

Grouting

Example of injection mix proportion

①	②	③	④	⑤	⑥	⑦	⑧
(s)	(%)	(kg)	(kg)	(kg)	(kg)	(%)	(kgf/cm2)
25±5	40±5	150	195	900	3.45	130	10

① Flow time (s)

② Air volume (%)

③ Cement (kg)

④ Water (kg)

⑤ Fine aggregate (kg)

⑥ Foaming agent (kg)

⑦ Water-cement ratio (%)

⑧ Design strength

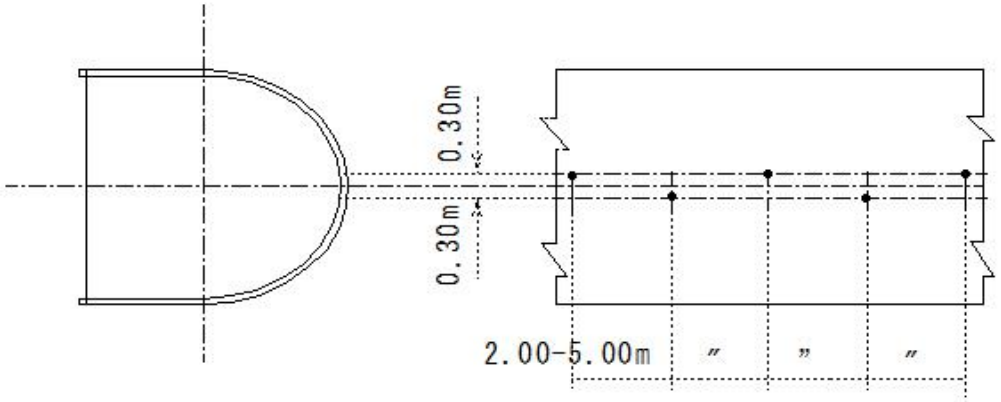
(T84)Tunnel(Grouting（injection pipe）)

(T84)Tunnel(Grouting（injection pipe）)

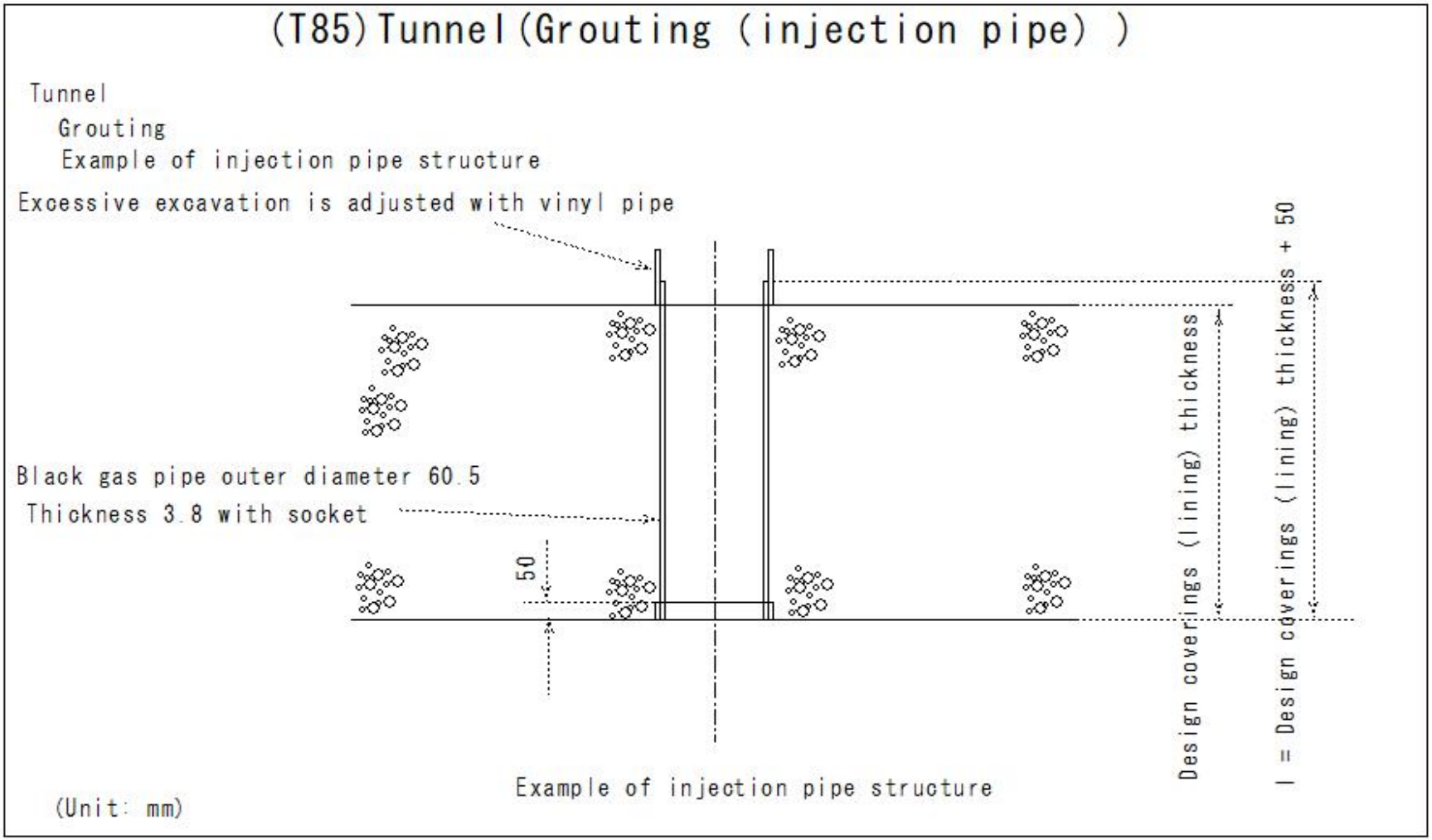
Tunnel

Grouting

Example of injection pipe layout



(T85)Tunnel(Grouting（injection pipe）)



(T86)Tunnel(Special methods)

(T86)Tunnel(Special methods)

Tunnels

Special methods

Rock bolts, sprayed concrete, steel supports

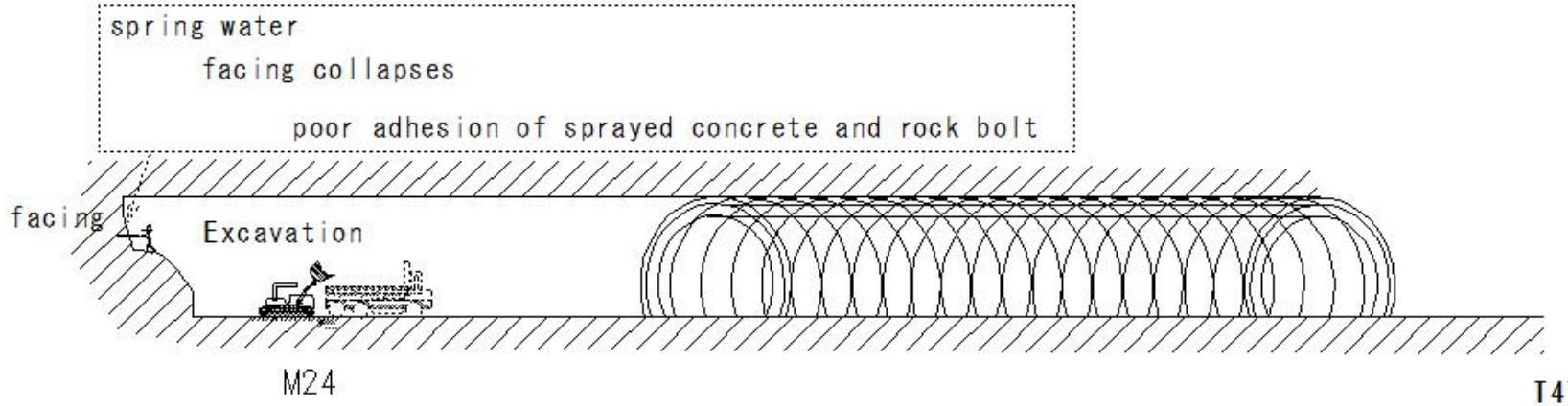
Drainage methods, injection methods: improving ground conditions

Fault fracture zones, unconsolidated: cutting edge does not stand up and excavation is difficult

In the case of a lot of spring water, cutting edge collapses, poor adhesion of sprayed concrete

Rock bolts do not settle

Injection methods, pipe roof methods: ground reinforcement



T47

(T87)Tunnel(facing stabilization measures-Measures against ground settlement)

(T87)Tunnel(facing stabilization measures-Measures against ground settlement)

Tunnels

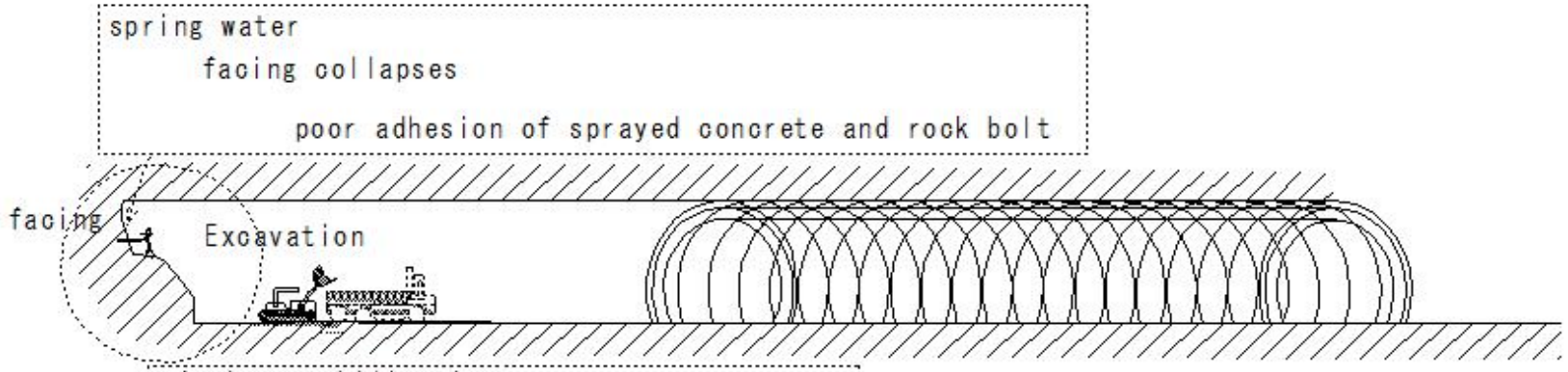
Special methods

- facing stabilization measures

  Drainage boring, drainage tunnel, well point, deep well,Compressed air method, injection method, pipe roof method, special steel sheet pile jacking method, freezing method

- Measures against ground settlement

  Injection method, cutoff wall method, pipe roof method, special steel sheet pile jacking method, freezing method



T47

T86

(T88)Tunnel(Injection method)

(T88)Tunnel(Injection method)

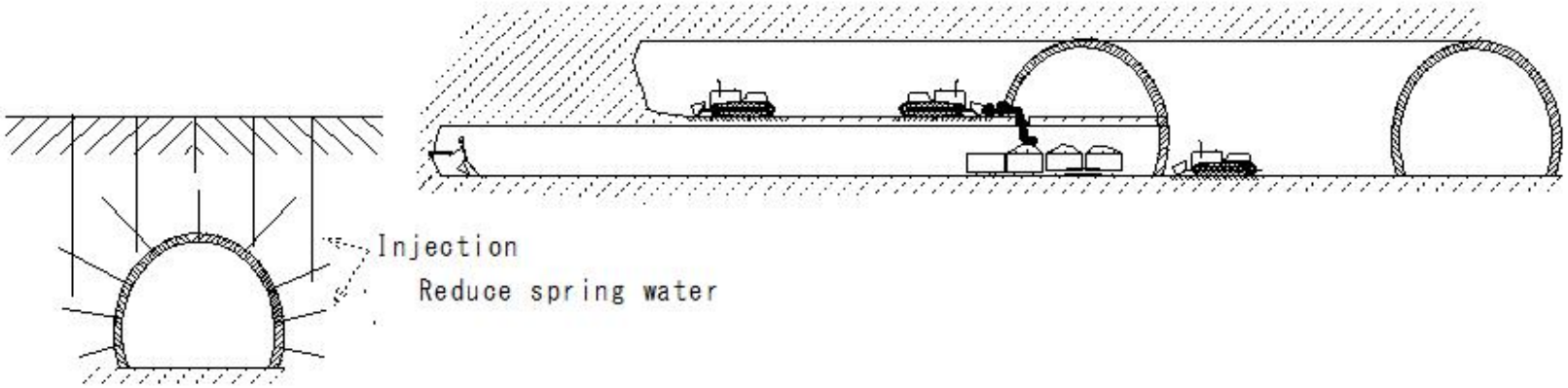
Tunnel

Injection method

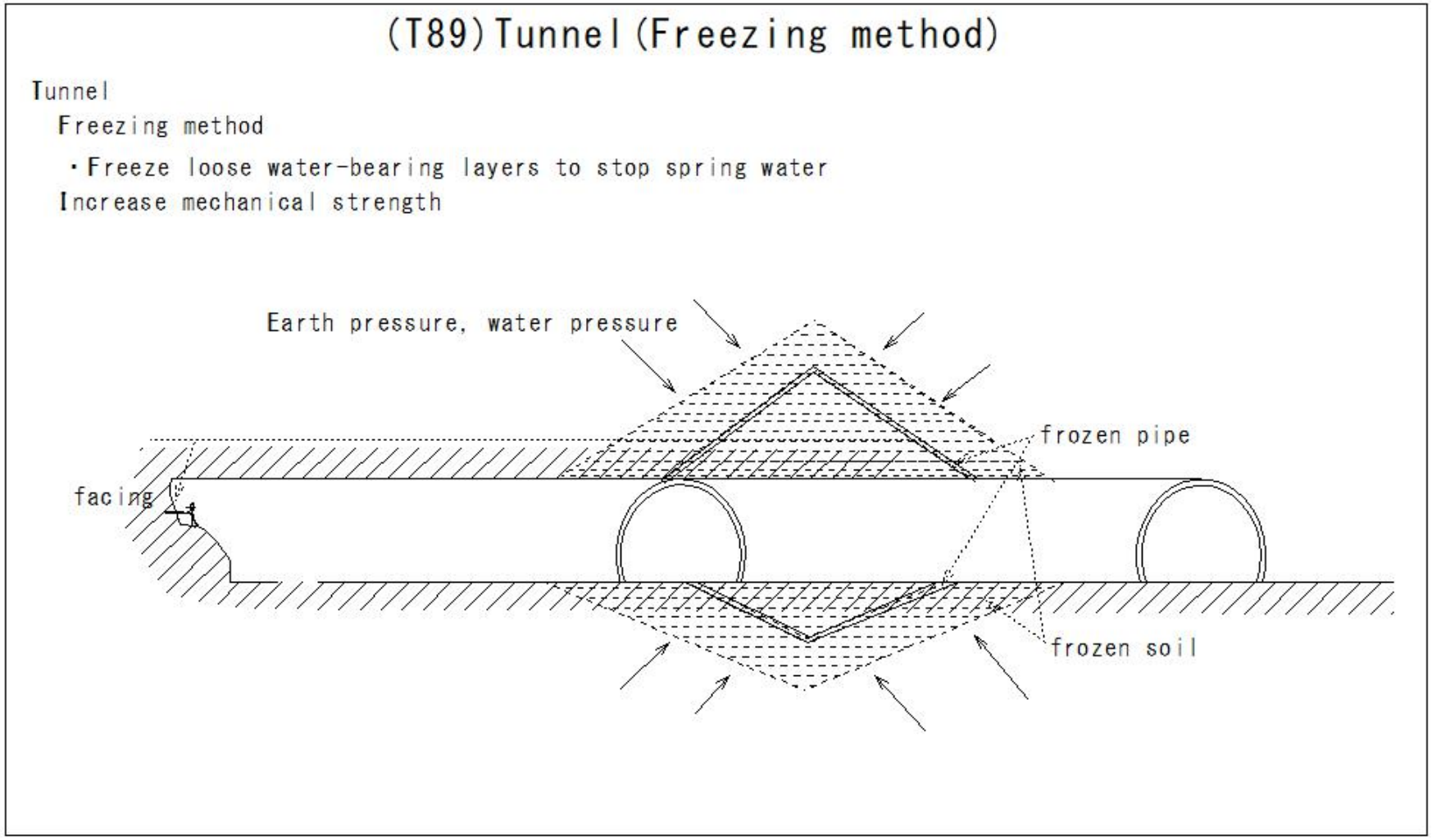
- Solidify liquids such as cement milk and sodium silicate in the ground
- Reduce spring water in the tunnel
- Injection pressure - in case of too high, it will damage the ground and surrounding structures
- At the end of injection, during injection work, check the amount of spring water in each hole, the amount of injection, the change in injection pressure, and the change

Confirm the injection effect

- Injection from the surface
- Injection from inside the mine



(T89)Tunnel(Freezing method)



(T90)Tunnel(Drainage boring)

(T90) Tunnel (Drainage boring)

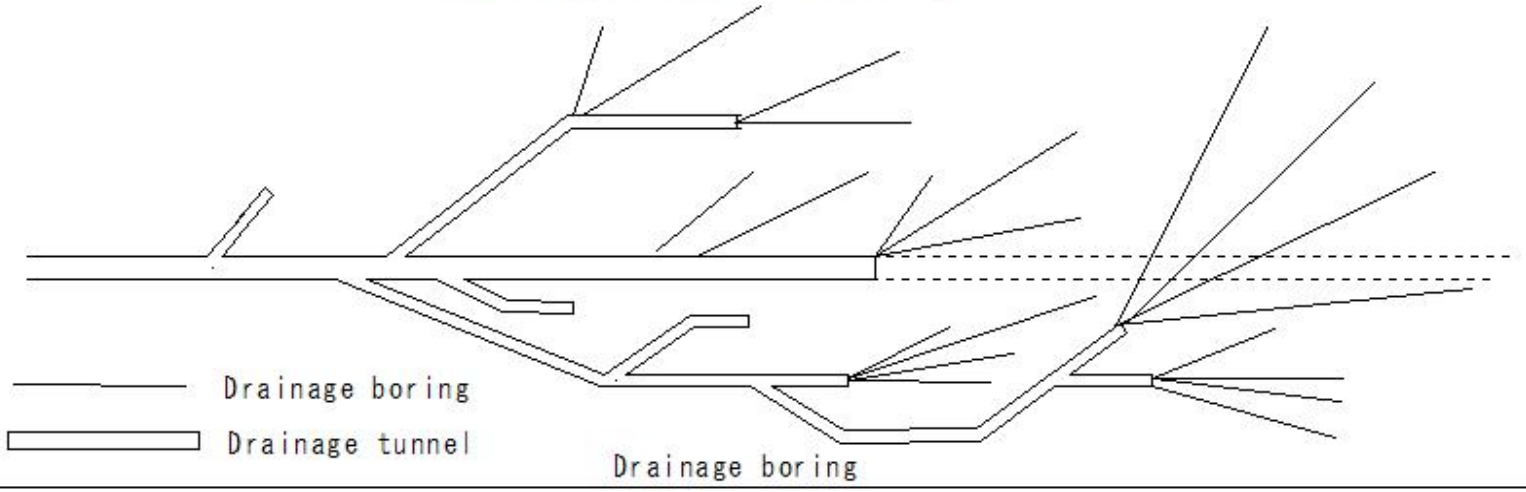
Tunnel

Drainage boring

- Method of lowering water pressure and groundwater level
- Drainage tunnel
- in case of there is a large amount of spring water

Advance a small-section tunnel to drain the water in advance

- Use in conjunction with drainage boring
- tunnel can be used as an investigation tunnel or detour tunnel
- in case of a pressurized aquifer with a large amount of spring water is widespread, a drainage tunnel is necessary



(T91)Tunnel(Well point method)

(T91)Tunnel(Well point method)

Tunnel

Well point method

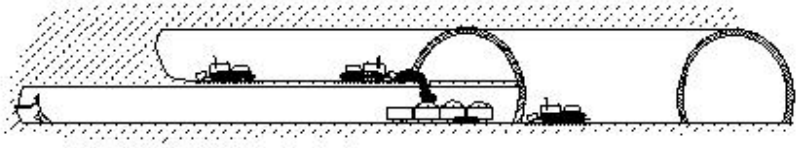
Installing a water collection pipe in the ground

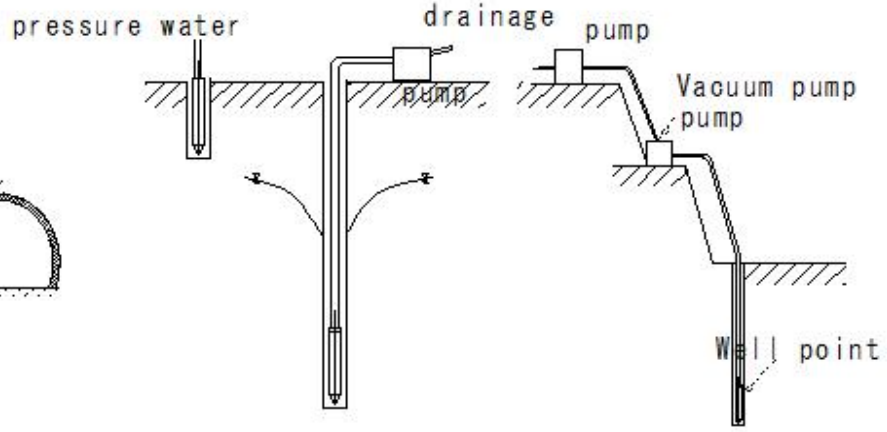
Applying negative pressure to the ground to suck up groundwater

Lowering groundwater - 5-8m

Construction inside the tunnel: Advance the upper half

in case of the soil cover is small: Construction from above ground





Well point method E149

(T92)Tunnel(Pipe roof methods)

(T92)Tunnel(Pipe roof methods)

Tunnels

Pipe roof methods

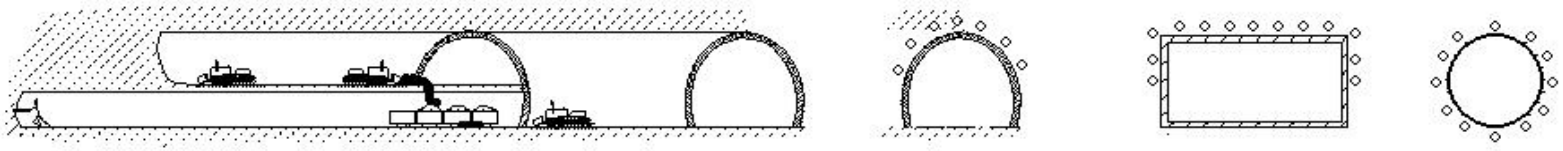
Boring is performed outside the excavation section

Injecting inside and outside the pipe to reinforce the outside of the excavation section

Reinforcing unstable ground such as talus and fault fracture zones

Preventing loosening of the facing

Stabilizing measures for the facing



◇ Pipe roof

Pipe roof methods

(T93)Tunnel(Special steel sheet pile jacking method)

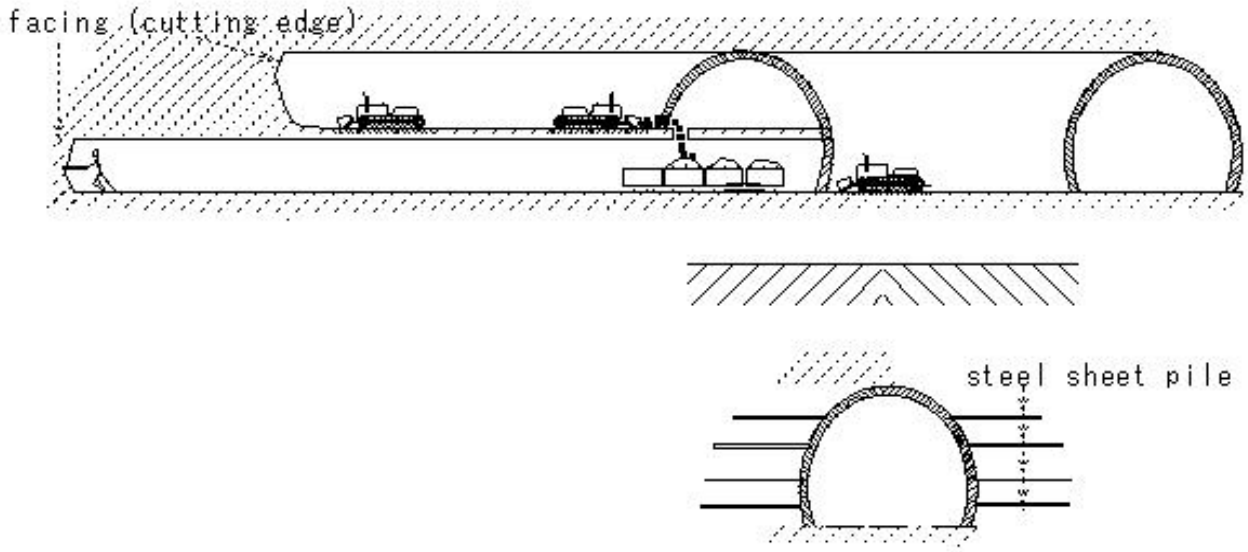
(T93)Tunnel(Special steel sheet pile jacking method)

Tunnels

Special steel sheet pile jacking method

facing (cutting edge) front - Ground reinforcement - Loosening prevention - Cutting edge stabilization measures

Specially processed steel sheet pile - Jack - Horizontal press-in



(T94)Tunnel(Barrier wall method)

(T94) Tunnel (Barrier wall method)

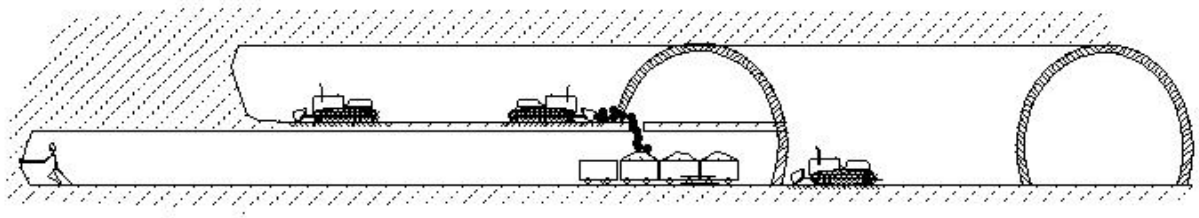
Tunnels

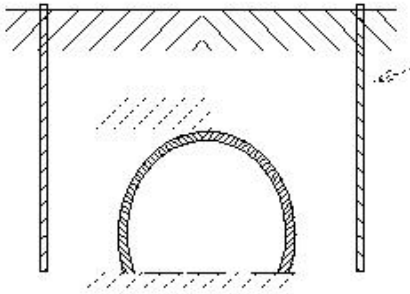
Barrier wall method

Installing a barrier wall on both sides (one side) of the tunnel to limit the range of loosening ground caused by tunnel excavation

Preventing ground Settlement from reaching the outside of the barrier wall

Continuous underground wall method, steel pipe, H-shaped steel, steel sheet pile





Barrier wall method

Continuous underground wall method, steel pipe, H-shaped steel, steel sheet pile

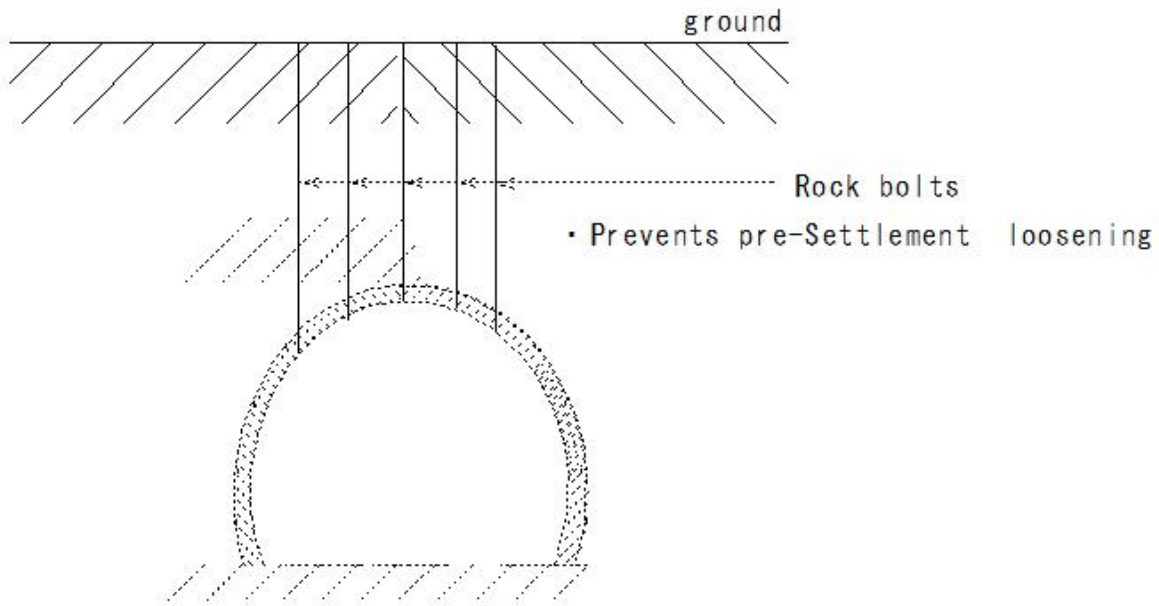
(T95)Tunnel(Downward bolt from the ground)

(T95)Tunnel(Downward bolt from the ground)

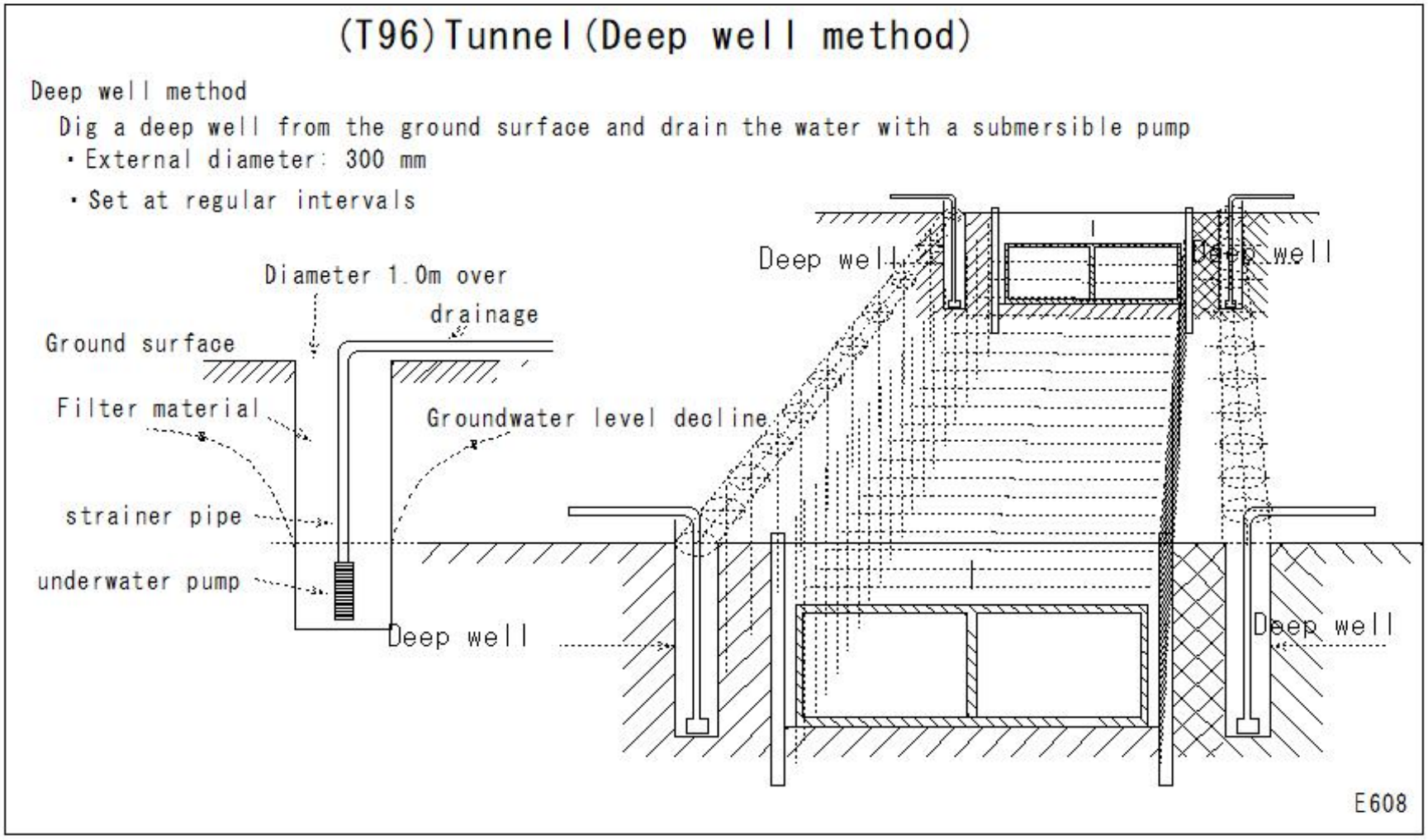
Tunnel

Downward bolt from the ground

- Rock bolts are installed almost vertically from the ground
- Prevents pre-Settlement
- Prevents loosening



(T96)Tunnel(Deep well method)



(T97)Tunnel(Investigations during construction)

(T97)Tunnel(Investigations during construction)

Tunnels

Investigations during construction

・Ground bearing capacity, magnitude of earth pressure, uneven pressure, weathering and water absorption changes, ground swelling, load on supports

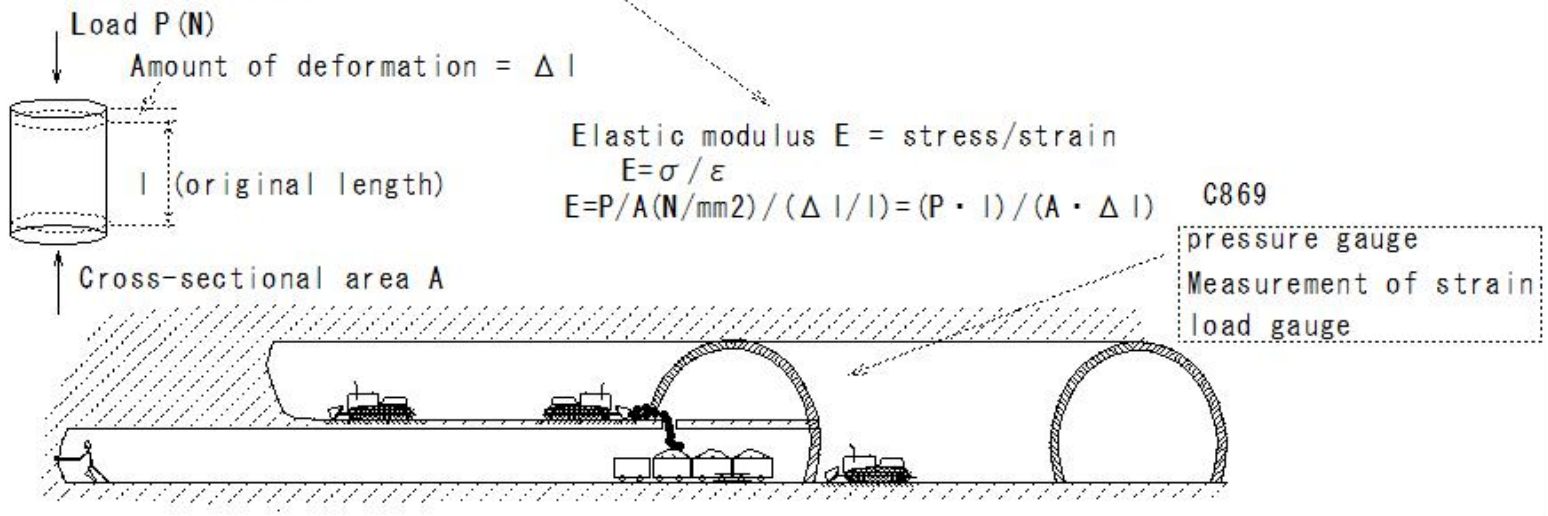
・Methods of measuring earth pressure

①Method using an earth pressure gauge

②Measurement of strain on supports and coverings

Back-calculating the applied load from the strain value

③Method using a load gauge



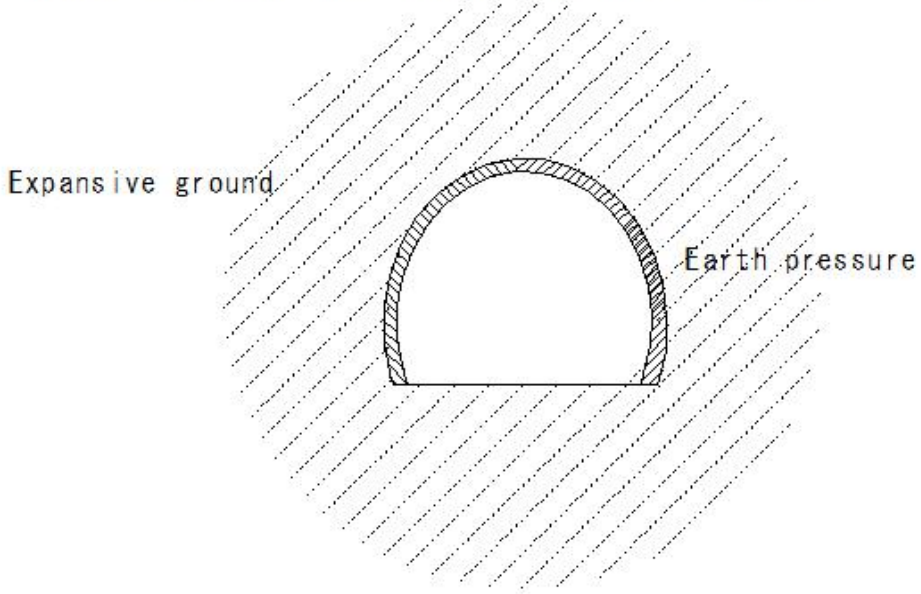
(T98)Tunnel(Expansive ground・Weathered rock zone)

(T98)Tunnel(Expansive ground・Weathered rock zone)

Tunnels

Expansive ground

- Large earth pressure from the top, side walls, and base
- Around the cutting edge, do not loosen the ground in front
- Close the entire cross section of the :support and covering work early
- Significant extrusion into the interior of the excavation section
- Earth pressure acts on the :support and covering work



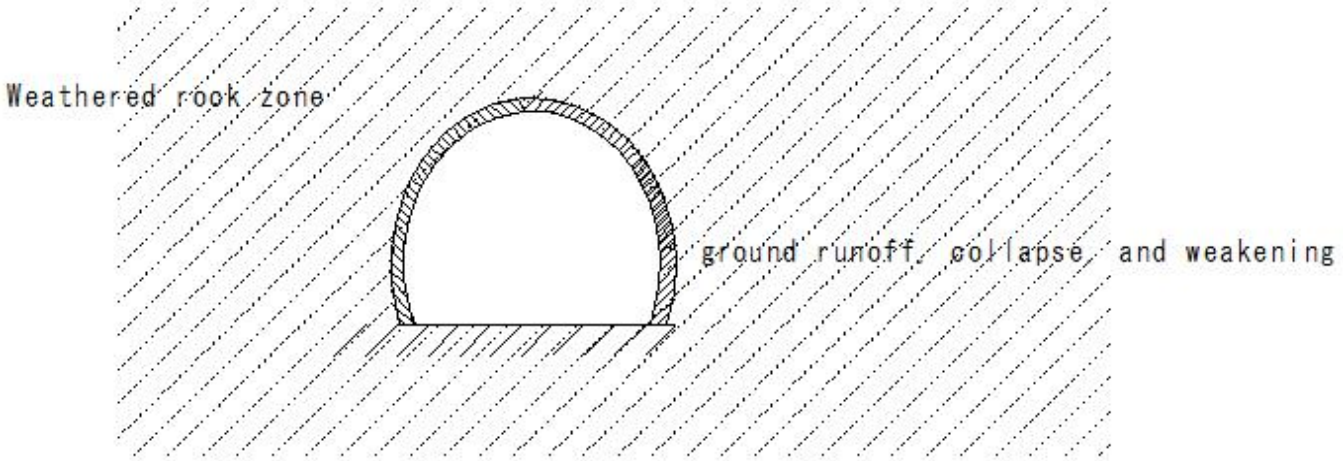
(T99)Tunnel(Weathered rock zone)

(T99)Tunnel(Weathered rock zone)

Tunnels

Weathered rock zone

- in case of the unconsolidated or low-consolidated ground in the crushed zone is at the groundwater level
- Accompanied by spring water, ground runoff, collapse, and weakening of the tunnel base
- Unconsolidated sandy soil: The cutting edge is less self-supporting
- Water-containing unconsolidated sandy soil: The ground is prone to fluidization



(T100)Tunnel(Tunnel survey)

(T100)Tunnel(Tunnel survey)

Tunnel

Tunnel surveys and associated facilities

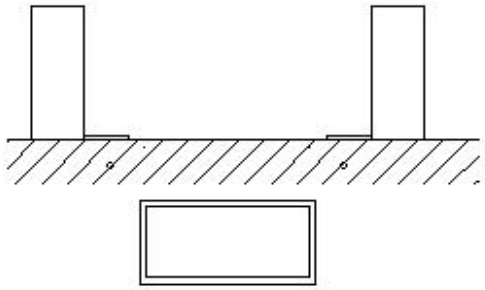
Tunnel survey

Selection of tunnel location

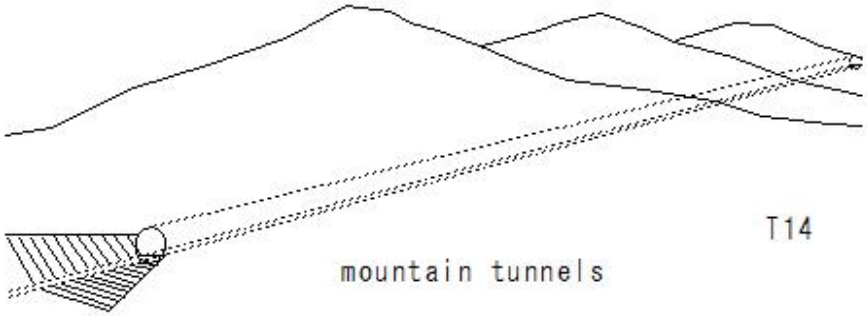
Design, construction, and post-completion maintenance

Geological surveys: important

Tunnel construction locations: mountain tunnels, urban tunnels, underwater tunnels

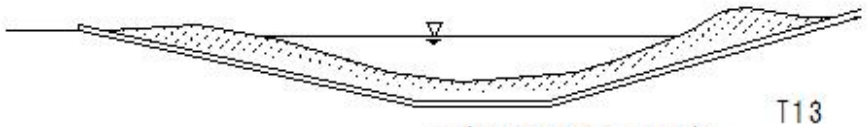


urban tunnels



T14

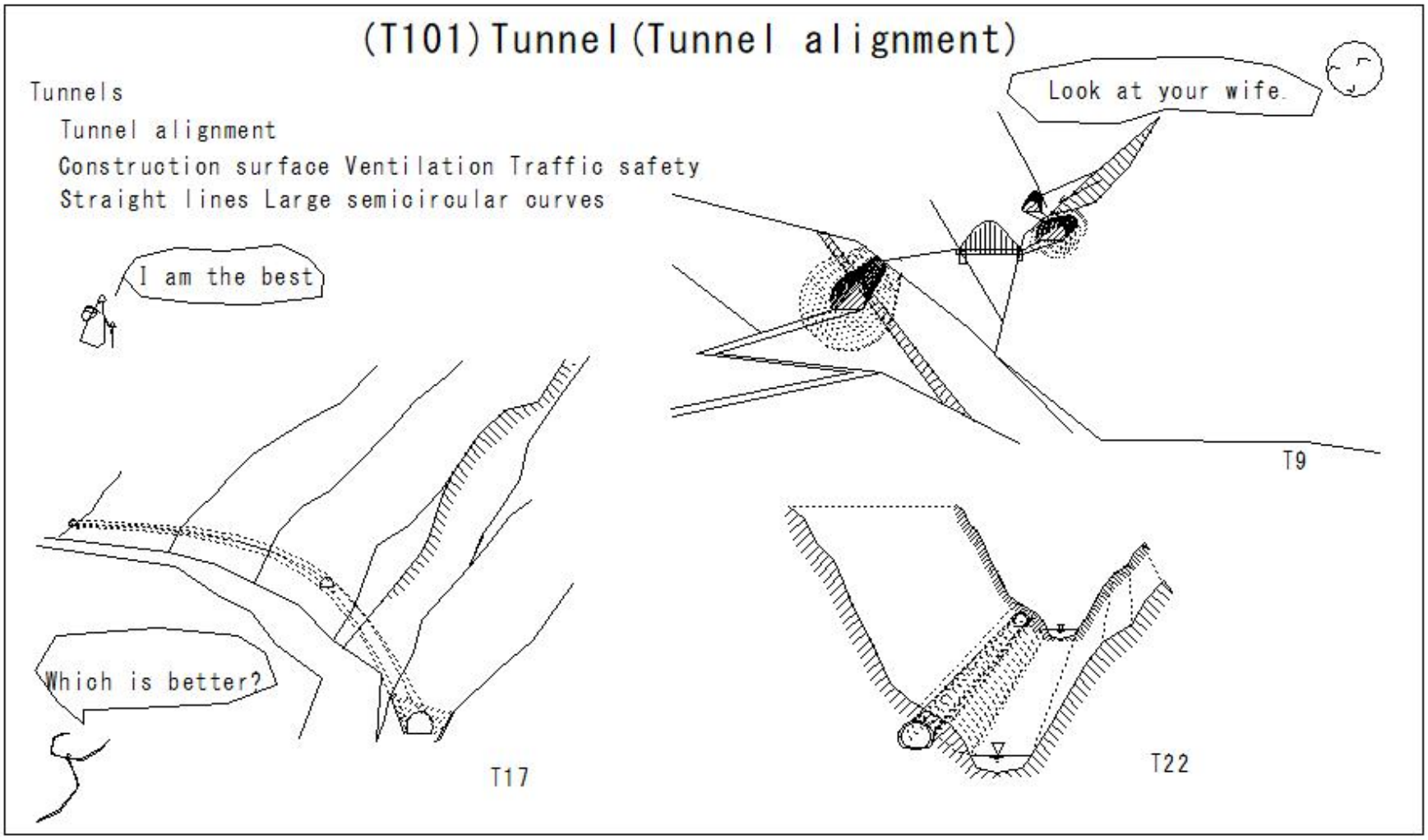
mountain tunnels



T13

underwater tunnels

(T101)Tunnel(Tunnel alignment)



(T102)Tunnel(Tunnel gradient)

(T102)Tunnel(Tunnel gradient)

Tunnel

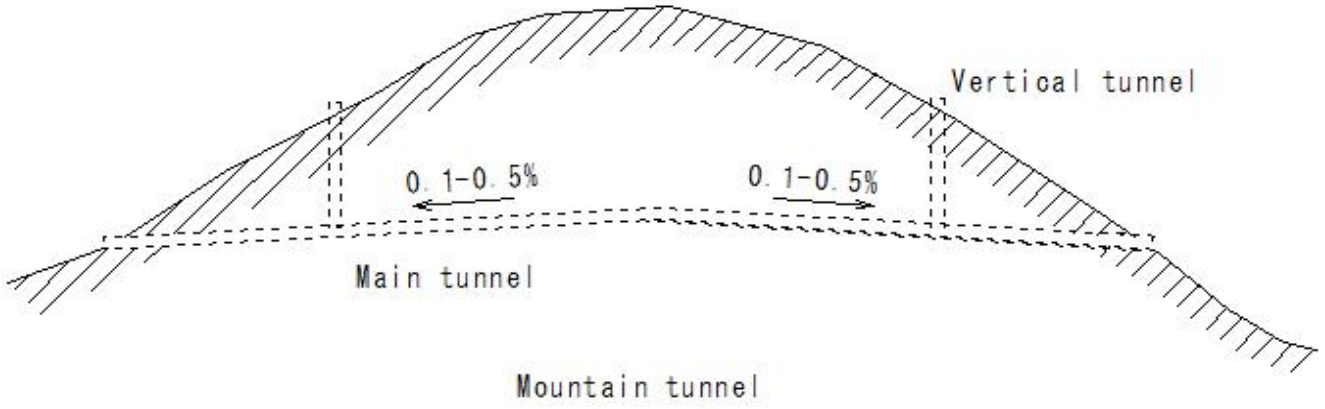
Tunnel gradient

During construction, drainage after completion is planed

①Mountain tunnel: 0.1-0.5% gradient toward the outside

Vertical tunnel

Main tunnel



(T103)Tunnel(Tunnel gradient)

(T103)Tunnel(Tunnel gradient)

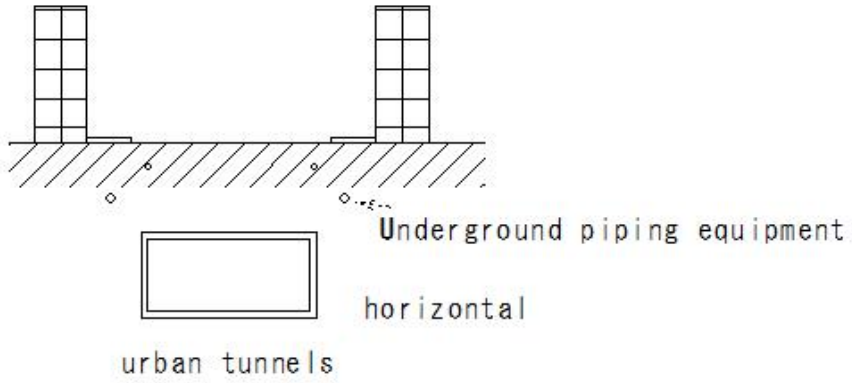
Tunnel

Tunnel gradient

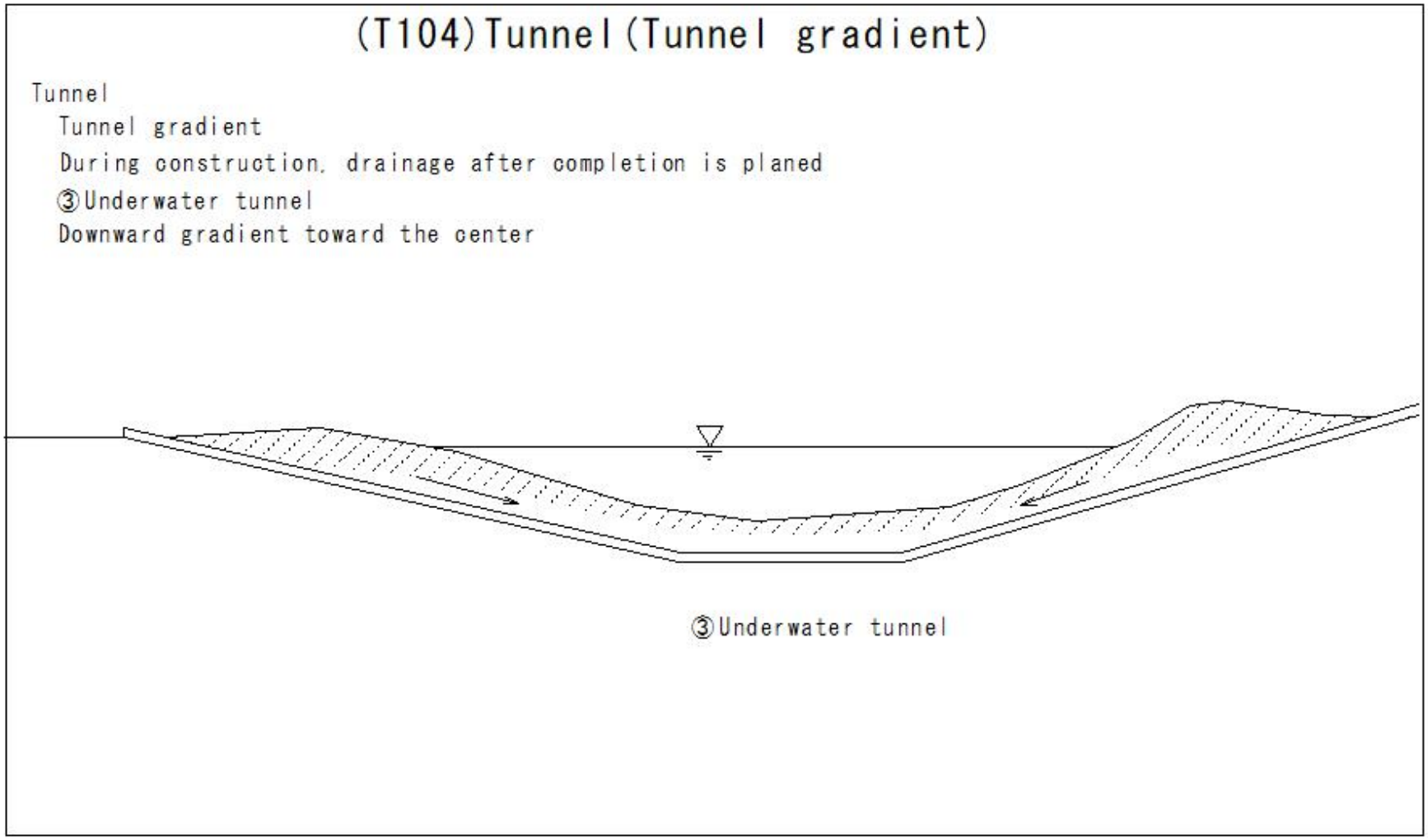
During construction, drainage after completion is planed

②Urban tunnel: Drainage is planed, as horizontal as possible

Underground piping equipment



(T104)Tunnel(Tunnel gradient)



(T105)Tunnel(Cross-sectional shape of the tunnel)

(T105)Tunnel(Cross-sectional shape of the tunnel)

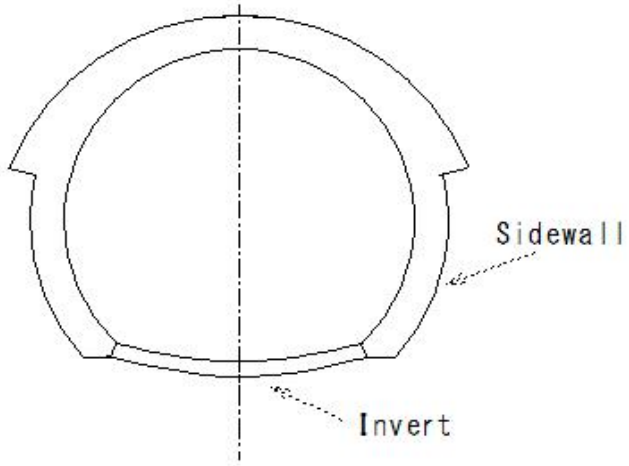
tunnel

Cross-sectional shape of the tunnel

・Purpose of use: Construction method

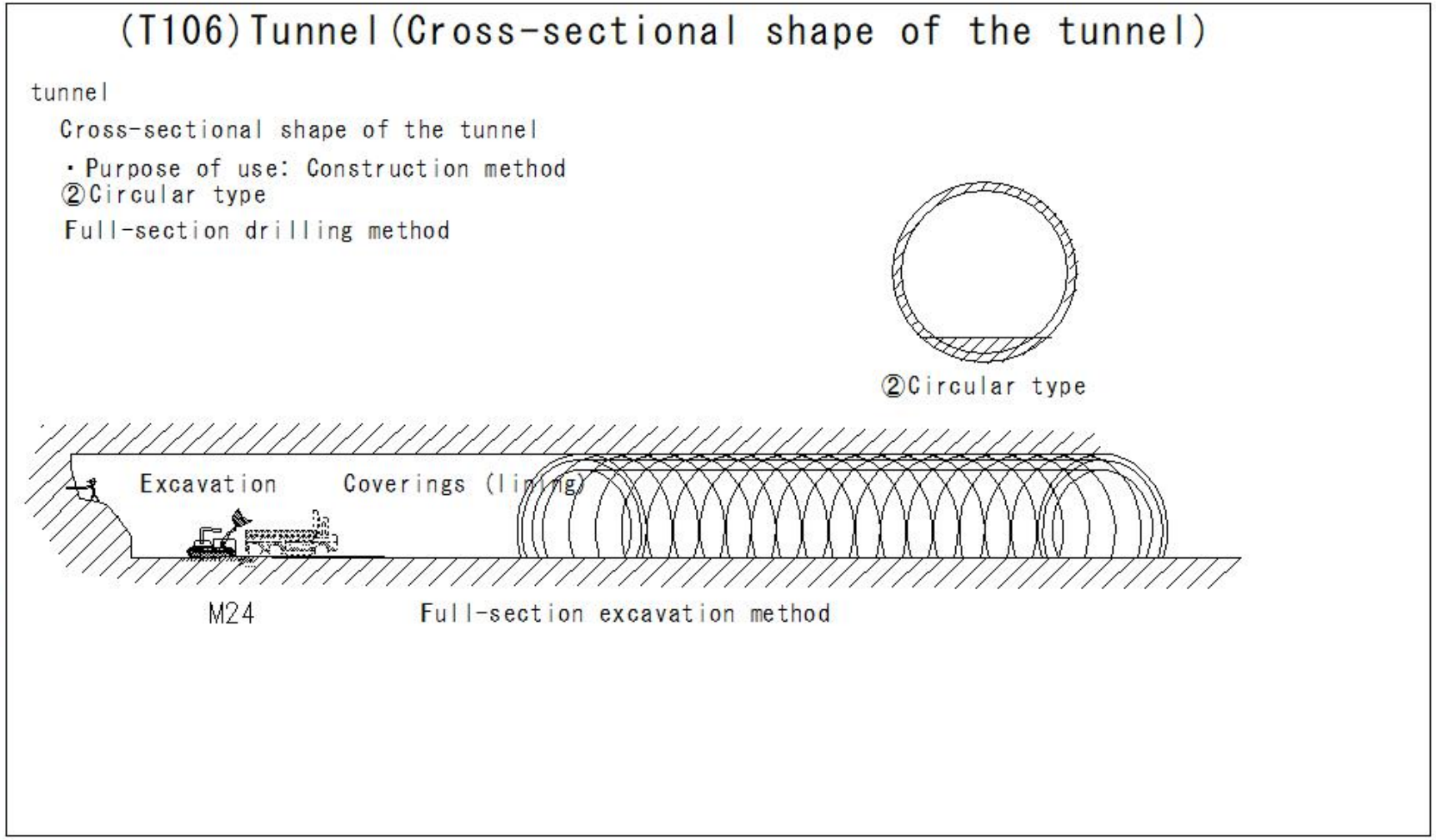
①Horseshoe type: Advanced heading method, upper half-section construction method

Construct for the arch part, the remaining moat, etc.



①Horseshoe type

(T106)Tunnel(Cross-sectional shape of the tunnel)



(T107)Tunnel(Cross-sectional shape of the tunnel)

(T107)Tunnel(Cross-sectional shape of the tunnel)

Tunnel

Cross-sectional shape of tunnel

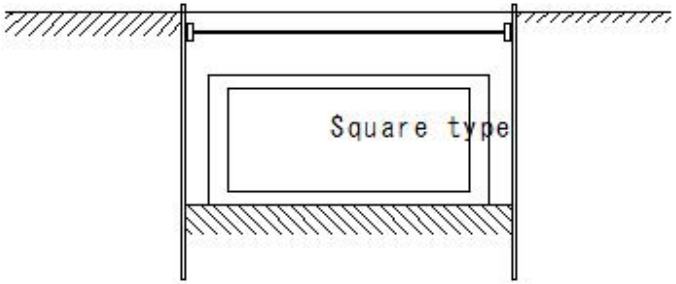
Purpose of use Construction method

③Square type

Open-cut method

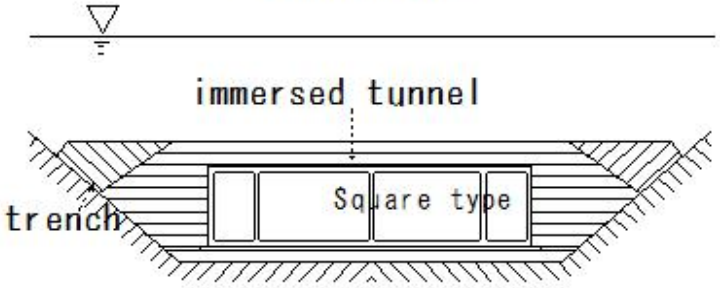
trench method

Open cutting method



E503

trench method



F125

(T108)Tunnel(Mountain tunnels)

(T108)Tunnel(Mountain tunnels)

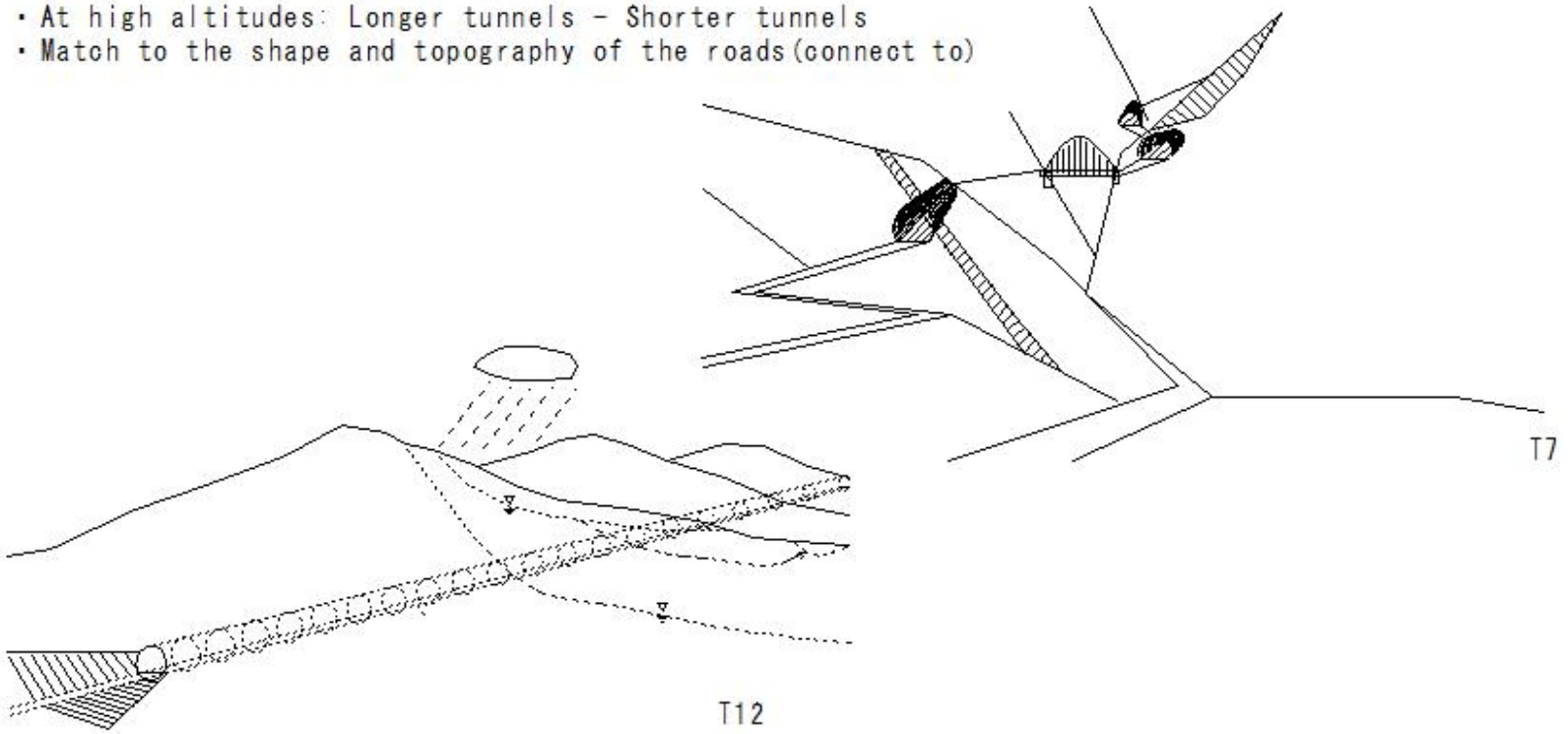
Tunnel

Tunnel construction plans

Mountain tunnels

・At high altitudes: Longer tunnels - Shorter tunnels

・Match to the shape and topography of the roads(connect to)



(T109)Tunnel(Urban tunnels)

(T109)Tunnel(Urban tunnels)

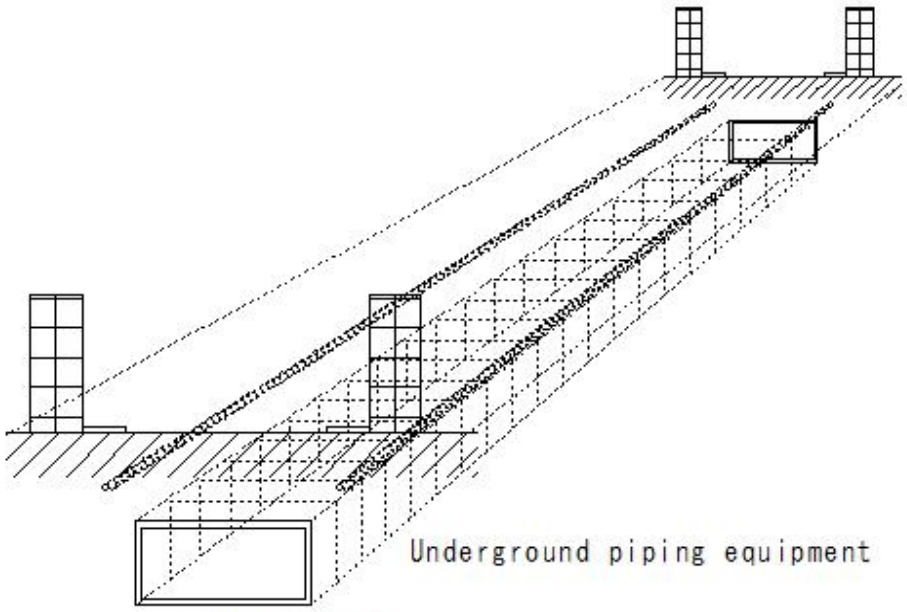
Tunnels

Tunnel construction plans

Urban tunnels

Measures to avoid impacting existing structures

(traffic, various underground facilities, building foundations)



(T110)Tunnel(Underwater tunnels)

(T110)Tunnel(Underwater tunnels)

Tunnels

Tunnel construction plans

Underwater tunnels

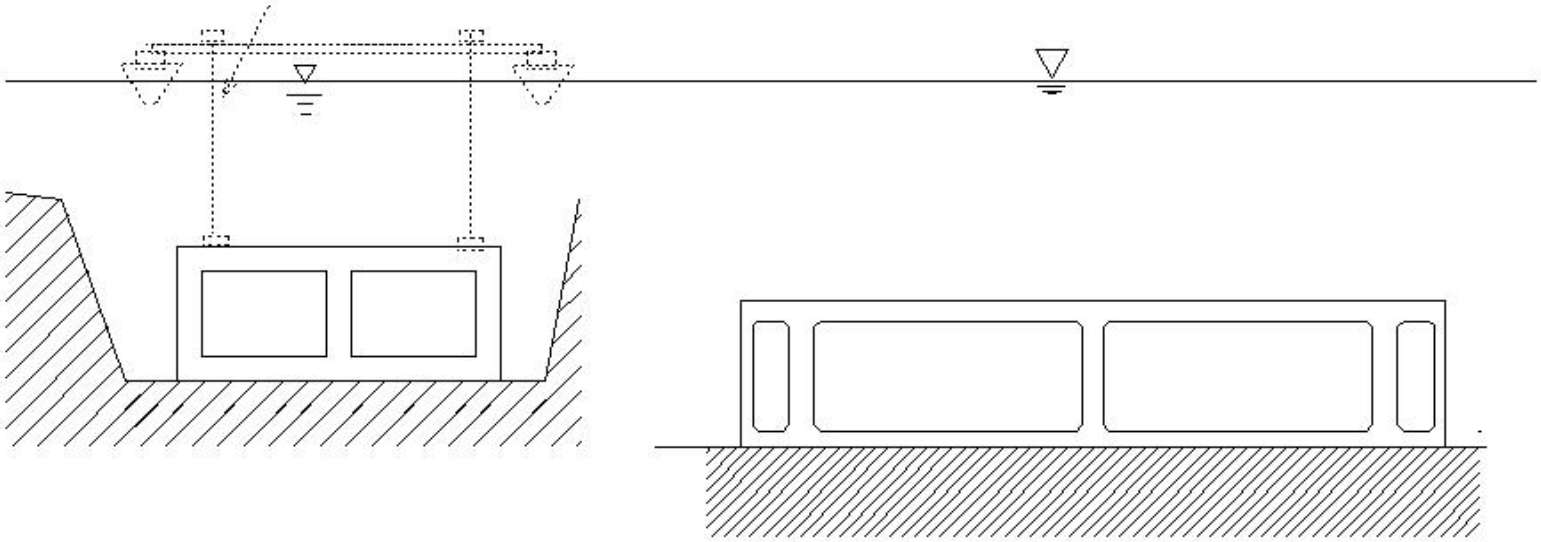
Standholes (for transporting soil and materials) cannot be installed midway through the tunnel

immersed tunnel(trench tunnel): Care must be taken to prevent scouring and settlement

Immersed tunnel

Submerged by crane girder

immersed tunnel(trench tunnel)



(T111)Tunnel(Full cross-section excavation method)

(T111)Tunnel(Full cross-section excavation method)

Tunnels

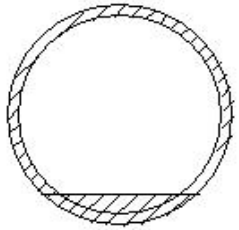
Tunnel construction methods

①Full cross-section excavation method

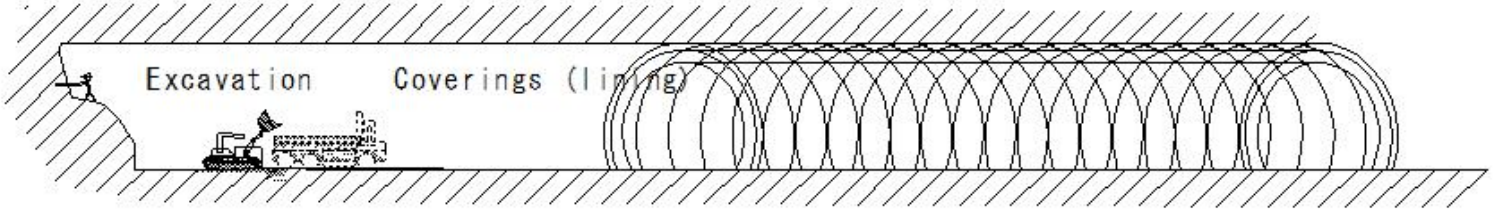
Suitable for hard rock

- Uses tunnel boring machines
- High safety
- Fast driving speed
- Support and miscellaneous labor costs - Savings
- Excavation machine costs (production, transportation, assembly) - High
- Used for long tunnels
- To stabilize the soil and groundwater at the cutting edge (excavation surface)

Shield machine with a shield at the front of the machine and pressurized with air

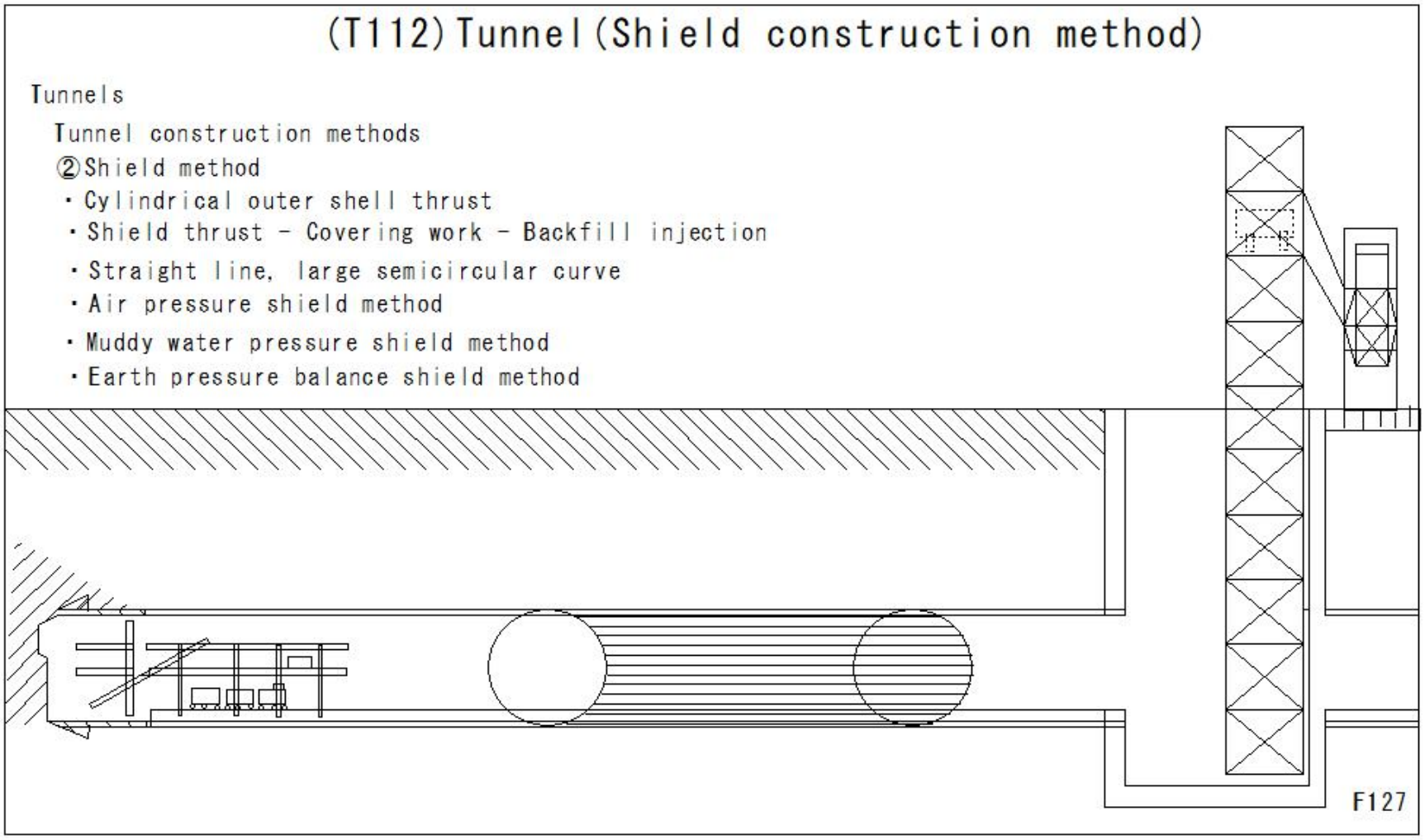


Circular type



M24 Full-section excavation method T106

(T112)Tunnel(Shield construction method)



(T113)Tunnel(Bench cut method)

(T113)Tunnel(Bench cut method)

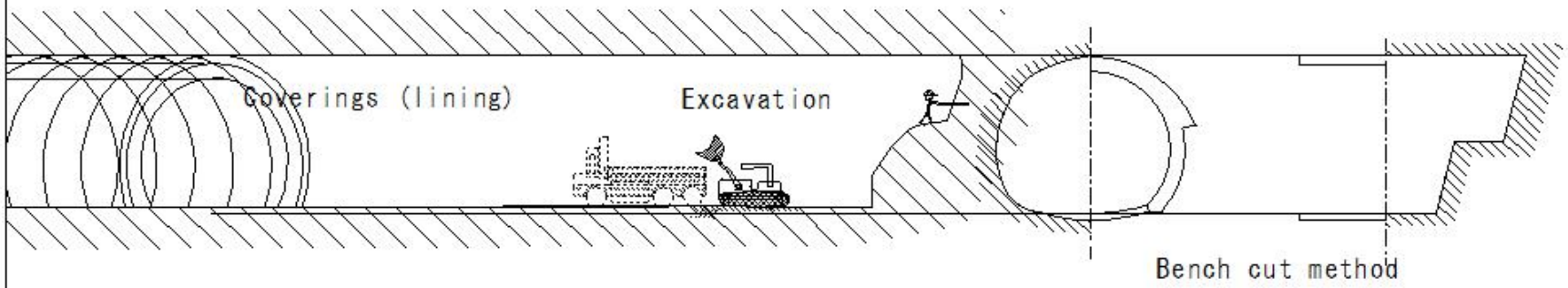
Tunnels

Tunnel construction methods

③Bench cut method

・Geology that allows the excavation surface to be kept vertical

・A method in which the upper layer is excavated first, and then a larger excavation is carried out



(T114)Tunnel(Advance heading(Pilot) tunnel excavation method)

(T114)Tunnel(Advance heading(Pilot) tunnel excavation method)

Tunnels

Tunnel construction methods

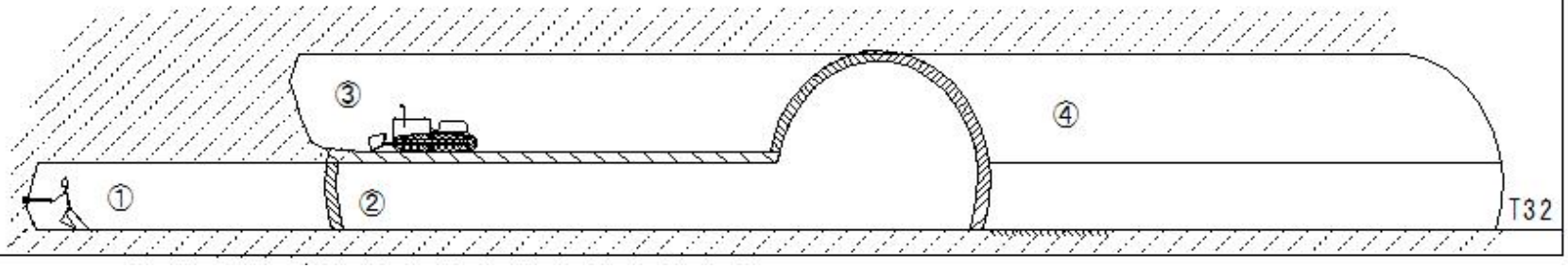
④Advance heading(Pilot) tunnel excavation method

・Start by digging a small heading(Pilot・guiding) first,
and then dig a wider tunnel (main tunnel) at the rear

While conducting geological surveys and determining the direction of travel

Digging a tunnel at the rear (main method)

④Advance heading(Pilot) tunnel excavation method



(T115)Tunnel(Open cut method)

(T115)Tunnel(Open cut method)

Tunnels

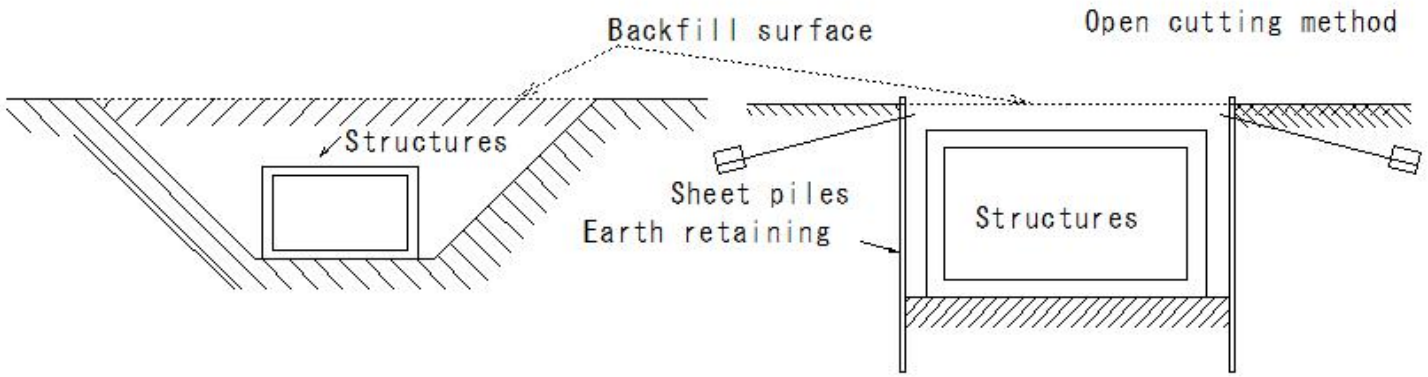
Tunnel construction methods

⑤ Open cut method

・Box-shaped cross-section tunnel in a shallow area

・Low construction costs and short construction period

Open cutting method



① Open cut method using bare excavation

② Section open cut method

(T116)Tunnel(immersed tunnel(trench tunnel))

(T116)Tunnel(immersed tunnel(trench tunnel))

Tunnels

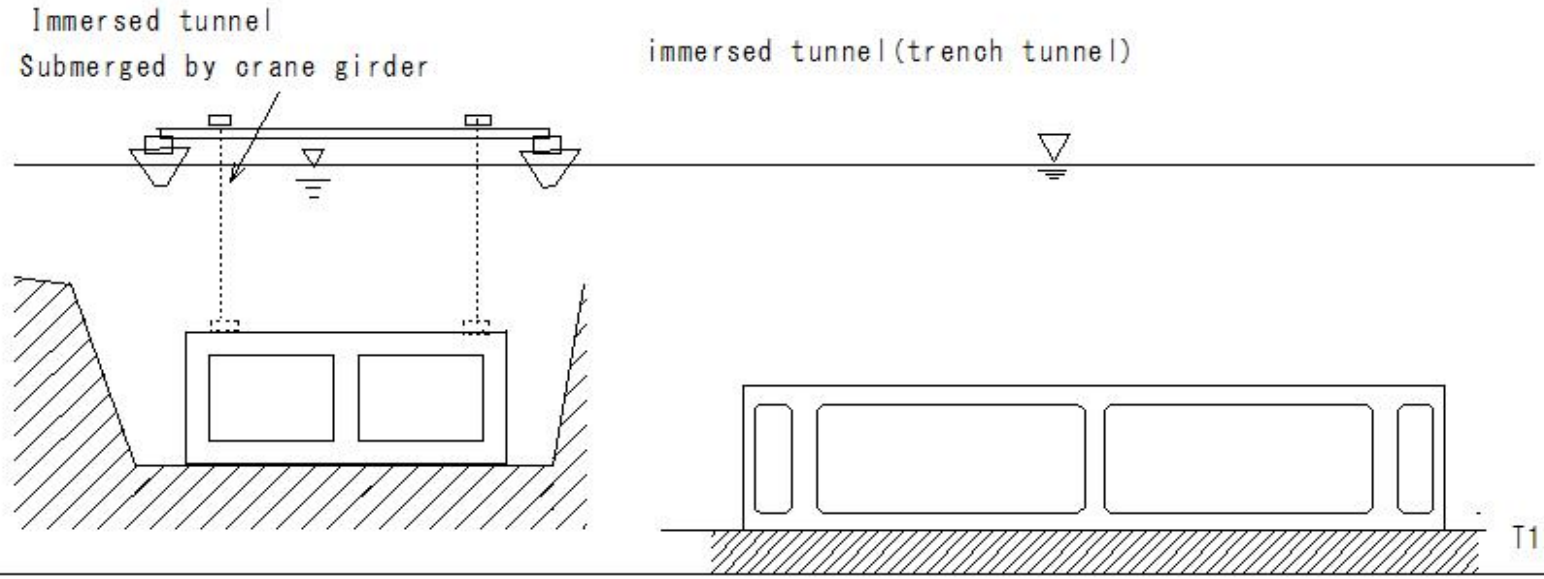
Tunnel construction methods

⑥ immersed tunnel(trench tunnel)

・Both ends of the tunnel element fabricated in a location other than the tunnel installation site (on land, dry dock) are closed

・Submerge in a dredged trench (ditch) and connect underwater

・Backfill to construct an underwater tunnel



T110

(T117)Tunnel(Assembled formwork)

(T117)Tunnel(Assembled formwork)

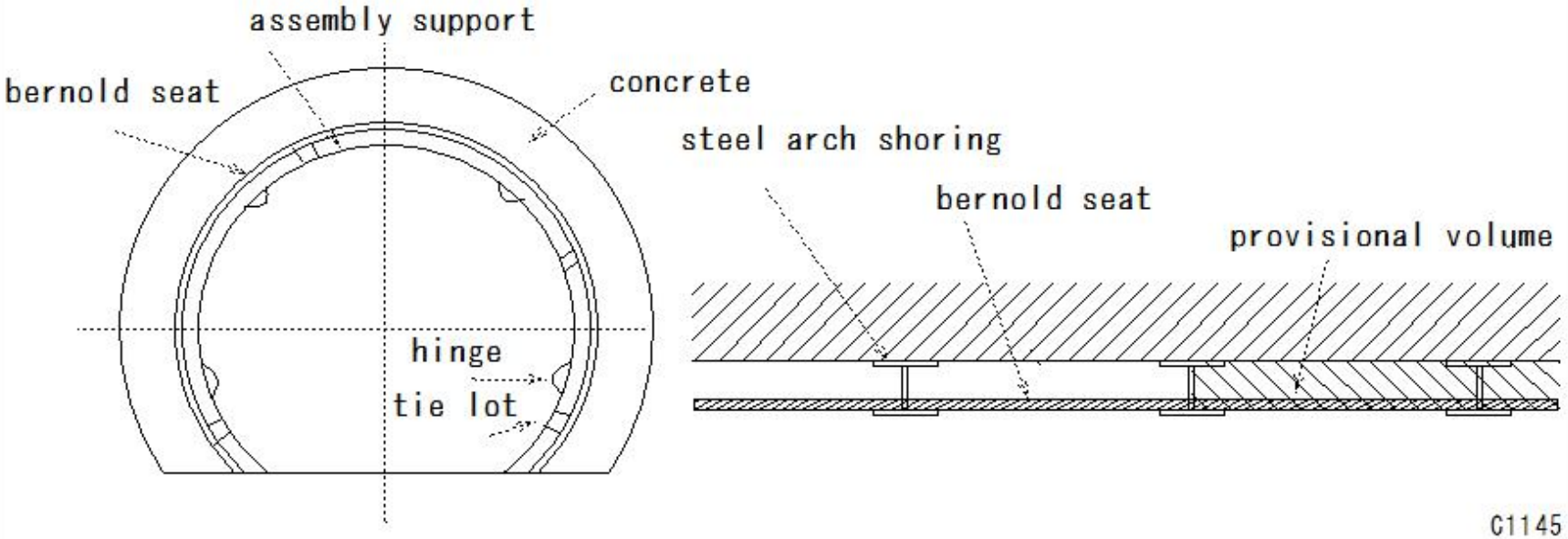
Tunnels

Tunnel construction methods

① Assembled formwork

・Survey and install in the correct position

・During the covering work, install 2-5cm higher (raised) taking into account the amount of settlement of the formwork



C1145

(T118)Tunnel(traveling form form)

(T118)Tunnel(traveling form form)

Tunnels

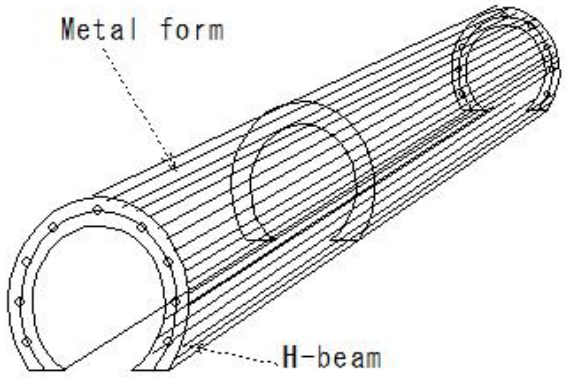
Tunnel construction methods

② traveling form

Steel arch center

Integrated metal form

Assembled on rails and made movable



(T119)Tunnel(NATM (New Austrian Tunneling Method)

Tunnels

Tunnel construction methods

③NATM (New Austrian Tunneling Method)

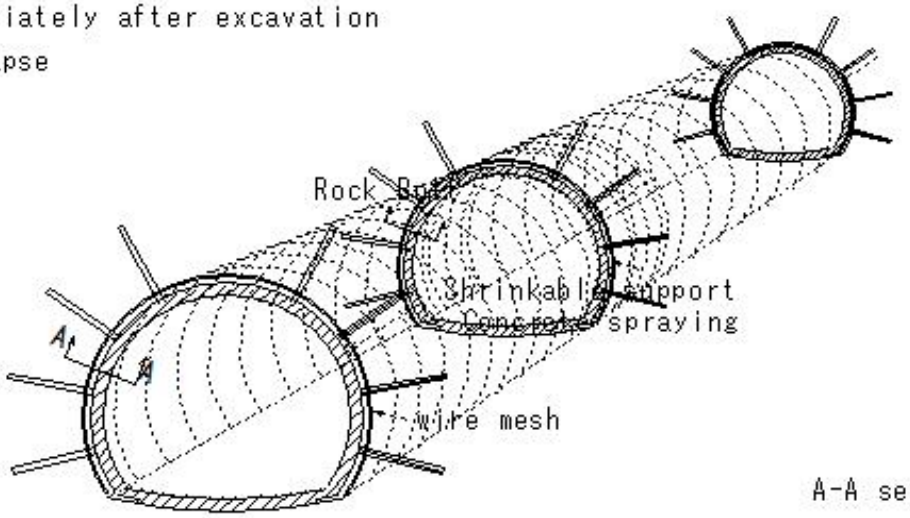
・Spray concrete immediately after excavation

・Prevent ground collapse

・Drive in rock bolts

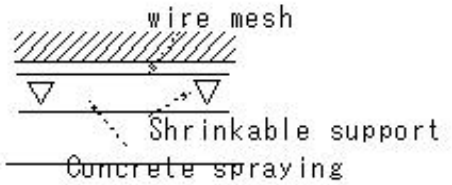
・Stabilize ground

Rock bolts fixed



NATM (New Austrian Tunneling Method)

A-A section



T61

(T120)Tunnel(Tunnel survey)

(T120) Tunnel (Tunnel survey)

Tunnels

Tunnel survey

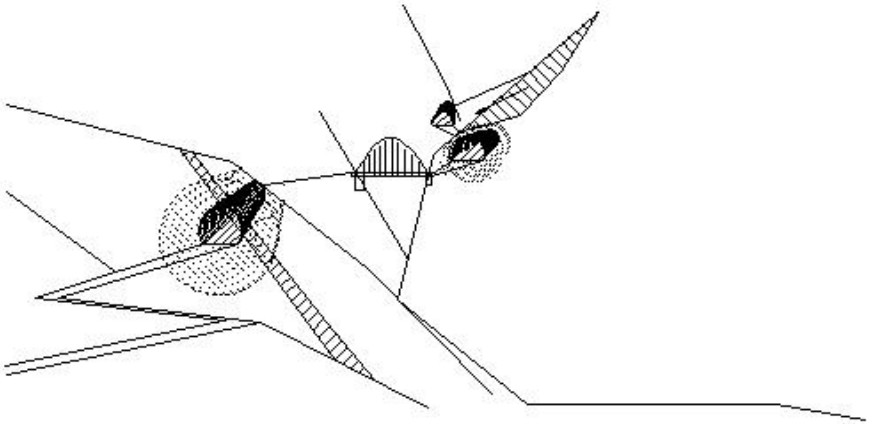
①Outline survey

②Detailed survey

③Pre-construction survey

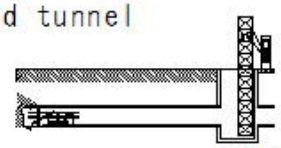
④Survey during construction

⑤Survey after completion



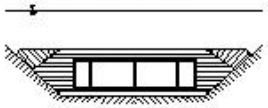
T10

shield tunnel



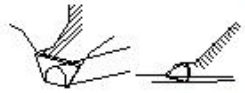
C1051
M420

immersed tunnel



C1072

Tunnel entrance stance



C1317

(T121)Tunnel(Outline survey)

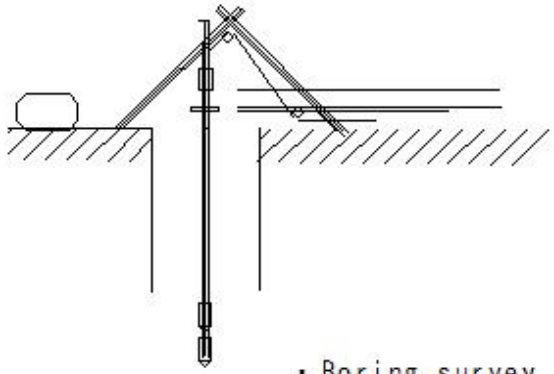
(T121)Tunnel(Outline survey)

Tunnels

Tunnel survey

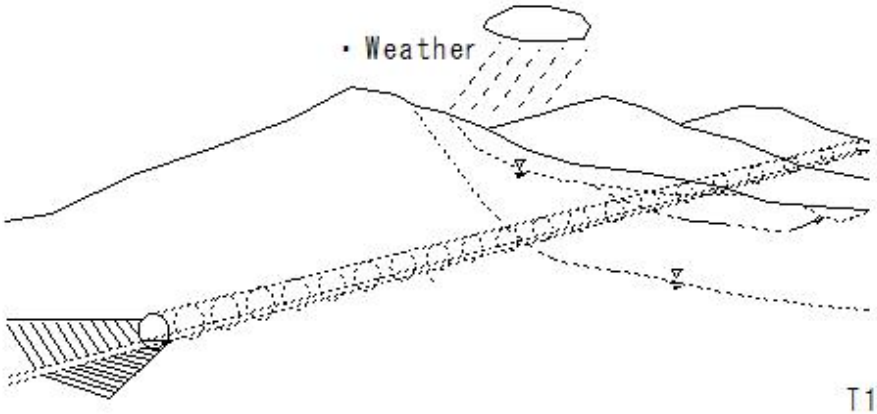
①Outline survey

- Existing materials
- Field survey
- Boring survey
- Elastic wave exploration (topography, geology, structure, lithology, groundwater)
- Weather
- Environment
- Underground resources
- Ruins
- Final route decision



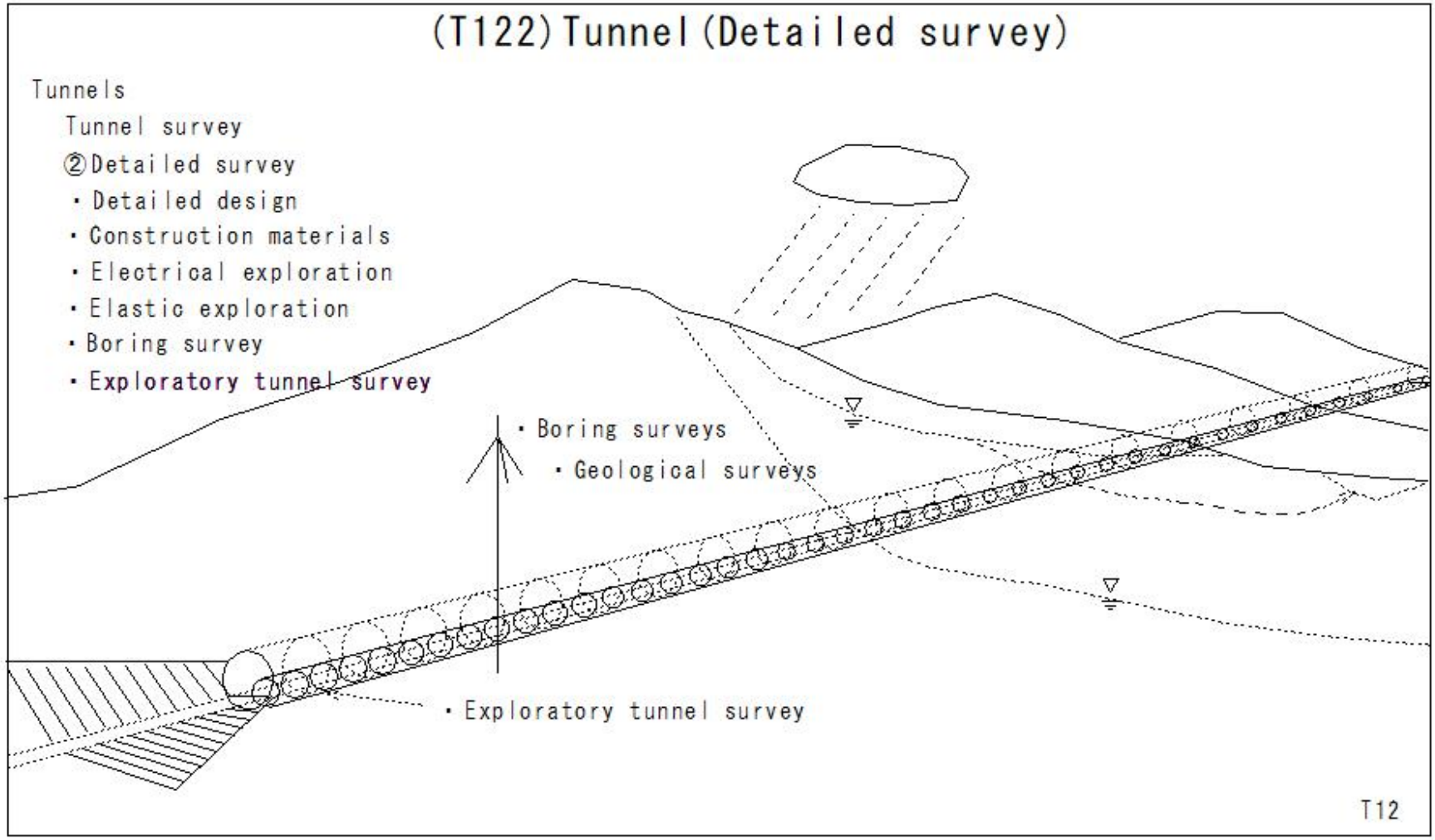
・Boring survey

E22

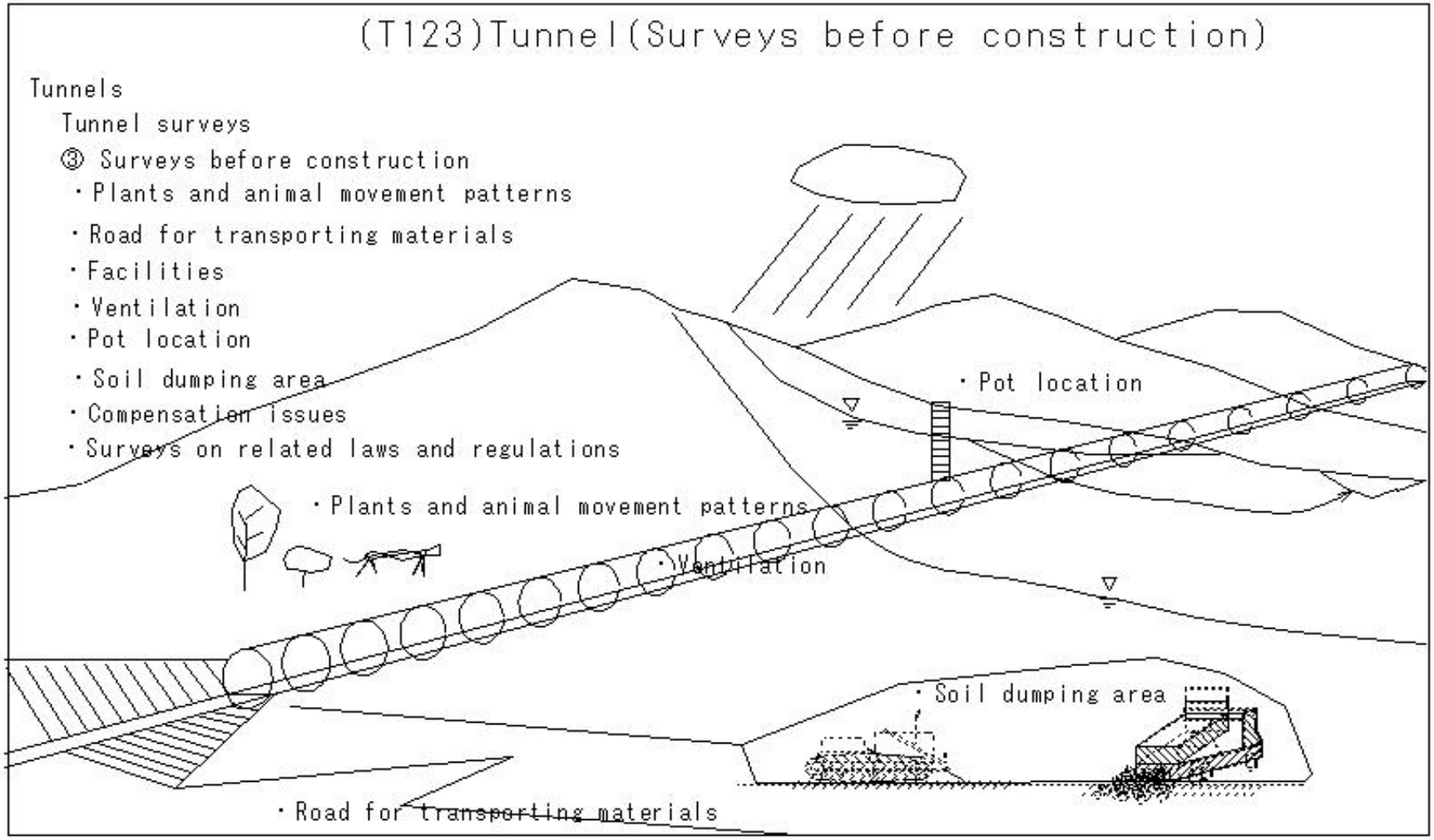


T12

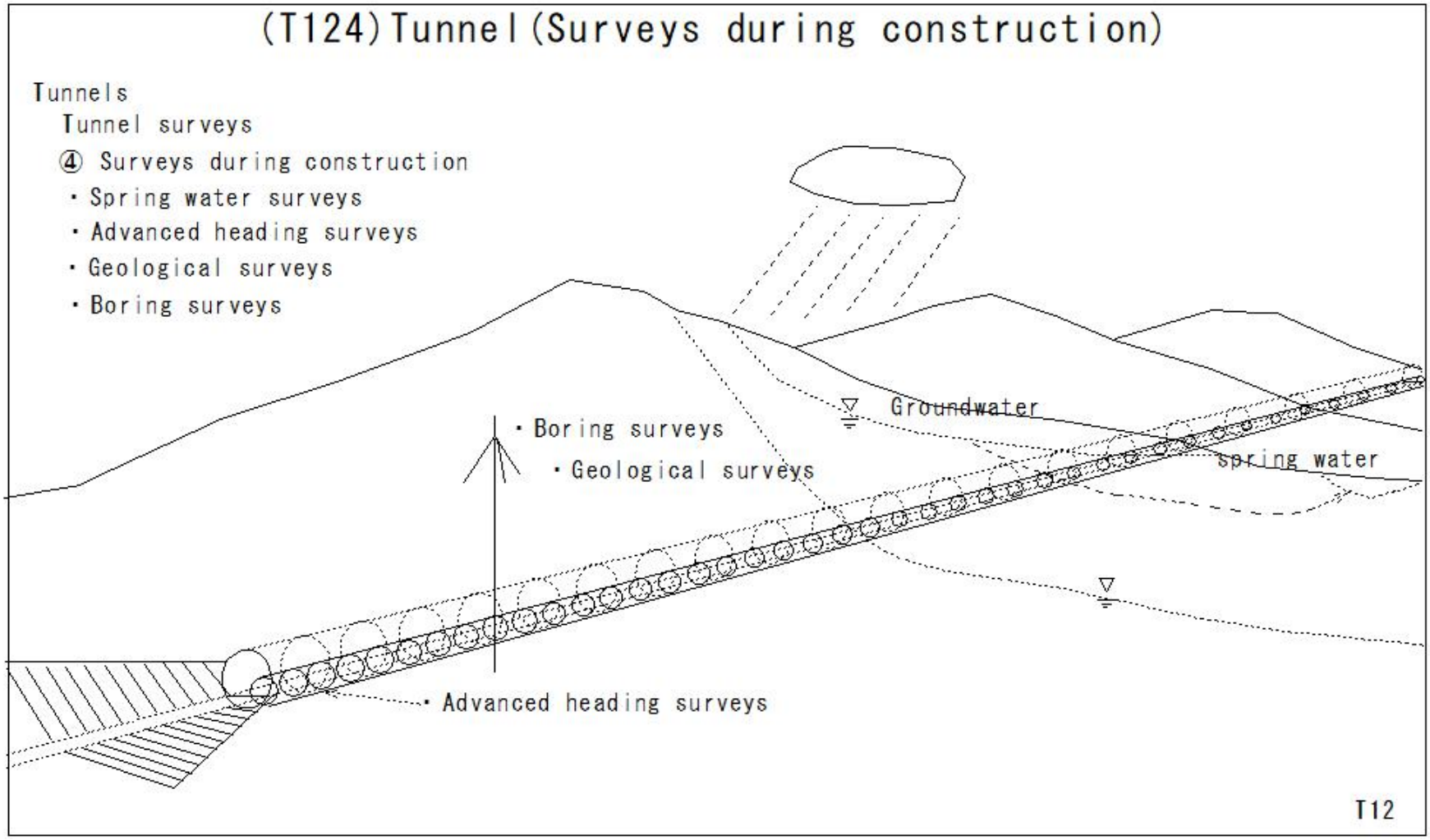
(T122)Tunnel(Detailed survey)



(T123)Tunnel(Surveys before construction)



(T124)Tunnel(Surveys during construction)



(T125)Tunnel(Survey after completion)

(T125)Tunnel(Survey after completion)

Tunnel

Tunnel survey

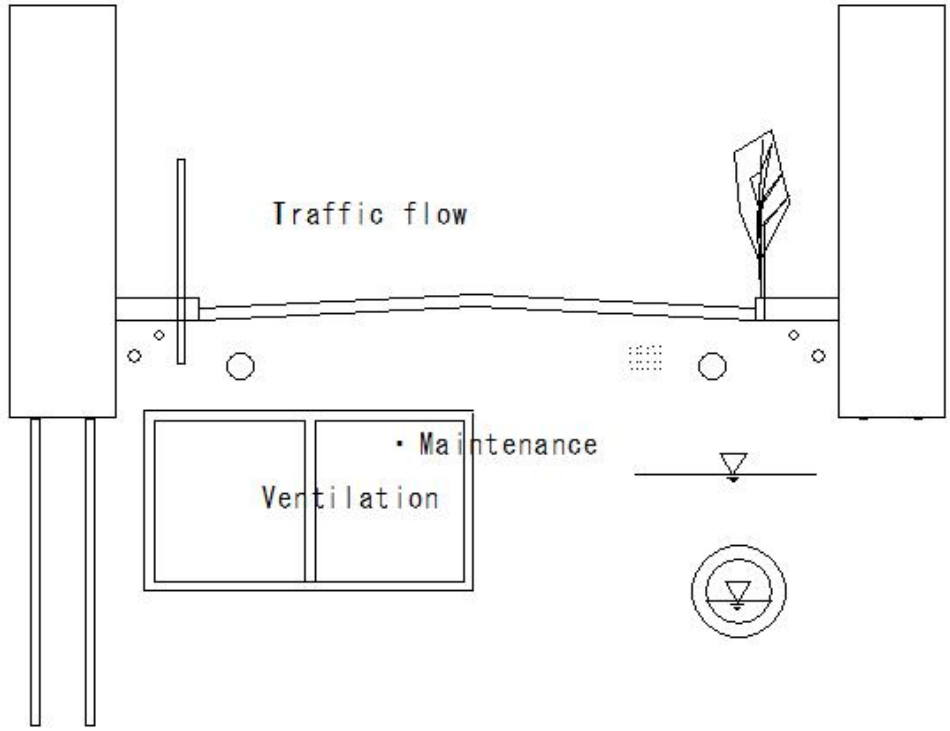
⑤ Survey after completion

・Traffic flow

・Stagnation situation

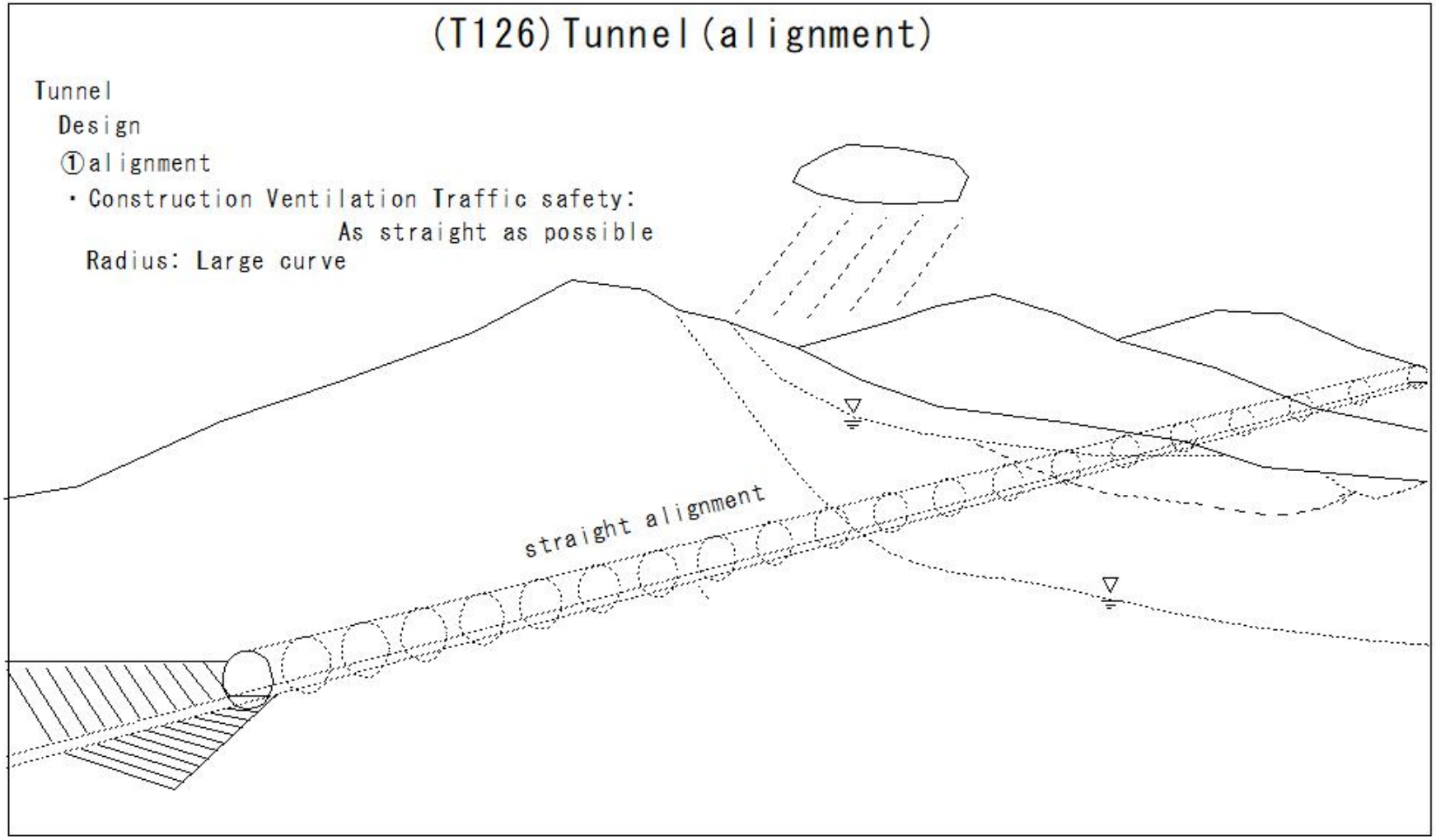
・Ventilation inside the tunnel

・Maintenance survey



F122

(T126)Tunnel(alignment)



(T127)Tunnel(Slope)

(T127) Tunnel (Slope)

Tunnel
Design

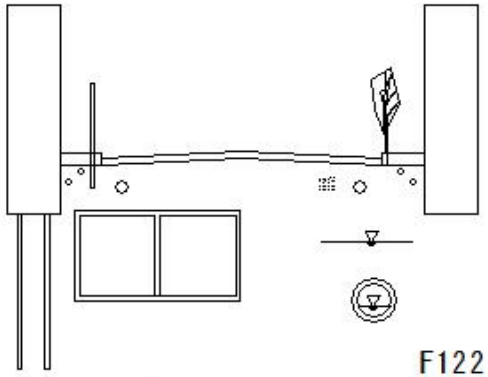
②Slope

・During construction, consider drainage after completion

①Mountain tunnel: 0.1-0.5% downward slope toward the entrance/exit

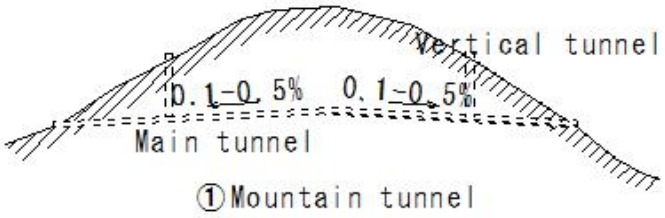
②Urban tunnel: As horizontal as possible

③Undersea tunnel: downward slope toward the center



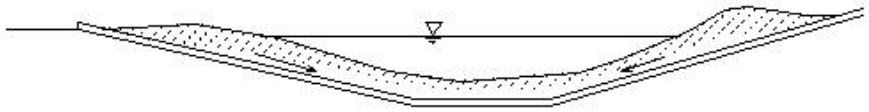
F122

②Urban tunnel



①Mountain tunnel

T102



③Underwater tunnel

T104

(T128)Tunnel(Cross-sectional shape)

(T128)Tunnel(Cross-sectional shape)

Tunnel

Design

③Cross-sectional shape

・Purpose of use: Determined from mechanical construction aspects

Deciding cross-sectional shape

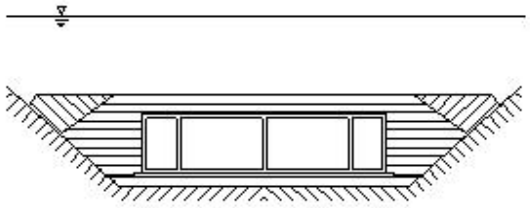
Situation/construction method

Deciding cross-sectional shape

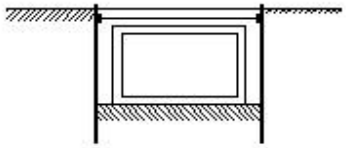
Earth pressure/water pressure: Circle
Excavation method: Circle/horseshoe

Cut-and-cover method/immersed tunnel (trench tunnel): Rectangle

In reality: Horseshoe shapes are common

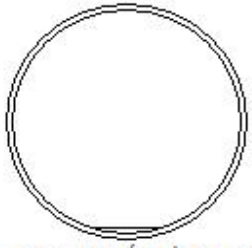


immersed tunnel(trench tunnel) C1072



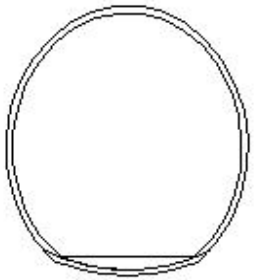
E505

track clearance(clearance limit): Rectangle



T66

Earth pressure/water pressure: Circle



T66 T66

Excavation method: Circle/horseshoe

(T129)Tunnel(Ancillary facilities)

(T129)Tunnel(Ancillary facilities)

Tunnel

Ancillary facilities

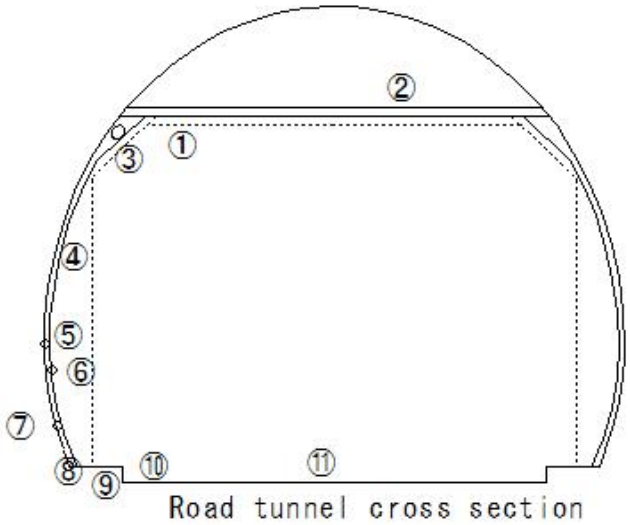
①Inner tunnel facilities

Lighting

During construction: Floodlights/light bulbs

After completion: Sodium lamps

Drainage facilities



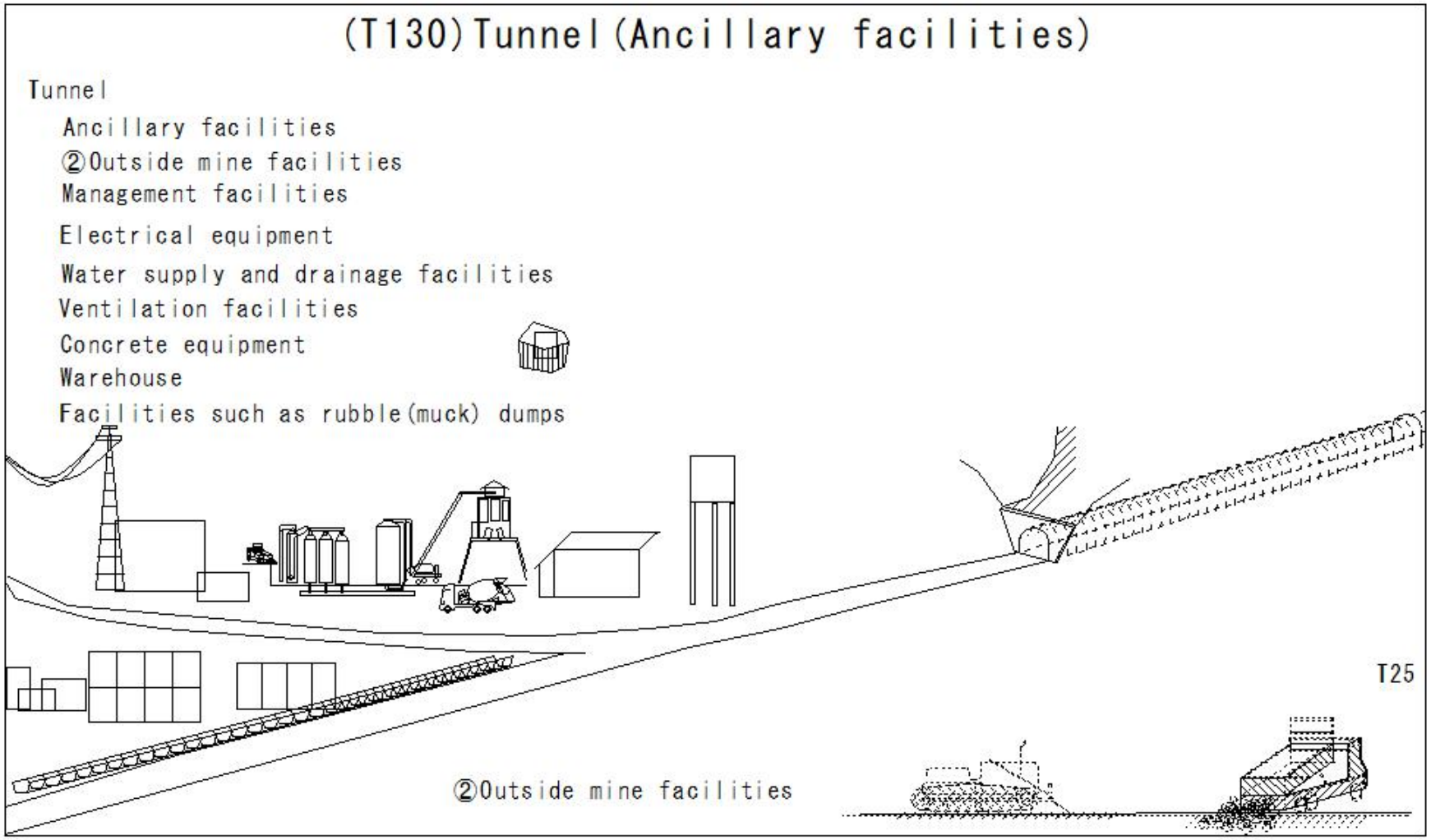
Road tunnel cross section

①Inner tunnel facilities

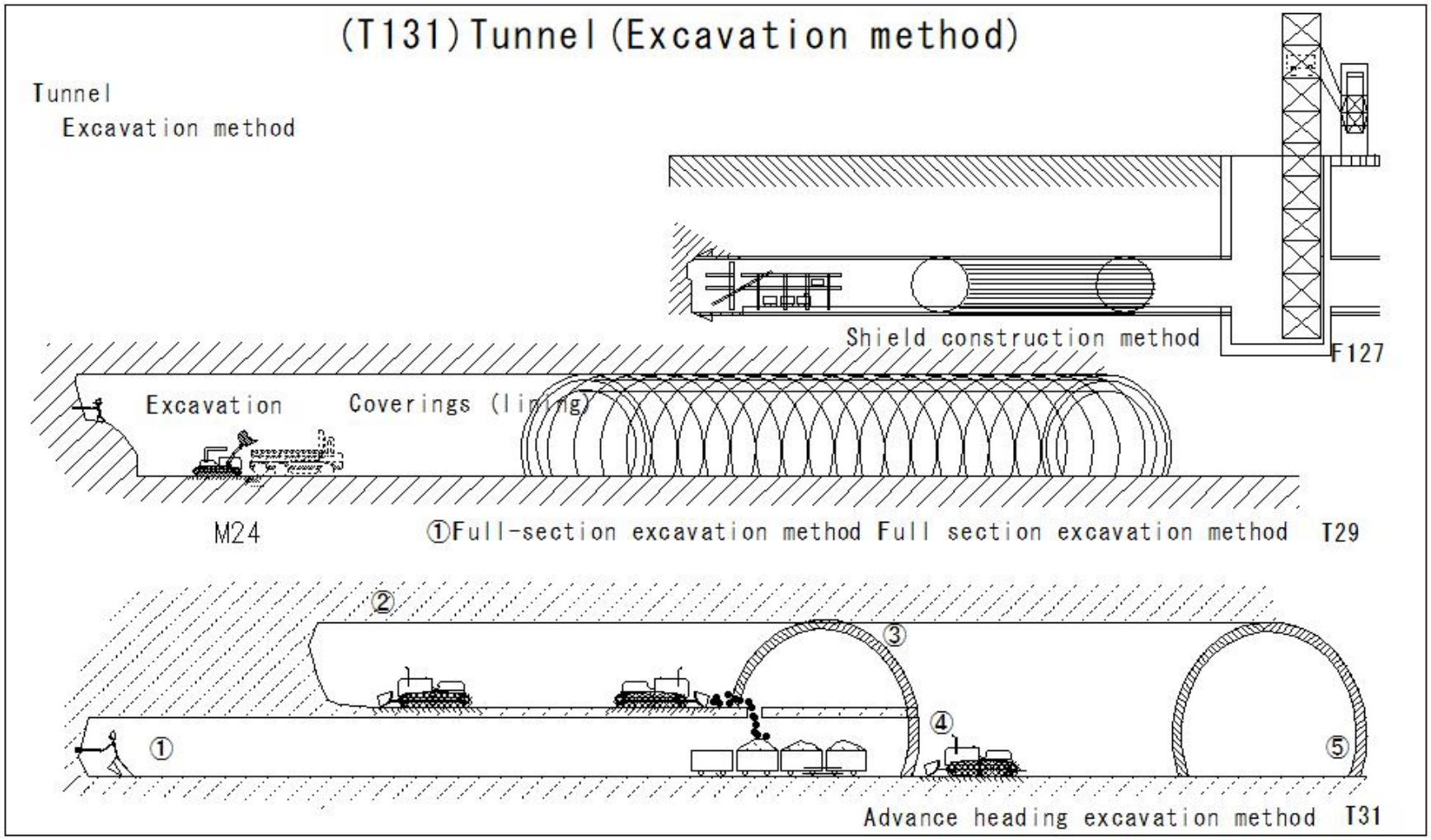
① Building limit
② Ceiling board
③ Lighting equipment
④ Interior materials
⑤ Fire detector
⑥ Emergency telephone
⑦ Fire hydrant box
⑧ Facility strip
⑨ Shoulder
⑩ Side strip
⑪ Roadway

T23

(T130)Tunnel(Ancillary facilities)



(T131)Tunnel(Excavation method)



(T132)Tunnel(tunnel section)

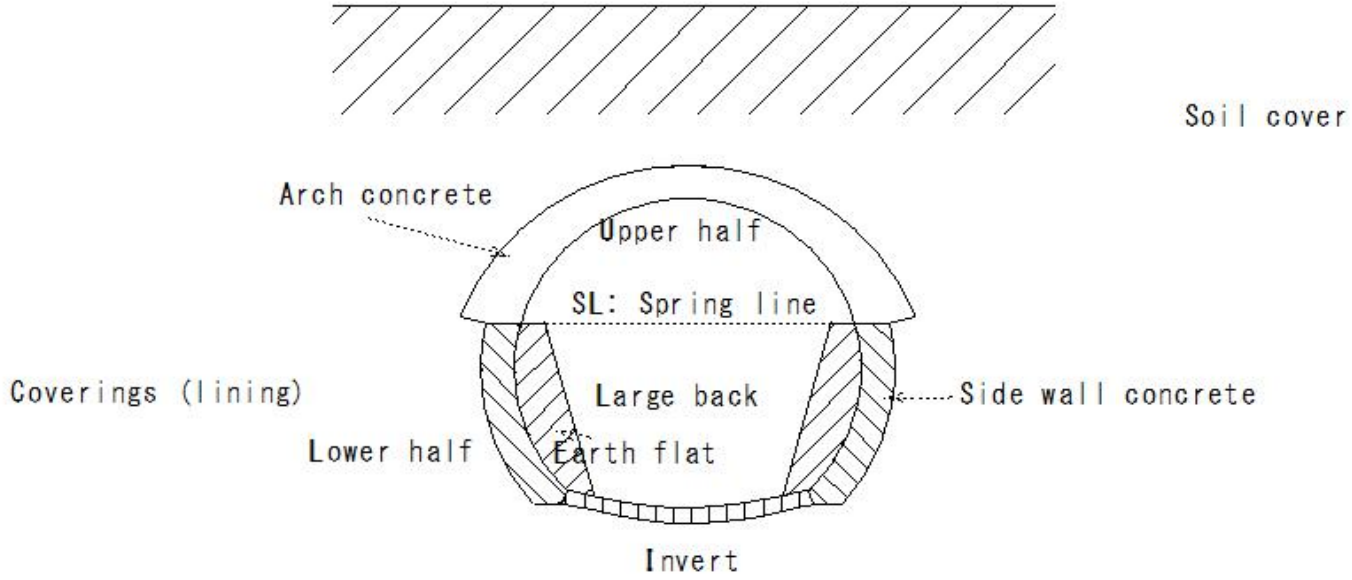
(T132)Tunnel(tunnel section)

Tunnel

Excavation method

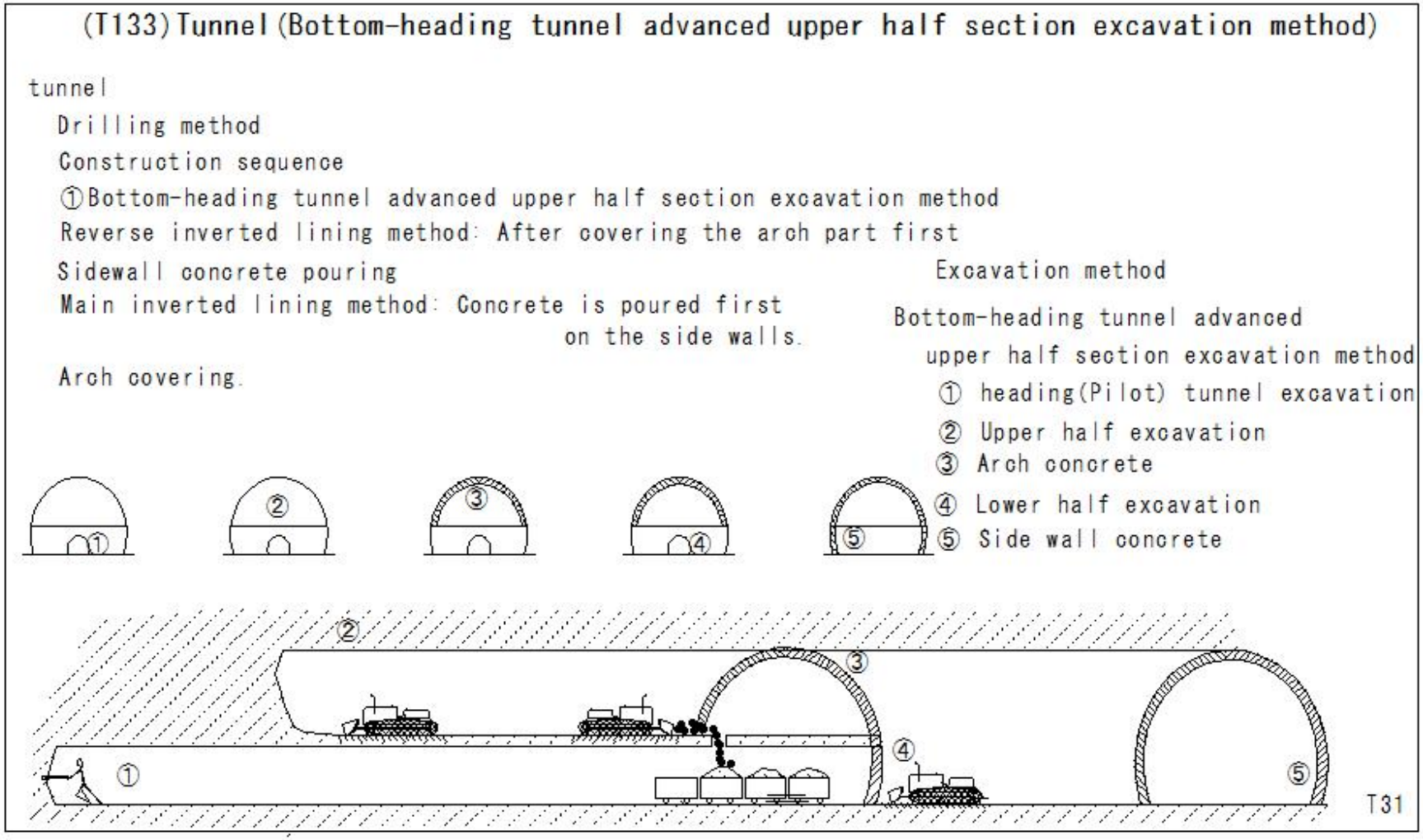
Name of tunnel section

Arch concrete



T13

(T133)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)



(T134)Tunnel(Advanced low heading-installation conduction)

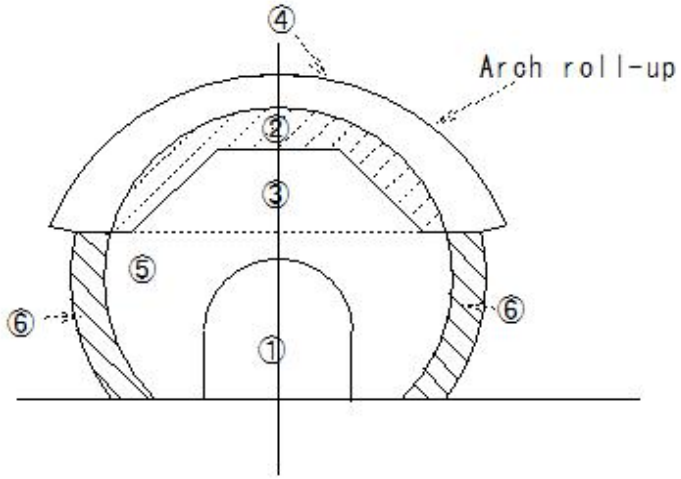
(T134)Tunnel(Advanced low heading-installation conduction)

tunnel

Drilling method

Construction sequence

②Advanced low heading-installation conduction



②Advanced low heading-installation conduction

T132

(T135)Tunnel(Side wall heading(guide) tunnel advance)

(T135)Tunnel(Side wall heading(guide) tunnel advance)

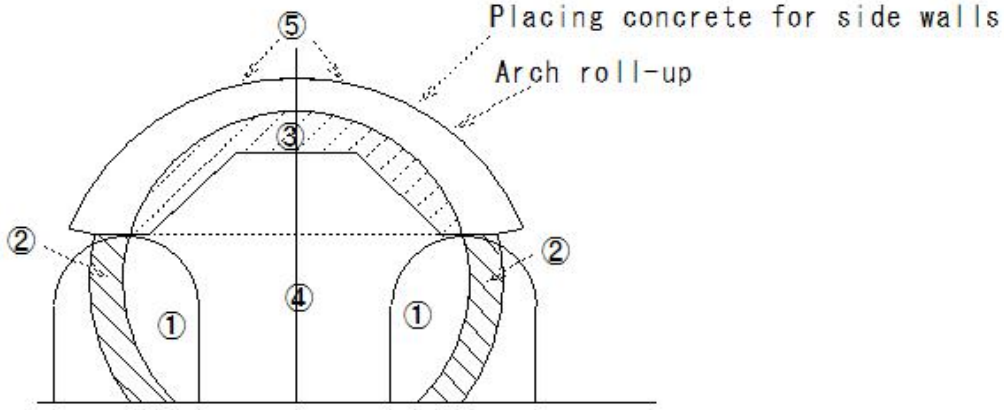
Tunnel

Excavation method

Construction sequence

③Side wall heading(guide) tunnel advance

Ring cut method



③Side wall heading(guide) tunnel advance

(T136)Tunnel(Upper half section excavation method)

(T136)Tunnel(Upper half section excavation method)

Tunnel

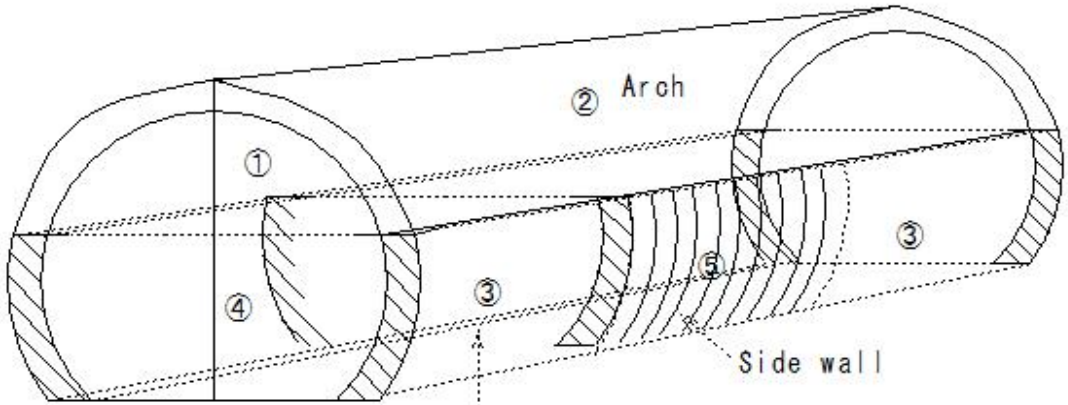
Excavation method

Construction sequence

Upper half section excavation method

・Full section excavation is impossible

・Geology that allows the excavation surface to be kept vertical



Placing concrete using the reverse placing method

Upper half section excavation method

(T137)Tunnel(tunnel boring machine)

(T137)Tunnel(tunnel boring machine)

Tunnel

Excavation method

・Good rock base

Hard Geology

・Uses tunnel boring machine

①Safety -Good

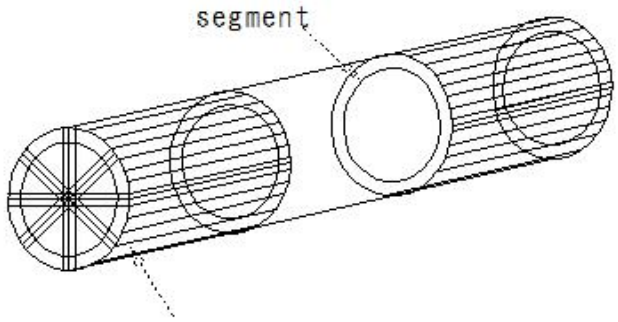
②Advancement speed -Fast

③Cost of support and covering -Savings

④Large machine -Excavation possible, good work efficiency

⑤The construction method cannot be changed due to changes in the geology

⑥The cost of excavation machine (manufacturing, transportation, maintenance costs) is high



(T138)Tunnel(Blast work)

(T138)Tunnel(Blast work)

Tunnel

Excavation method

Blast work

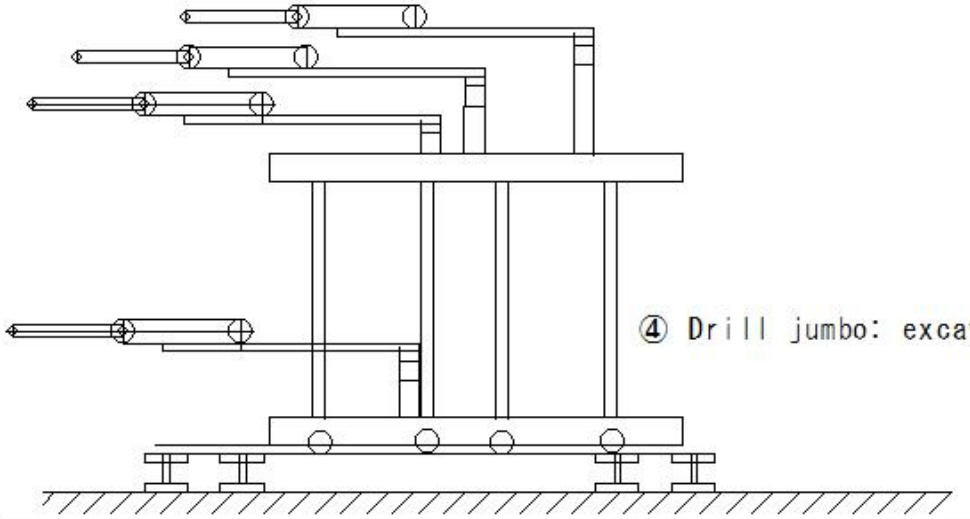
① in case of the geology is rock, excavation is done by blasting

② Rock drill - explosives loaded

③ Hole length 1-2m, diameter about 45mm

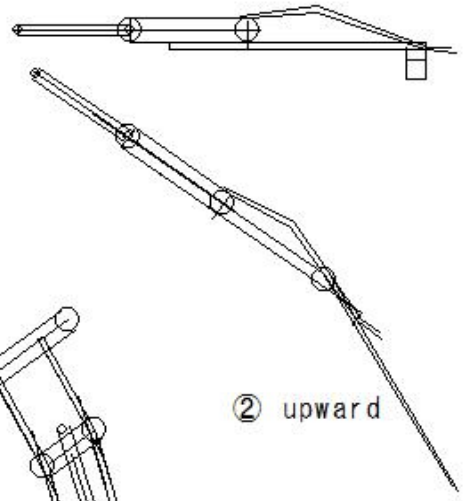
④ There are various rock drills depending on the purpose

⑤ Drill jumbo can excavate multiple holes at the same time, which is good for construction efficiency

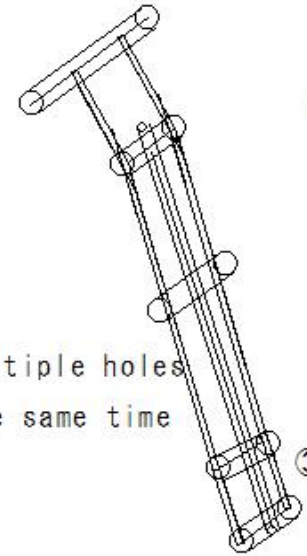


④ Drill jumbo: excavate multiple holes at the same time

① Drifter: horizontal hole



② upward



③ downward

(T139)Tunnel(Blasting work)

(T139)Tunnel(Blasting work)

Tunnel

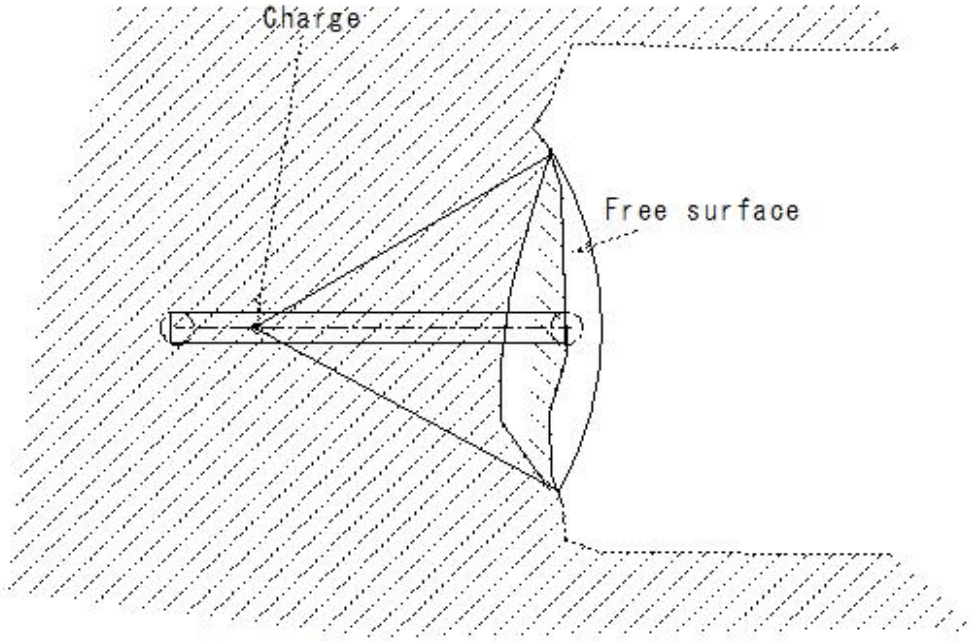
Excavation method

Blasting work

① Blasting: Amount of explosives, direction of hole

② Electric detonator

③ Blasting drill



Standard type

(T140)Tunnel(Blasting work)

(T140) Tunnel (Blasting work)

Tunnel

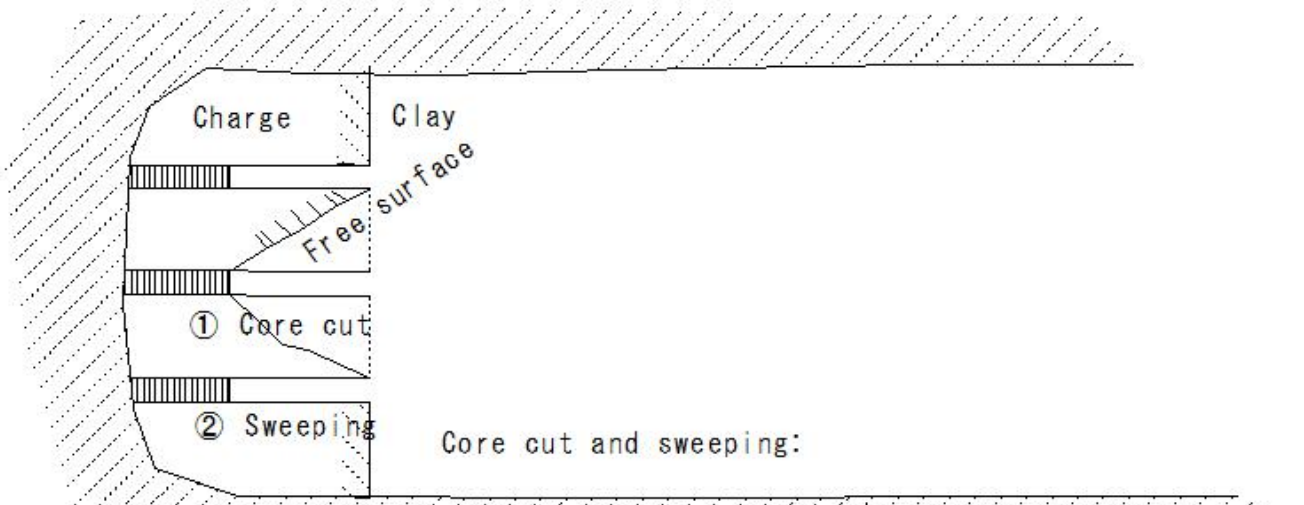
Excavation method

Blasting work

④ Blasting, free surface: more efficient

Core cut and sweeping: The center of the facing is blown up first to increase the free surface

Sweeping and blasting: The surrounding area is blown up after a delay of 0.01-0.5 seconds



The direction of the debris scattering can be adjusted not only inside the mine

(T141)Tunnel(Blasting work)

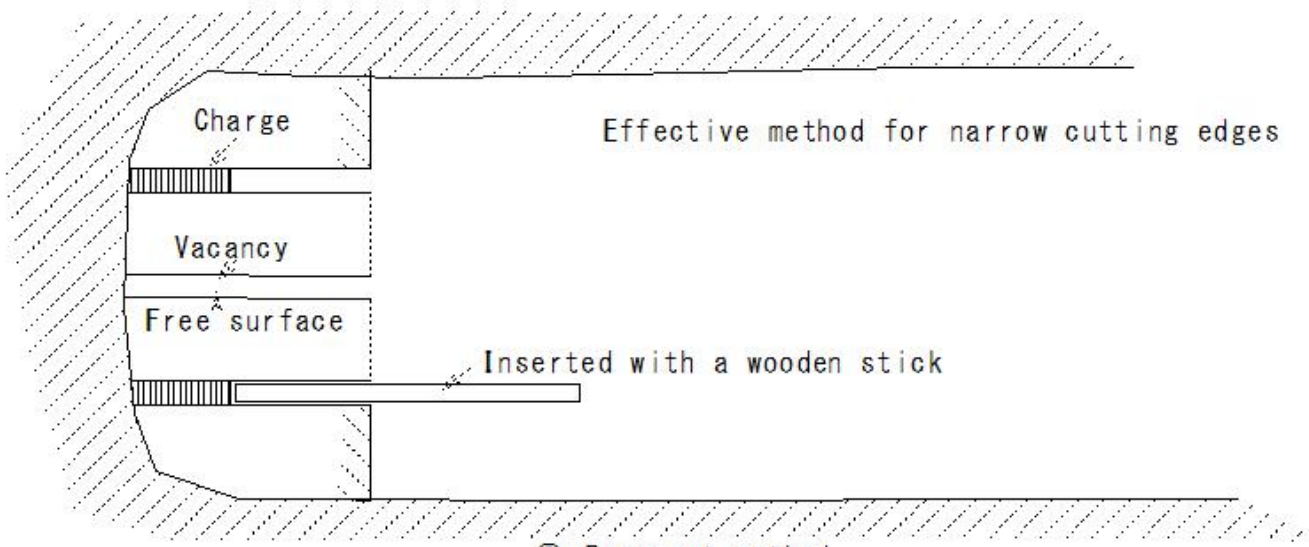
(T141)Tunnel(Blasting work)

Tunnel

Excavation method

Blasting work

④ Blasting, free surface: more efficient



② Burn cut method

Create a hole that is not loaded with explosives to make it a free surface

(T142)Tunnel(Explosives: Gunpowder, explosives)

(T142)Tunnel(Explosives: Gunpowder, explosives)

Tunnel

Explosives: Gunpowder, explosives

・Explodes in case of detonated by a detonator

Tunnel

Gunpowder

・Gunpowder explodes easily, has low explosive power

・fuse core

・Fuse, black powder, burns at 50cm/min

Tunnel

Explosives

①Explosives are difficult to explode, ignited and detonated using a detonator

②Dynamite is used as explosives

・Mixed dynamite

・Colloidal dynamite

・Powdered dynamite

・ANFO explosives

Tunnel

Dynamite

①Nitroglycerin

(T143)Tunnel(Explosives: Gunpowder, explosives)

(T143)Tunnel(Explosives: Gunpowder, explosives)

Tunnel

Explosion

Charge

① Carefully push the explosives into the back of the blast hole one by one with a wooden stick

② Load the main dynamite at the front and fill with clay to the same length as the dynamite

facing stabilization measures:

Fuse explosion

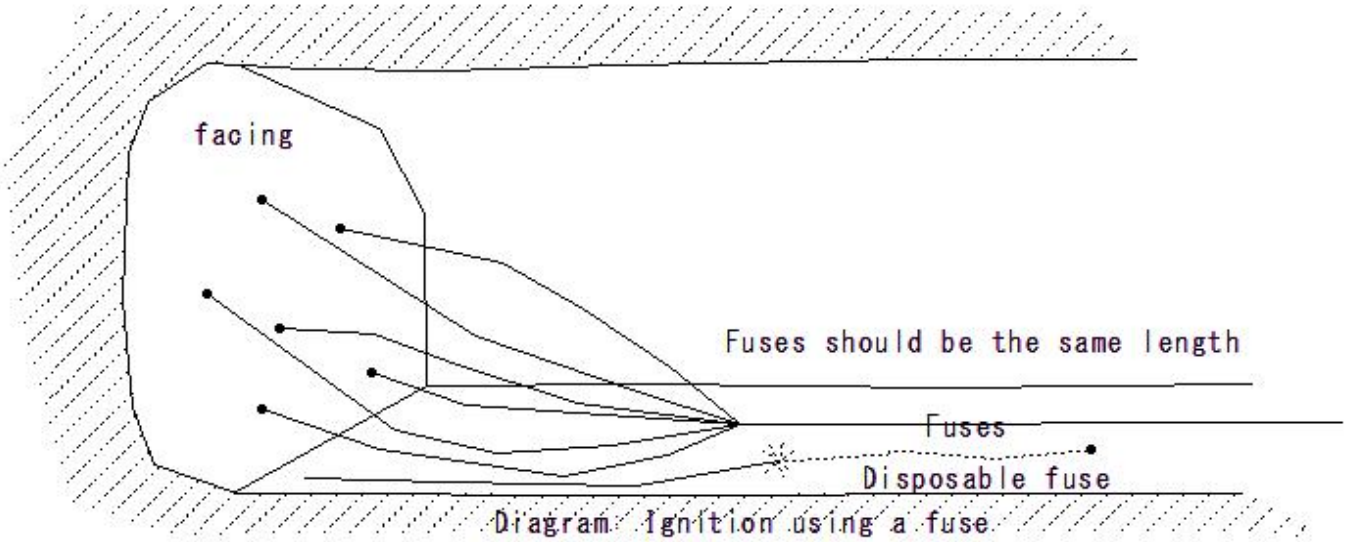


Diagram: Ignition using a fuse

(T144)Tunnel(Explosives: Gunpowder, explosives)

(T144)Tunnel(Explosives: Gunpowder, explosives)

Tunnel

Ignition

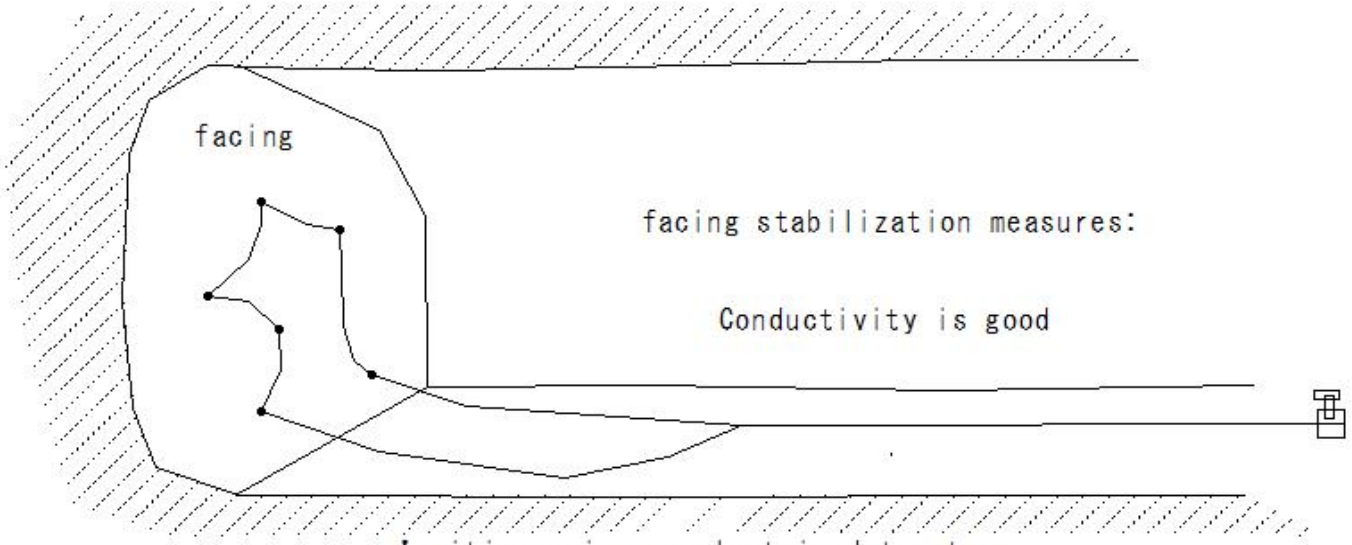
① After thoroughly checking safety

Use an industrial detonator to ensure ignition

② Use a discarded fuse to check the ignition time

③ Always perform a continuity test on electric detonators

Pay close attention to unexploded explosives



Ignition using an electric detonator

(T145)Tunnel(Tunnel excavation soil treatment(Muck disposal))

(T145)Tunnel(Tunnel excavation soil treatment(Muck disposal))

Tunnel

Tunnel excavation soil treatment(Muck disposal)

・Transport outside the tunnel

・Loading, transporting, dumping soil

①Loading: Mechanical excavation

②Transportation: Dump truck, tire type

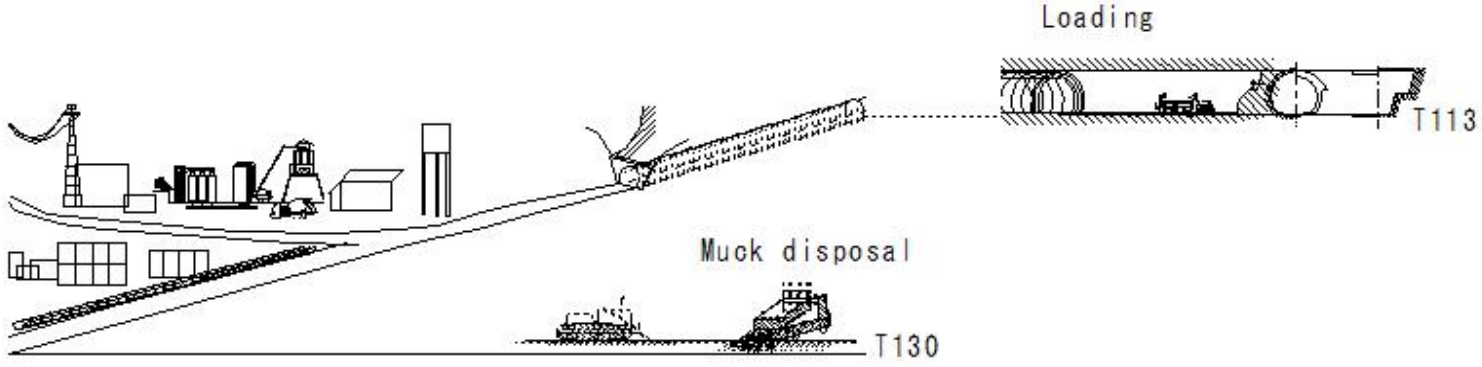
Trolley: Track type

①Tire type: Short tunnel

②Tire type: Exhaust gas, ventilation equipment

③Tire type: Soil dump site - direct transport

Track type: Track extension or transfer to dump truck for transport



(T146)Tunnel(Support)

(T146)Tunnel(Support)

Tunnel

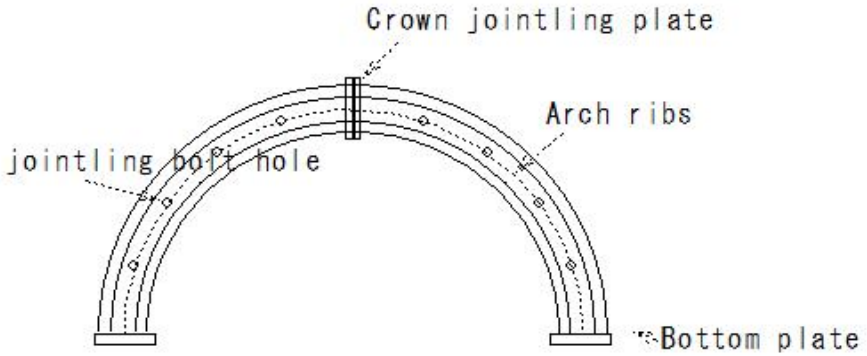
Support

Temporary structure installed to absorb earth pressure after tunnel excavation and before covering work

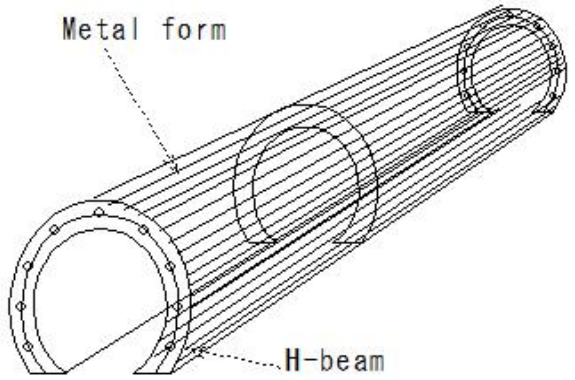
①Steel arch support

①H-shaped steel, assembled in an arch shape, erection interval 1.2m or less as standard

②Support is wrapped in concrete and used as steel beam

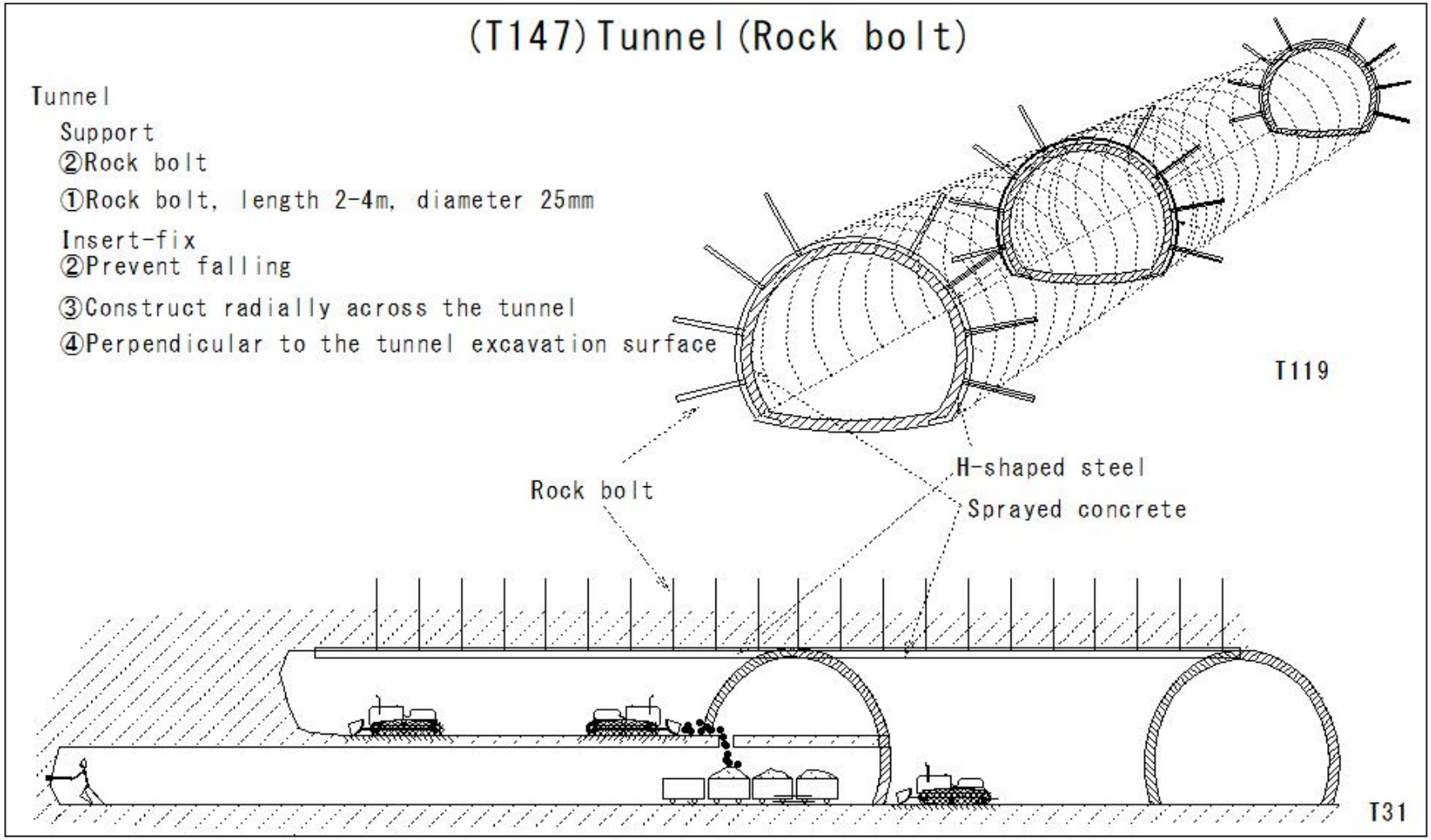


a: Half-section type T53

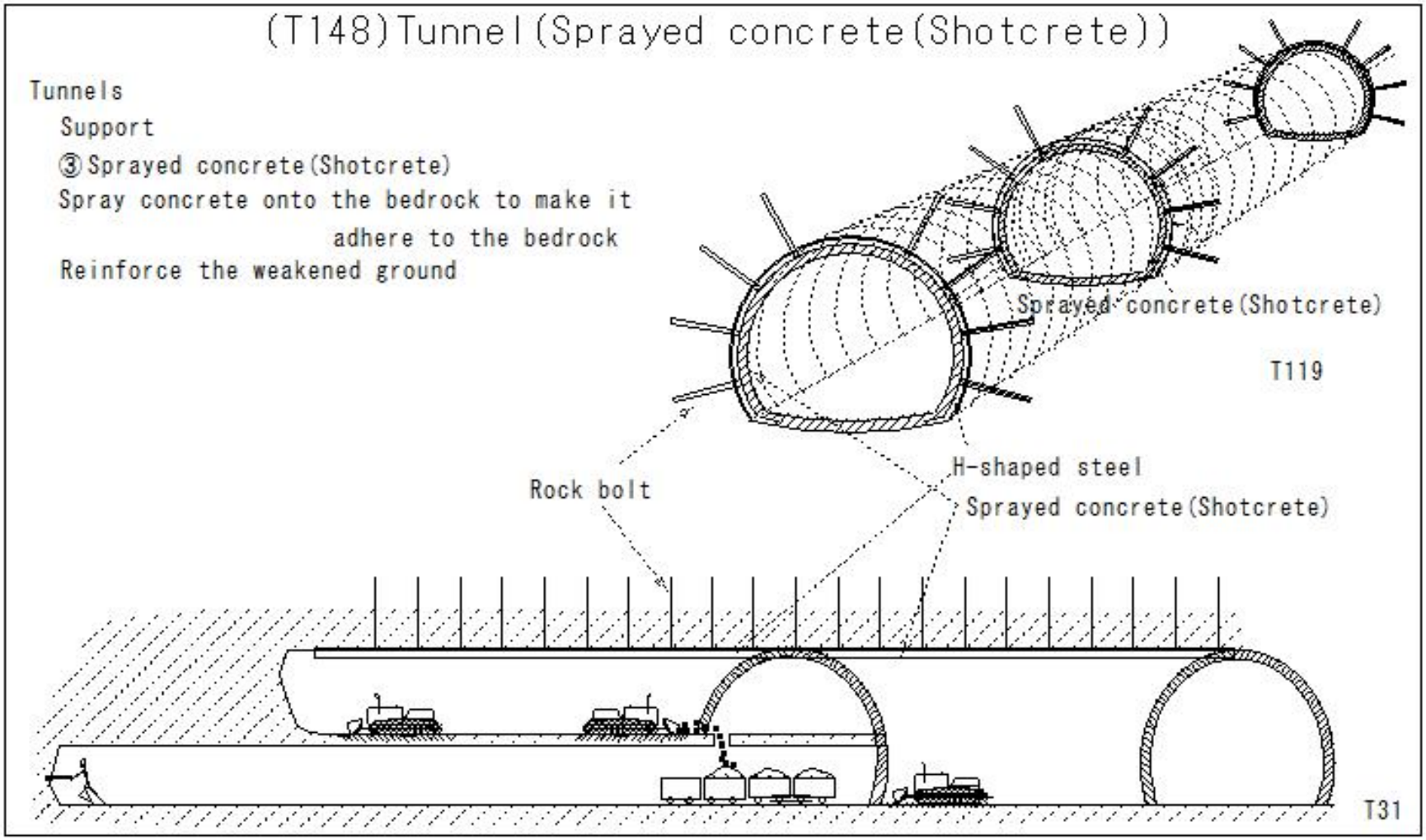


T118

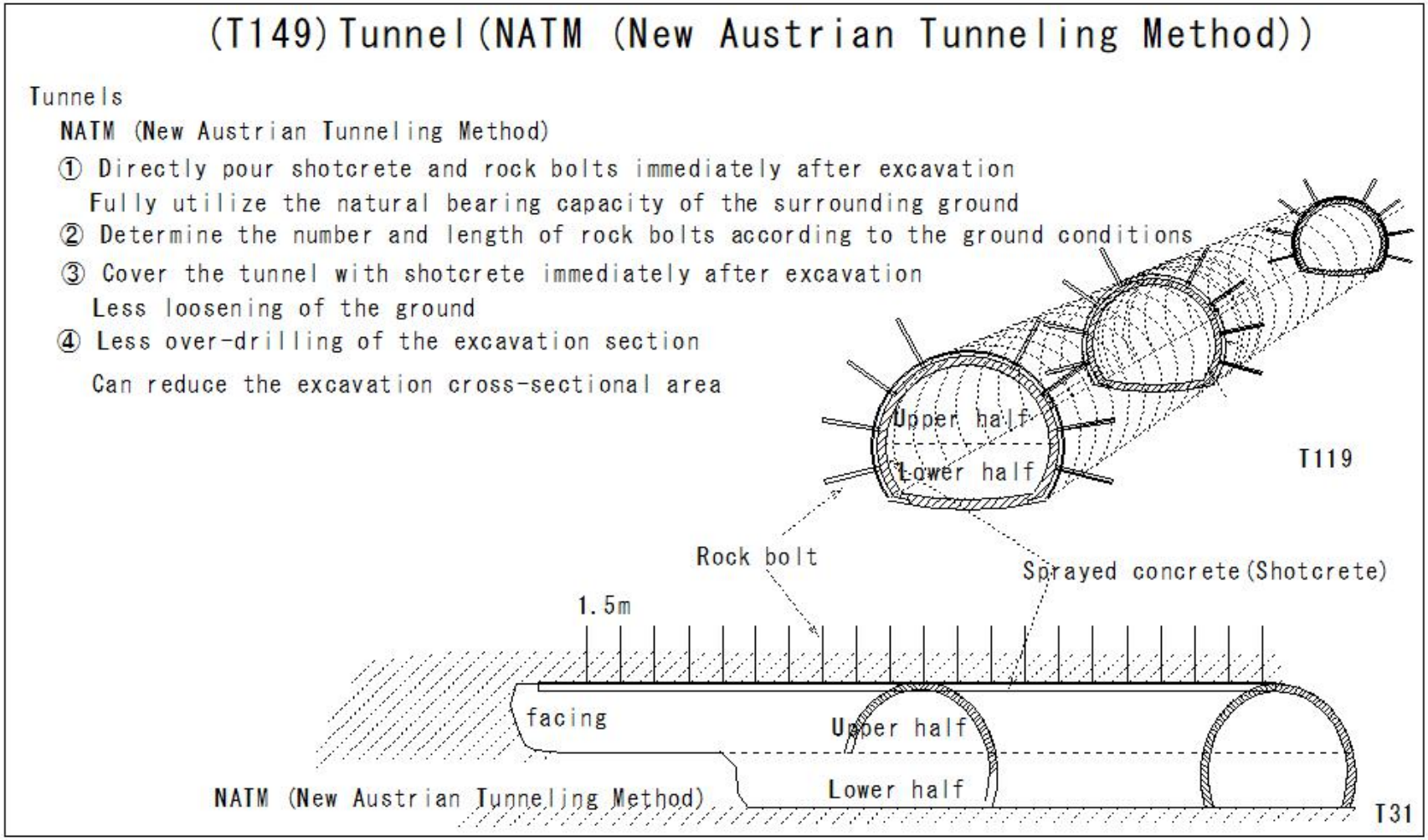
(T147)Tunnel(Rock bolt)



(T148)Tunnel(Sprayed concrete(Shotcrete))



(T149)Tunnel(NATM (New Austrian Tunneling Method))



(T150)Tunnel(Coverings (lining))

(T150)Tunnel(Coverings (lining))

Tunnels

Coverings (lining) works

Prevents tunnel collapse and water leakage

Safely supports the ground

Maintains strength and safety

Coverings (lining) work materials

① Segments: Shield construction method Steel and concrete blocks

Combined to form a circular support

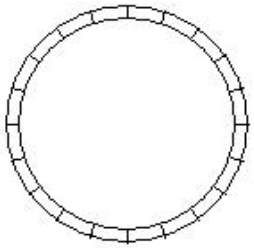
Figure Segments combined to form a circular support

② Cast-in-place unreinforced concrete

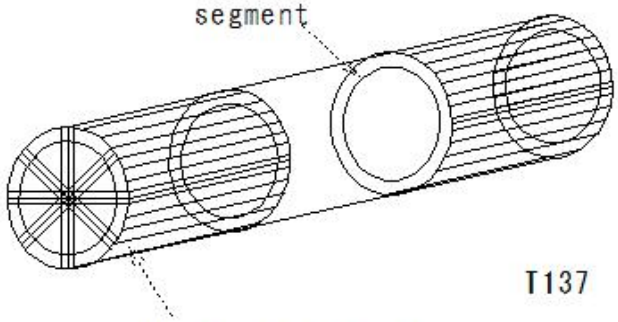
③ Cast-in-place reinforced concrete

④ Stone, brick, precast blocks

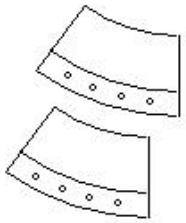
⑤ Liner plates



Shield



T137



Segment

(T151)Tunnel(Formwork)

(T151)Tunnel(Formwork)

Tunnel

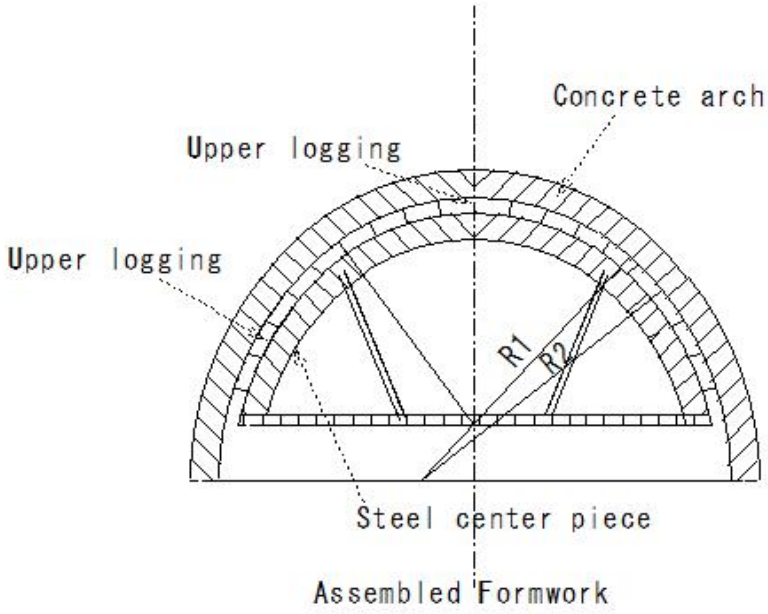
Formwork

① Assembled

② Pay attention to the spacing of the center (arch formwork)

③ Spacing between steel center pieces: approx. 1.2-1.5m

④ Install 2-5cm higher, taking into account the amount of settlement during the covering work



(T152)Tunnel(traveling form(Mobile formwork))

(T152)Tunnel(traveling form(Mobile formwork))

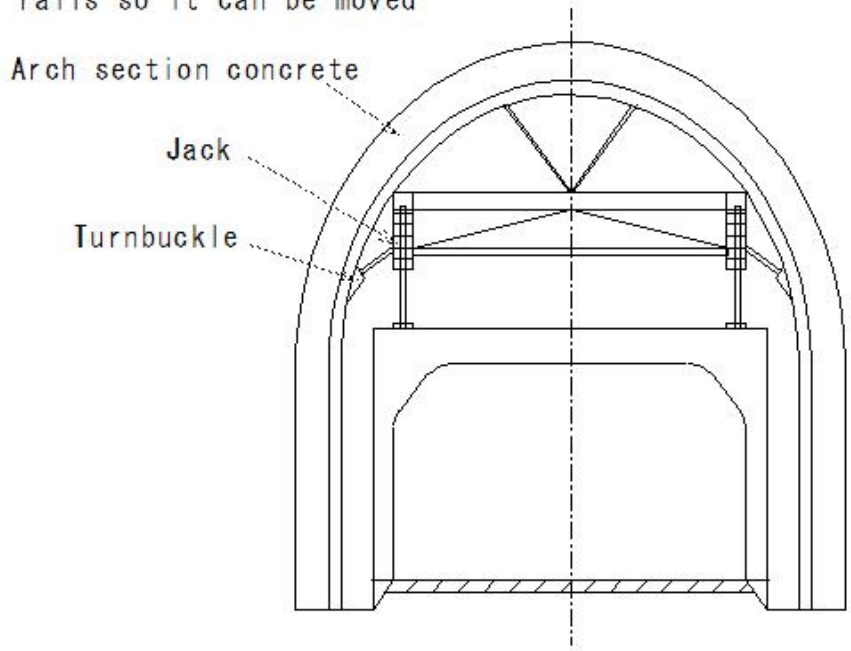
Tunnel

Formwork

①traveling form(Mobile formwork)

④traveling form(Mobile formwork): Steel centre and metal form integrated

Assembled on rails so it can be moved



traveling form(Mobile formwork)

(T153)Tunnel(Coverings (lining)

(T153) Tunnel (Coverings (lining)

Tunnel

Coverings (lining)

①Full cross-section covering method

Construction divided into three parts: arch, side wall, and inverted lining

②Reverse inverted lining method: After construction of arch section → side wall → inverted lining

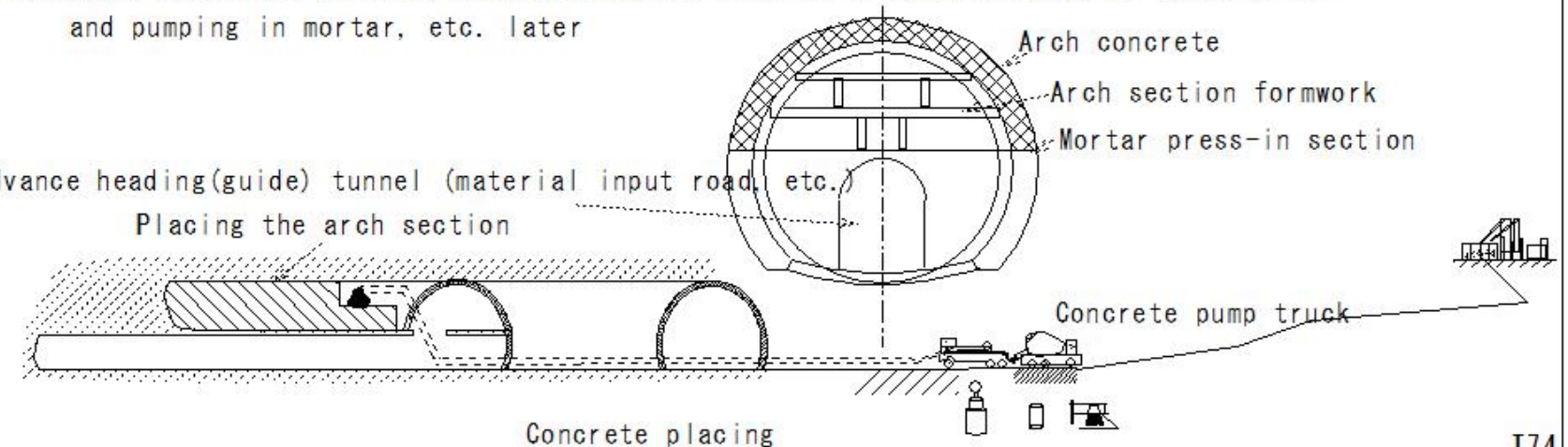
Main Coverings (lining) method: side wall → arch → inverted lining

③Concrete: Concrete with good workability

④Ready mixed concrete -placed using a concrete pump

⑤Arch section: Careful construction

⑥Reverse Coverings (lining) method: Arch and side wall, leaving a gap of about 10 cm and pumping in mortar, etc. later



T74

(T154)Tunnel(waterproof・drainage pipes)

(T154)Tunnel(waterproof・drainage pipes)

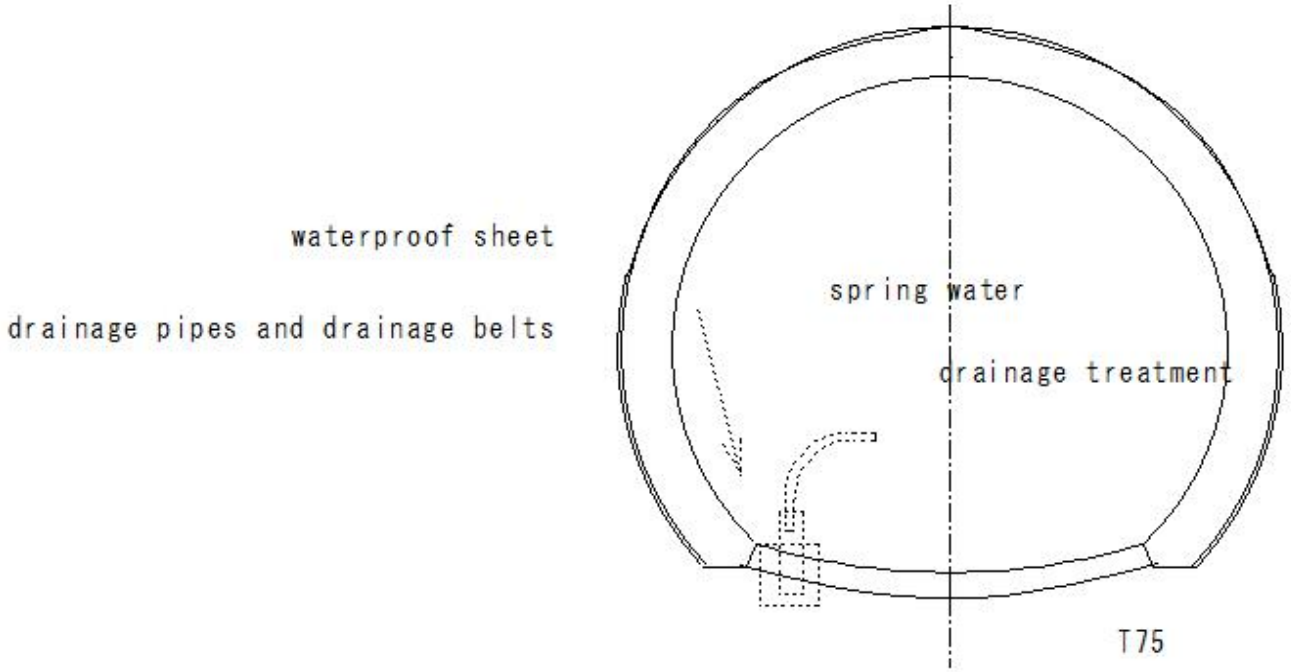
Tunnel

Ancillary works

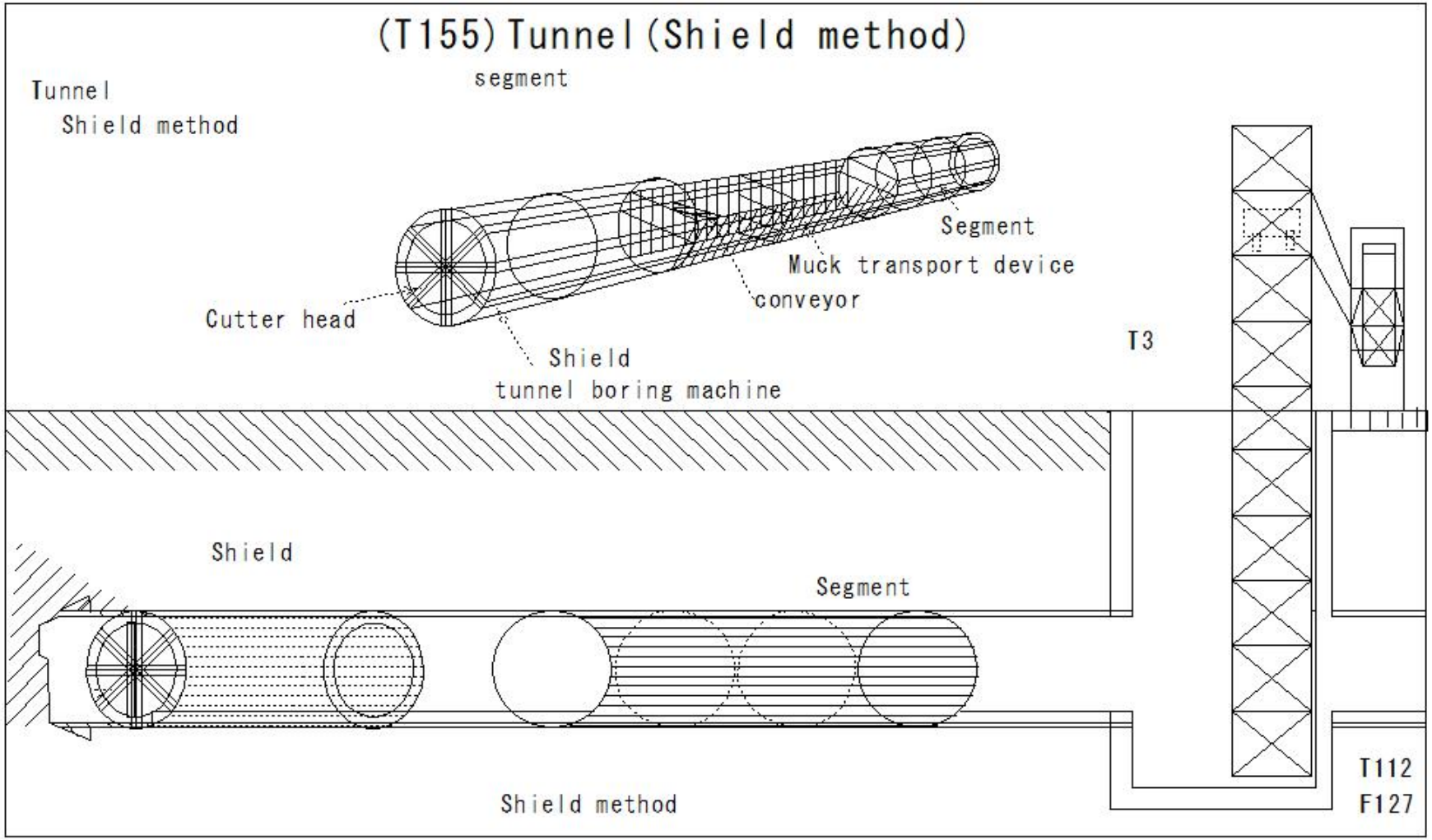
Areas with a lot of spring water

Install a waterproof sheet between the tunnel and the ground

Install drainage pipes and drainage belts



(T155)Tunnel(Shield method)



(T156)Tunnel(Shield tunneling)

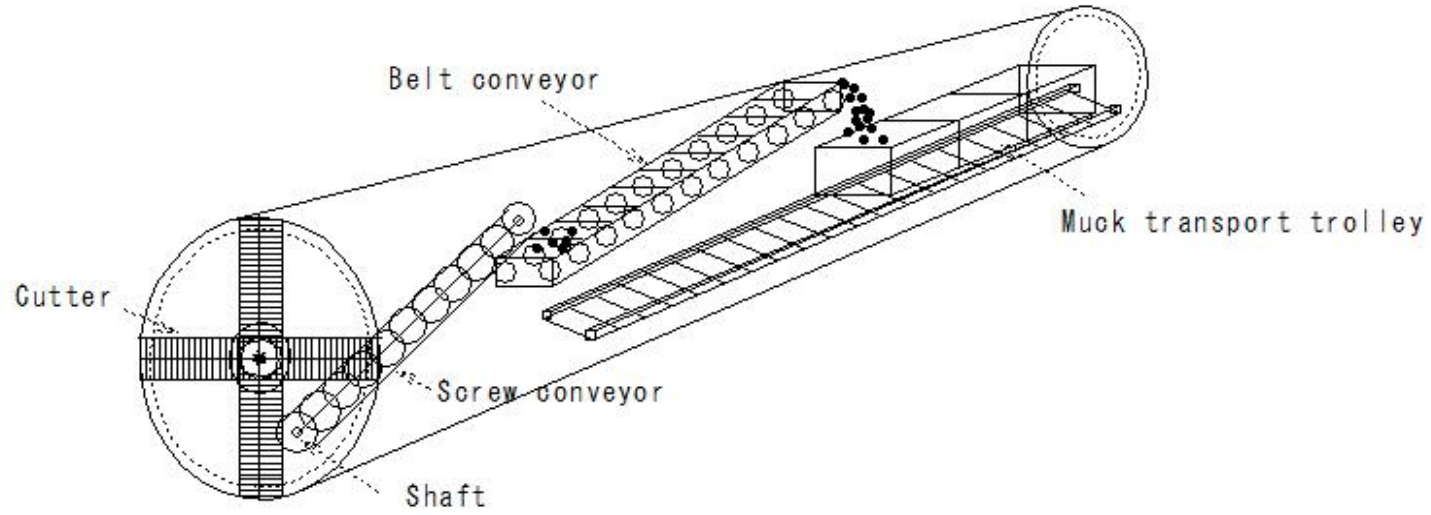
(T156)Tunnel(Shield tunneling)

Tunnel

Shield tunneling

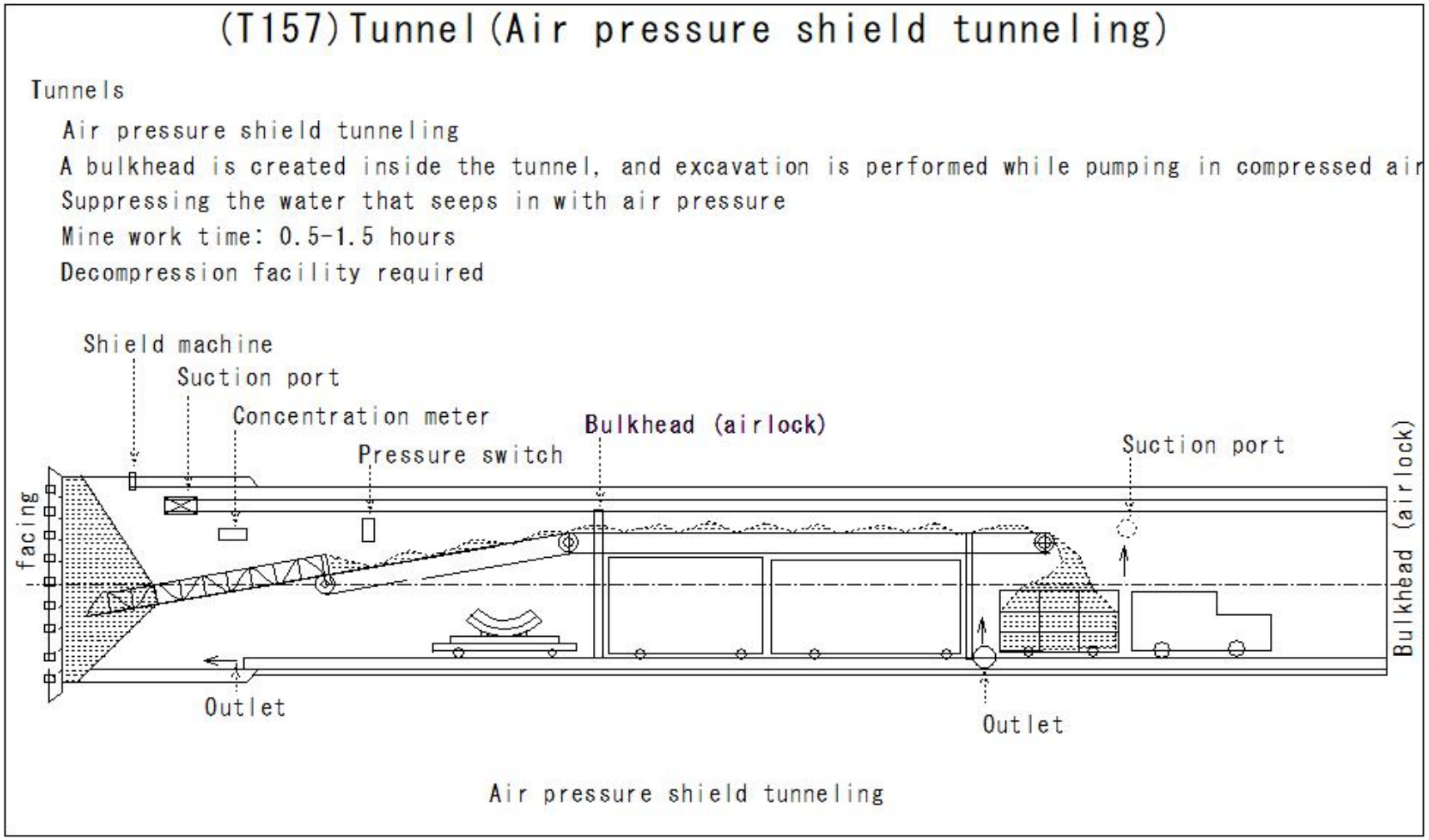
Inside the shield: Excavation → Shield tunneling →Coverings (lining)work → Backfill injection

Linear shape is straight or with a large curve radius



Shield tunneling

(T157)Tunnel(Air pressure shield tunneling)



(T158)Tunnel(Muddy water pressurized shield method)

(T158)Tunnel(Muddy water pressurized shield method)

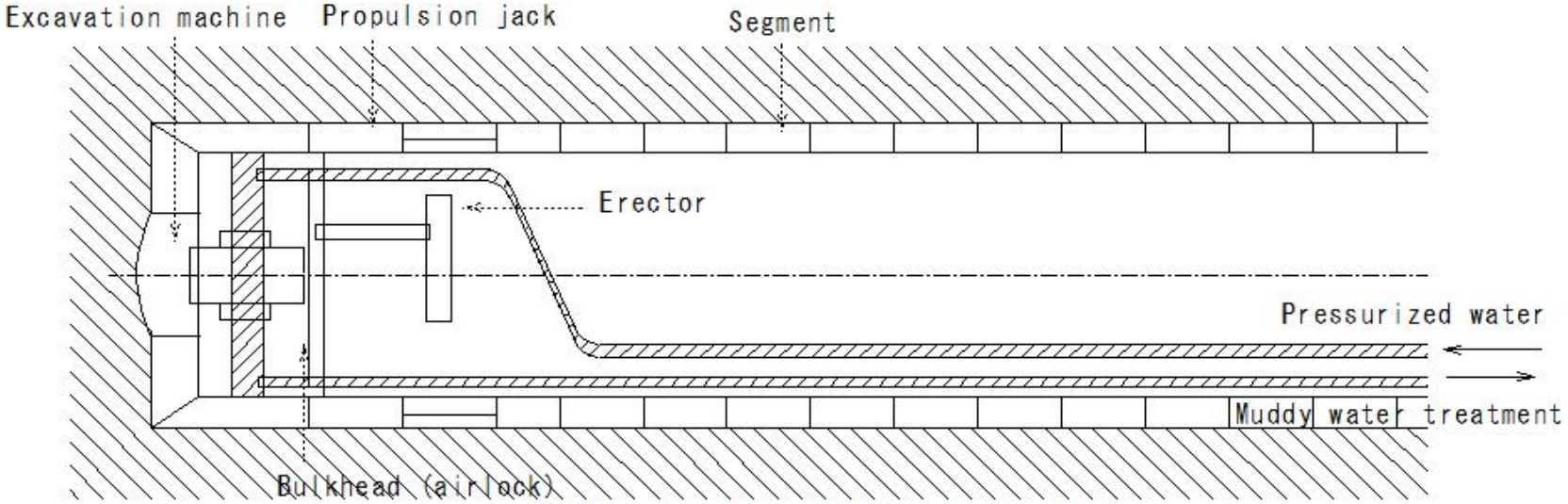
Tunnel

Muddy water pressurized shield method

① Muck out: A large amount of water is pumped into the cutting edge(face), which turns it into muddy water and discharges it outside the tunnel through a pipe

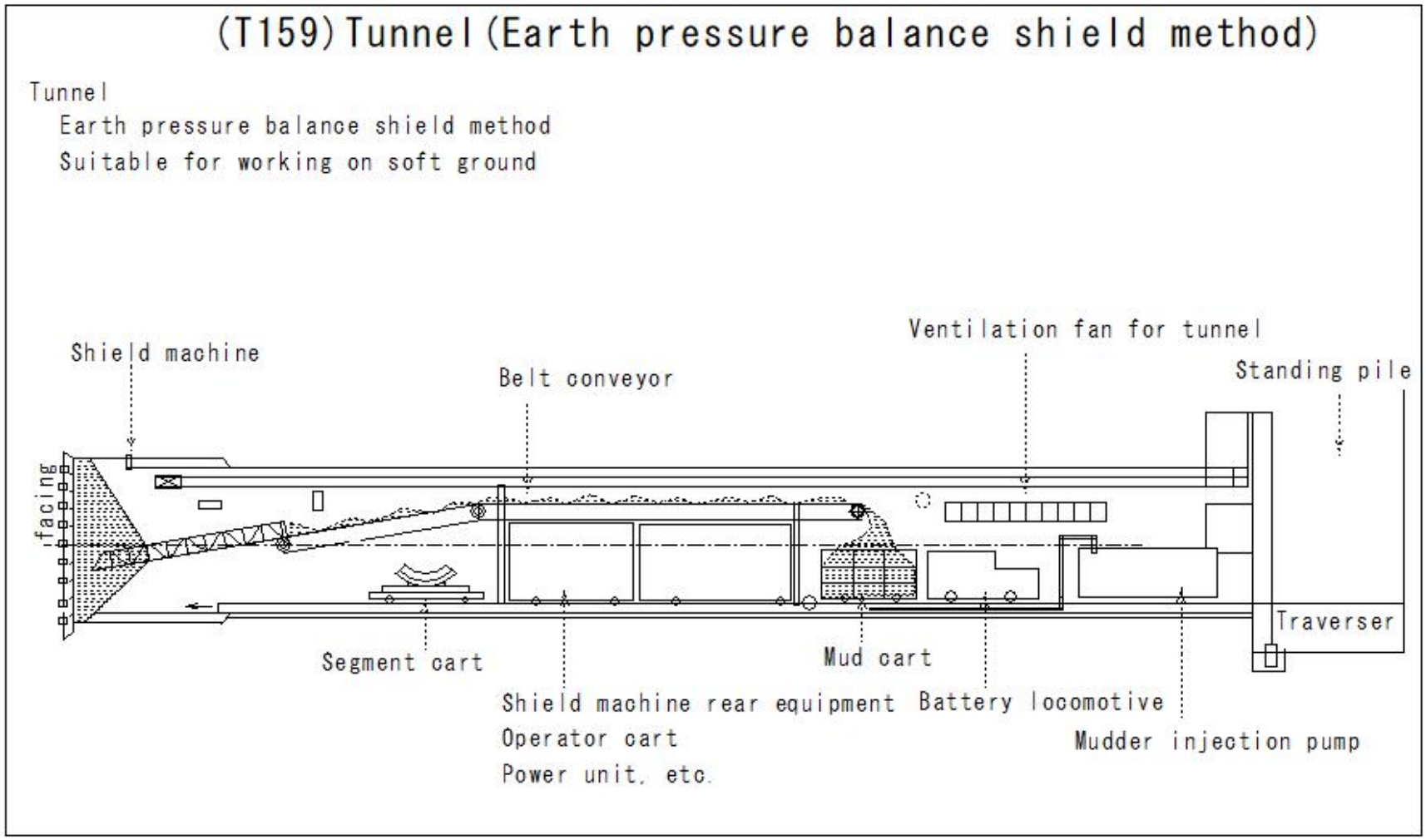
② Space and facilities are required for a large sedimentation pond

③ Construction is possible in areas with a lot of spring water, and only a small number of workers are required



Muddy water pressurized shield method

(T159)Tunnel(Earth pressure balance shield method)



(T160)Tunnel(Open cut excavation without timbering)

(T160)Tunnel(Open cut excavation without timbering)

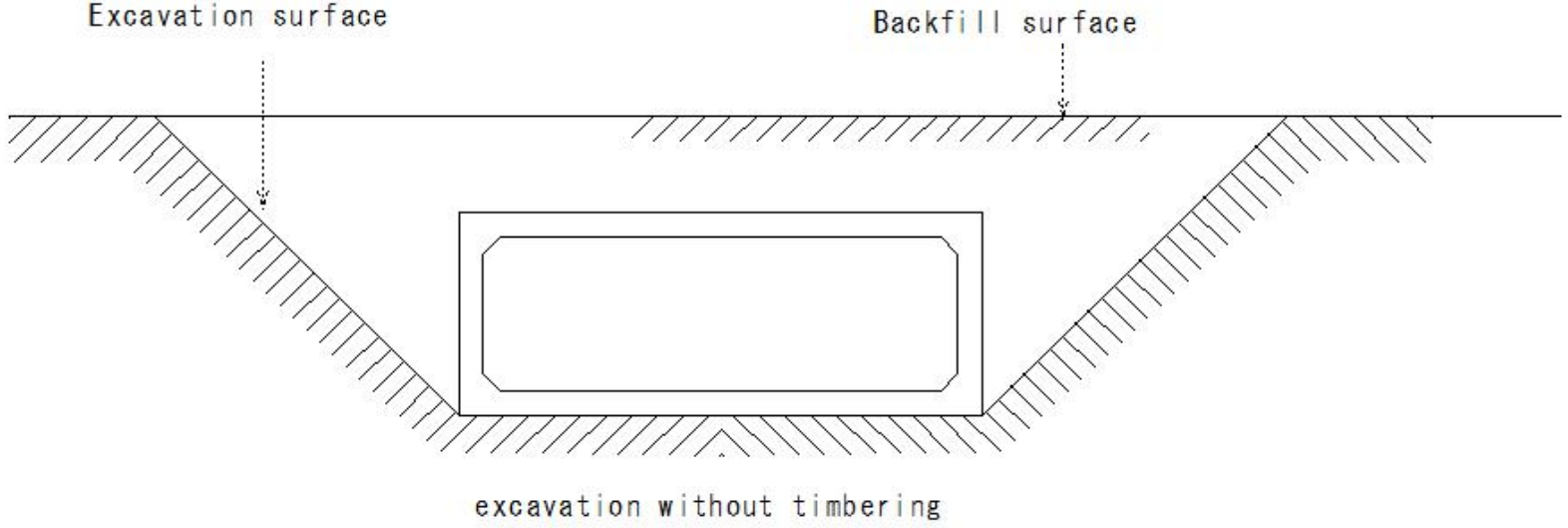
Tunnels

Open cut(Cut-and-cover)method

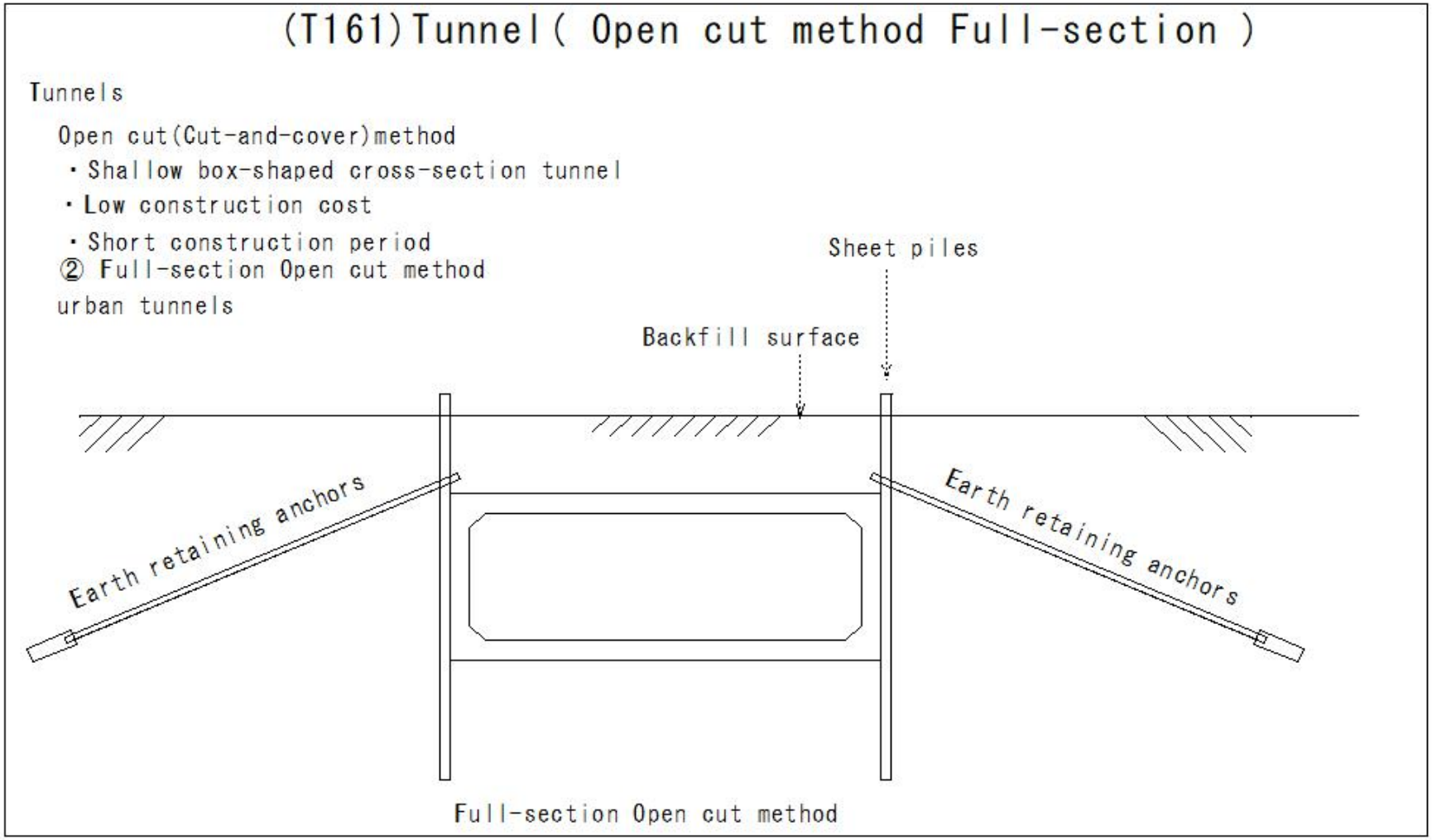
- Shallow box-shaped cross-section tunnel
- Low construction cost
- Short construction period

①excavation without timbering

- Wider site width



(T161)Tunnel(Open cut method Full-section)



(T162)Tunnel(Partial excavation method (trench method))

(T162)Tunnel(Partial excavation method (trench method))

Tunnels

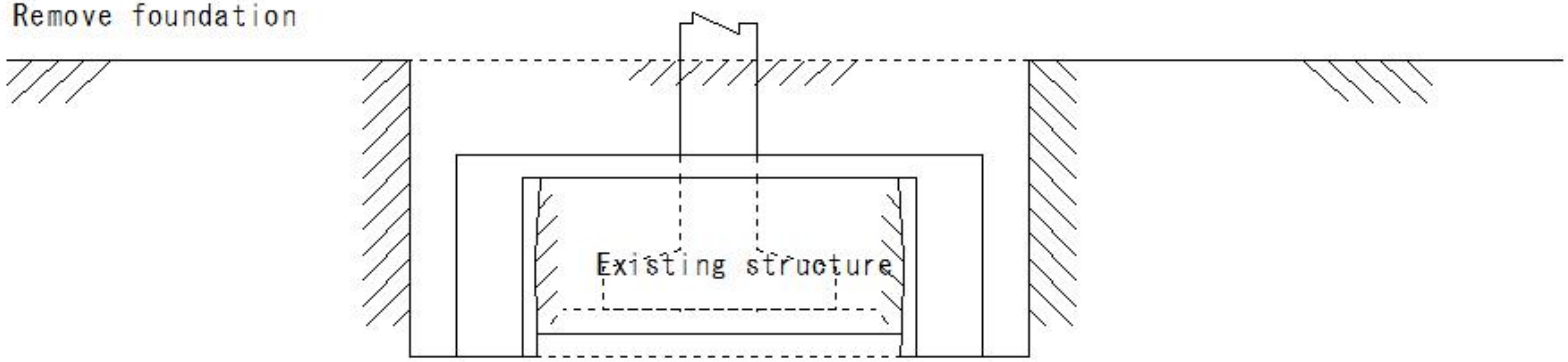
Open cut(Cut-and-cover)method

- Shallow box-shaped cross-section tunnel
- Low construction cost
- Short construction period

③Partial excavation method (trench method)

Existing structure

- in case of digging a tunnel under an existing structure
- Remove foundation



Partial excavation method (trench method)

(T163)Tunnel(edge cutting pipe jacking)

(T163)Tunnel(edge cutting pipe jacking)

Tunnel

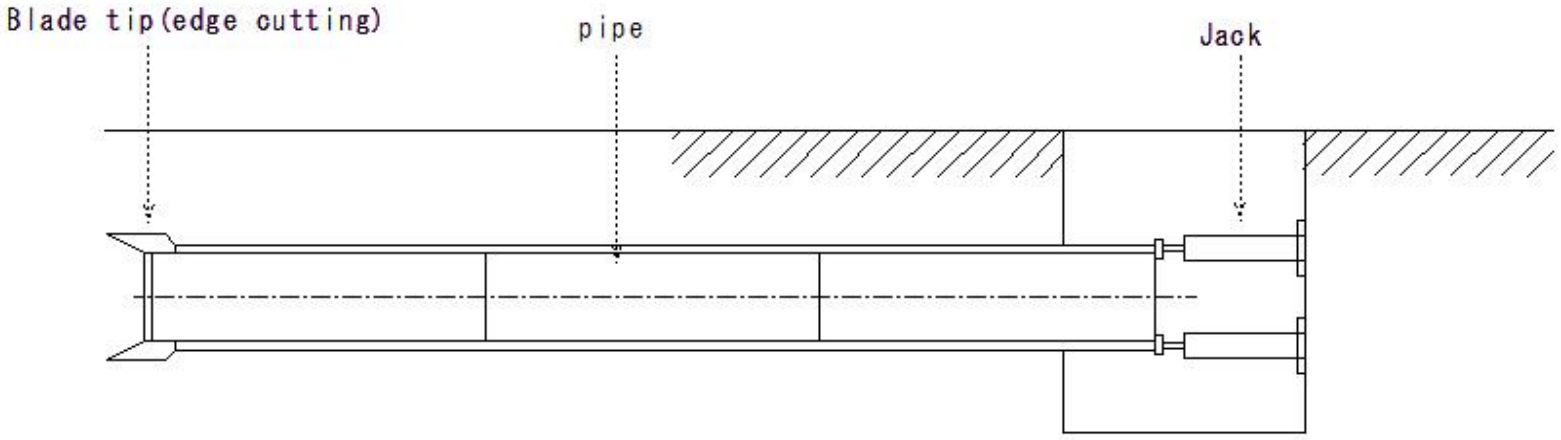
pipe jacking method

A method in which the pipe is pushed in one after another with a powerful jack

Construction of underground buried pipes that cross under roads and railways

Pipe diameter: 600-2000mm

①edge cutting pipe jacking



edge cutting pipe jacking

(T164)Tunnel(Semi-shield pipe jacking method)

(T164)Tunnel(Semi-shield pipe jacking method)

Tunnel

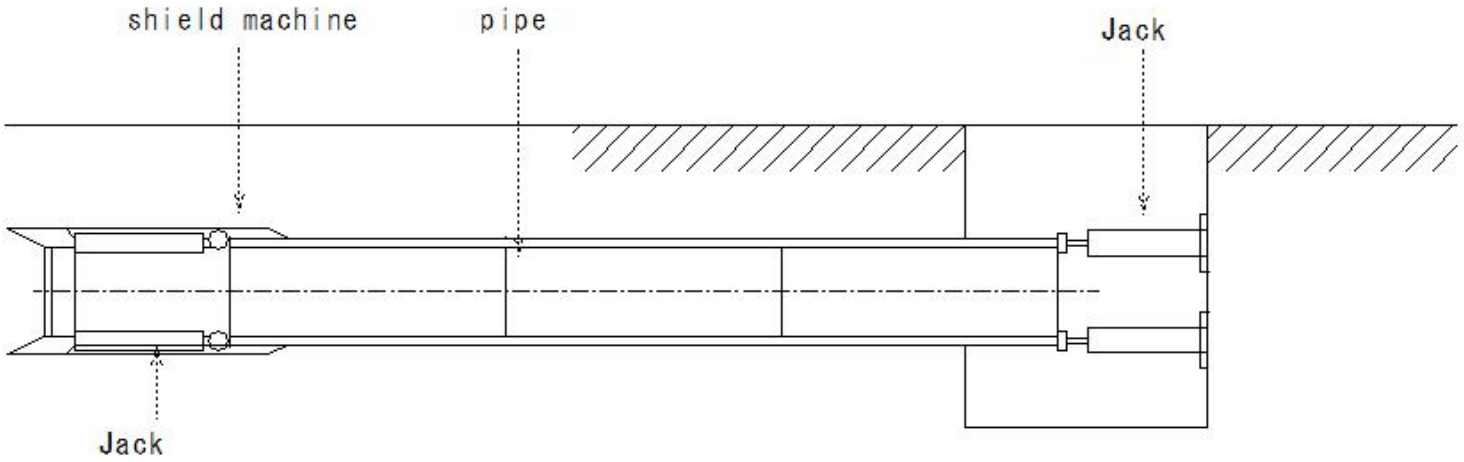
pipe jacking method

A method in which the pipe is pushed in one after another with a powerful jack

Construction of underground buried pipes that cross under roads and railways

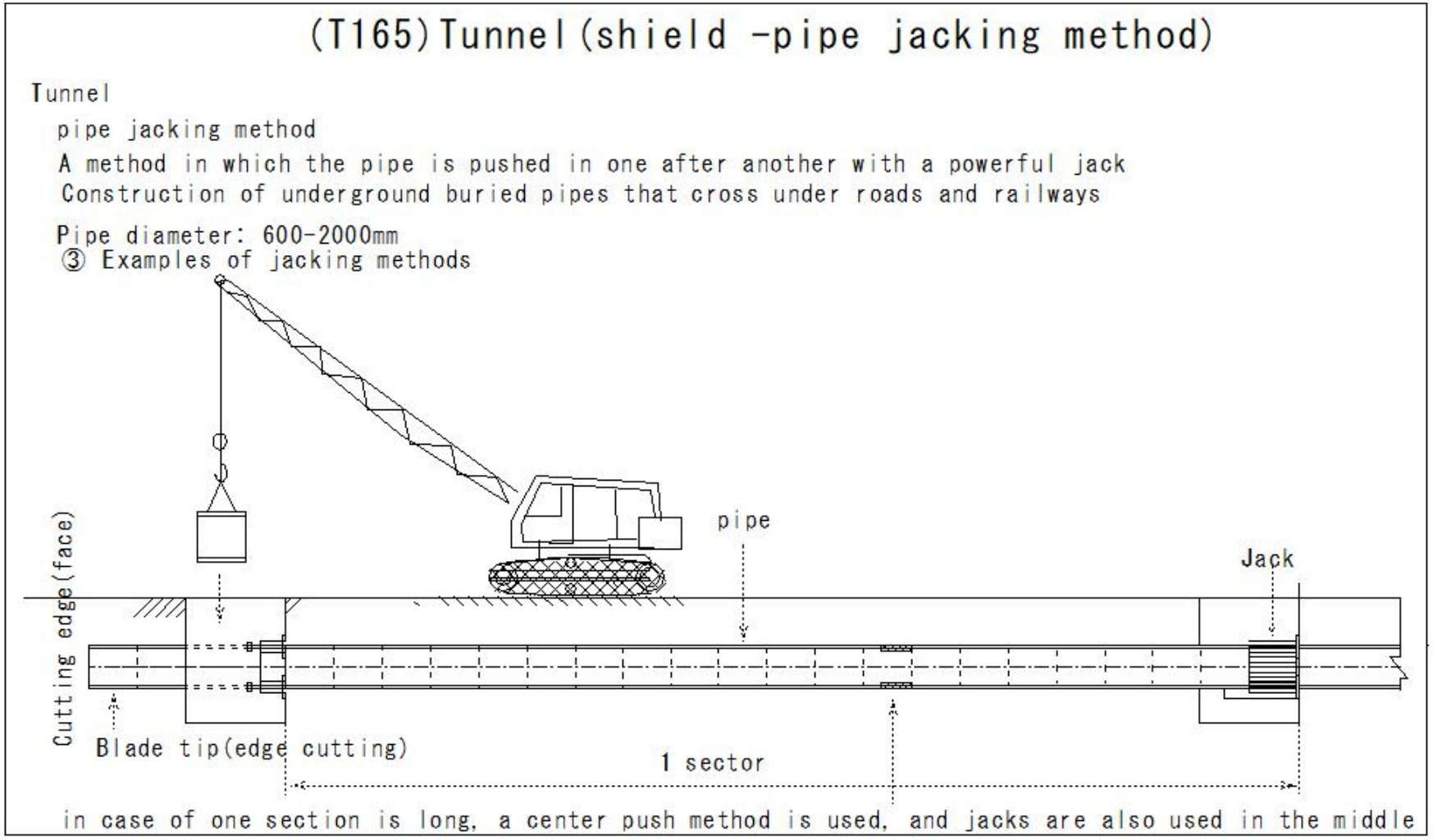
Pipe diameter: 600-2000mm

② Semi-shield pipe jacking method

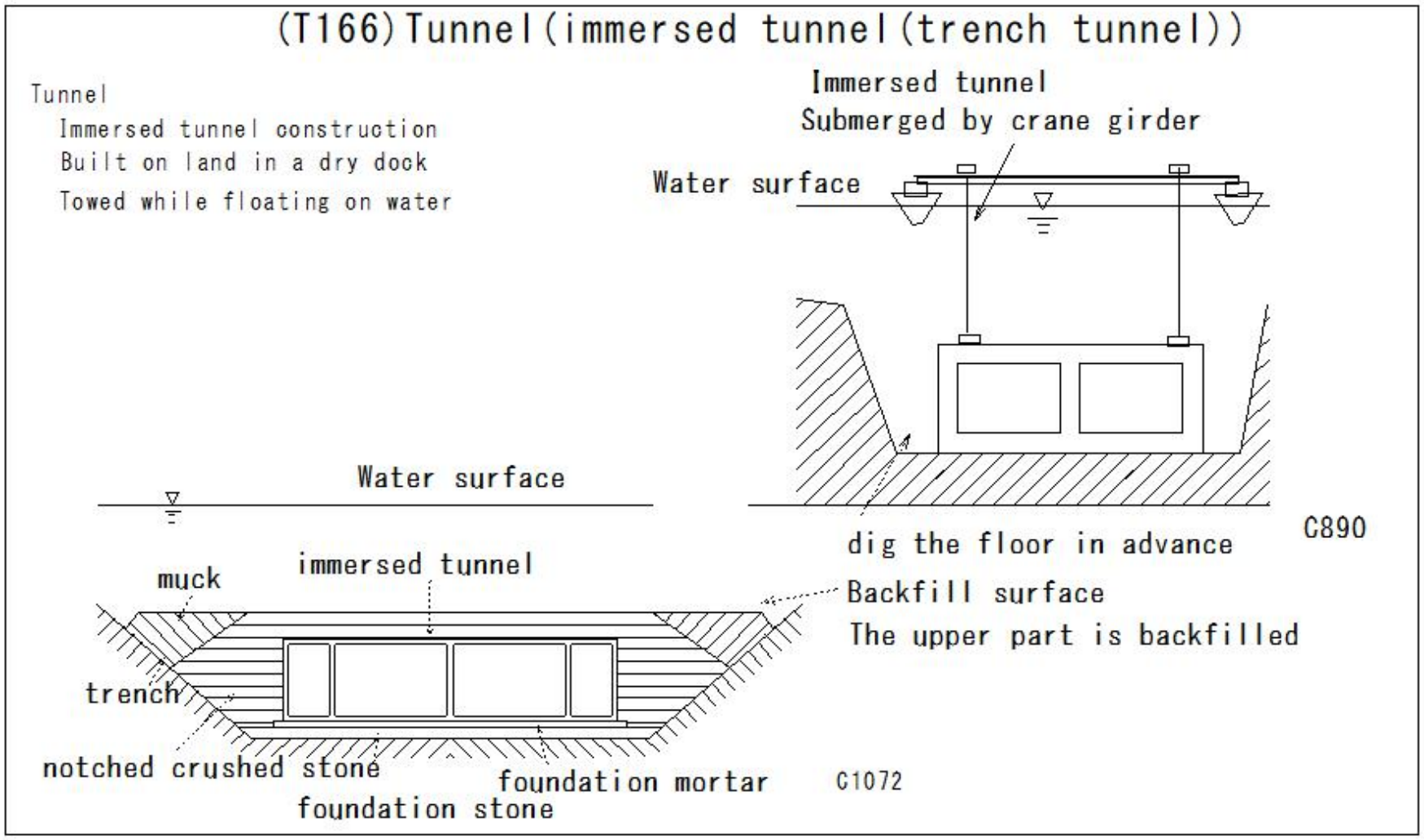


Semi-shield pipe jacking method

(T165)Tunnel(shield -pipe jacking method)



(T166)Tunnel(immersed tunnel(trench tunnel))



(T167)Tunnel(immersed tunnel(trench tunnel))

(T167)Tunnel(immersed tunnel(trench tunnel))

Tunnels

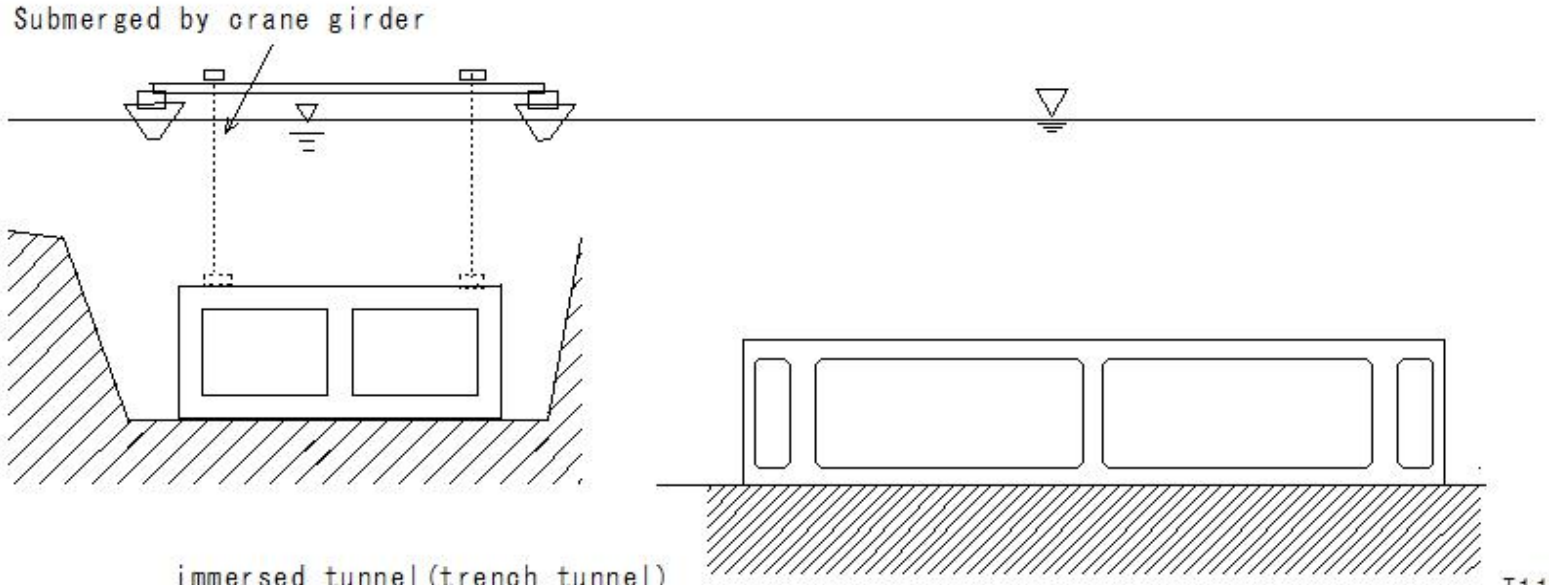
immersed tunnel(trench tunnel)

Characteristics

① No risk during tunnel excavation

② Construction work on land and dredging underwater are carried out simultaneously

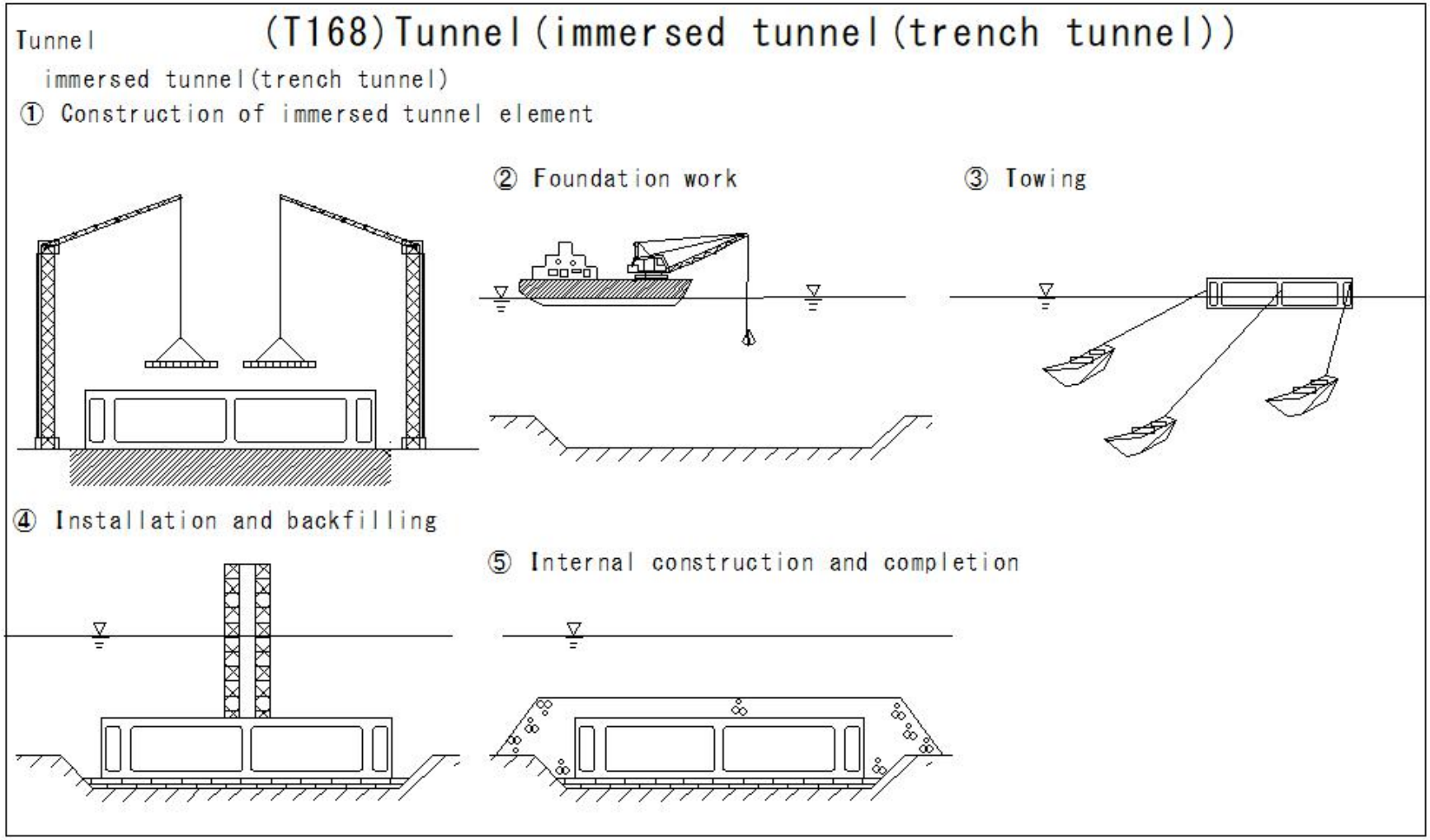
③ The tunnel is installed at a shallow depth, so the total length is shorter



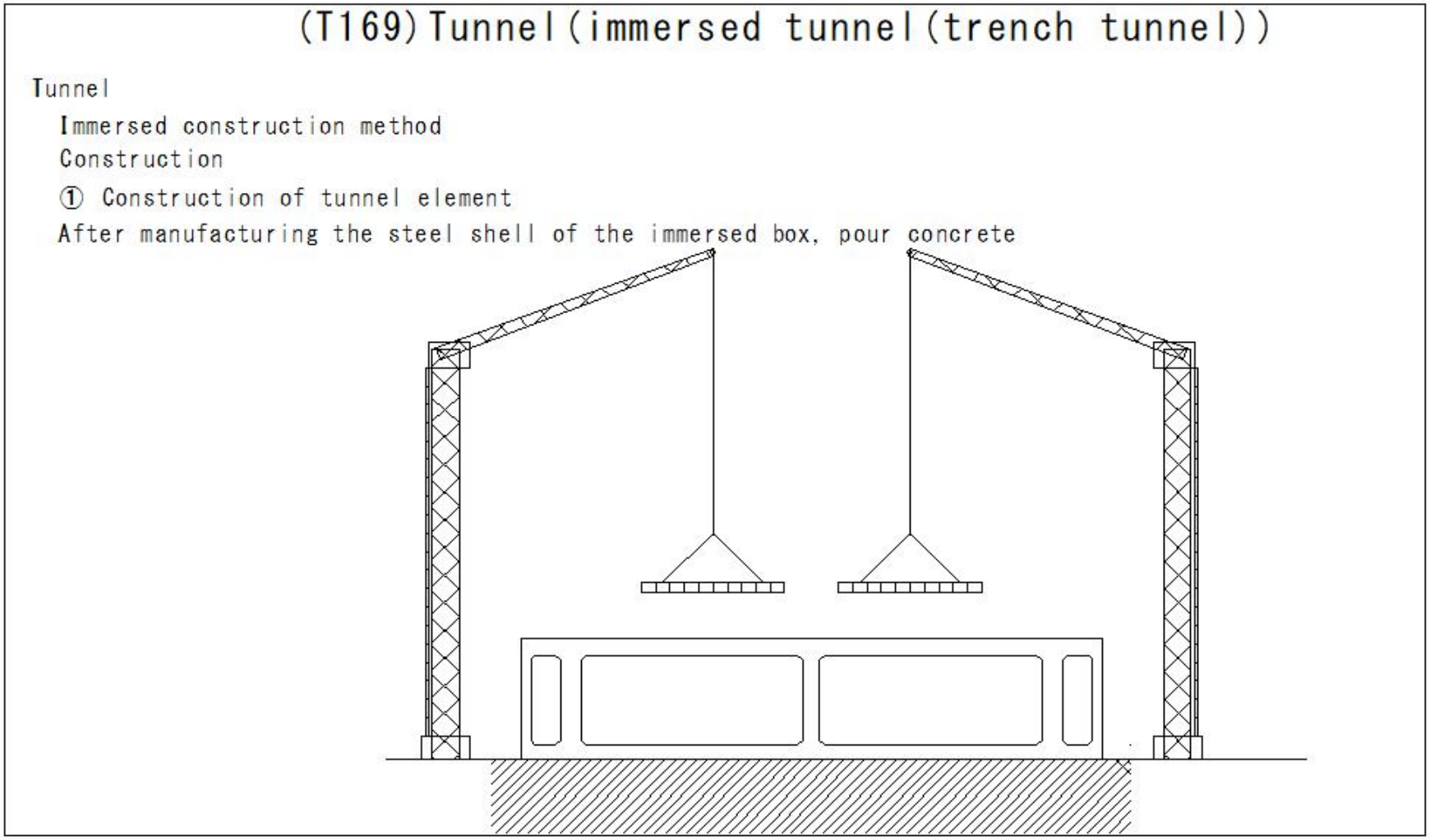
immersed tunnel(trench tunnel)

T110

(T168)Tunnel(immersed tunnel(trench tunnel))



(T169)Tunnel(immersed tunnel(trench tunnel))



(T170)Tunnel(immersed tunnel(trench tunnel))

(T170)Tunnel(immersed tunnel(trench tunnel))

Tunnel

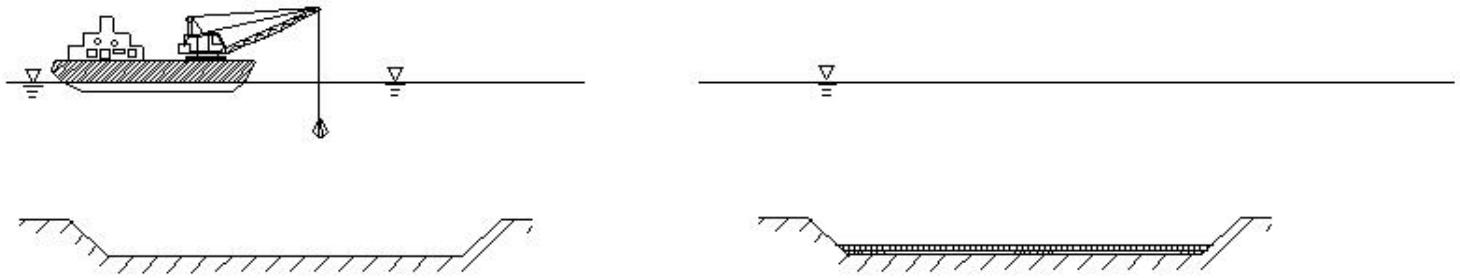
Immersed construction method

Construction

② Foundation work

After digging the floor, a layer of rubble and a pedestal are installed

② Foundation work



(T171)Tunnel(immersed tunnel(trench tunnel))

(T171)Tunnel(immersed tunnel(trench tunnel))

Tunnel

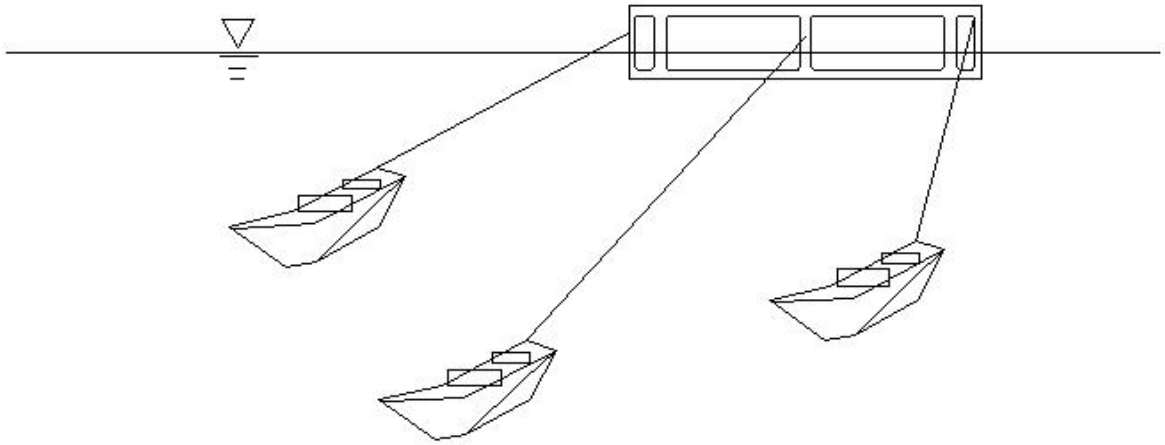
Immersed construction method

Construction

③ Towing

Both ends of the immersed tunnel are blocked with bulkheads to raise it to the surface and tow it to the site.

③ Towing



(T172)Tunnel(immersed tunnel(trench tunnel))

(T172)Tunnel(immersed tunnel(trench tunnel))

Tunnel

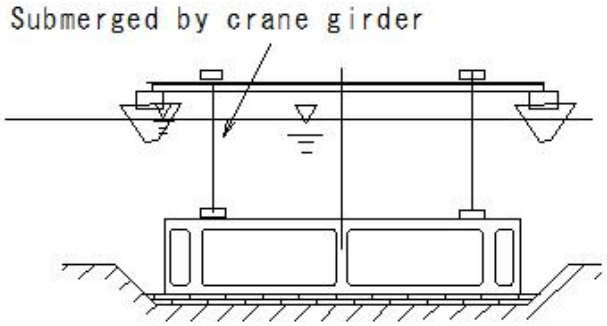
Immersed construction method

Construction

④Immersion and backfilling

Immersion is carried out by manipulating the box with anchor wires and placing it on a pedestal, then applying mortar to the foundation.

④ Installation and backfilling



(T173)Tunnel(immersed tunnel(trench tunnel))

(T173)Tunnel(immersed tunnel(trench tunnel))

Tunnel

Immersed construction method

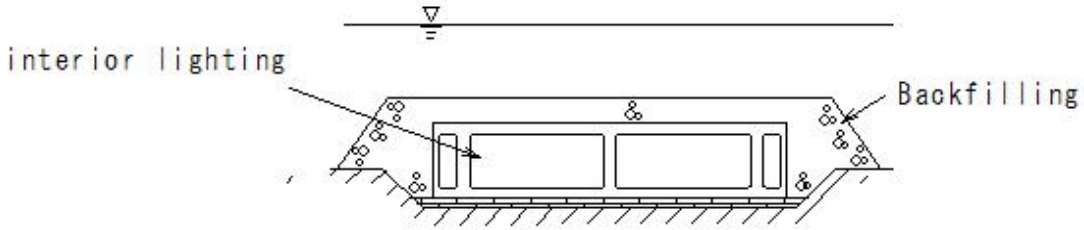
Construction

⑤ Internal construction and completion

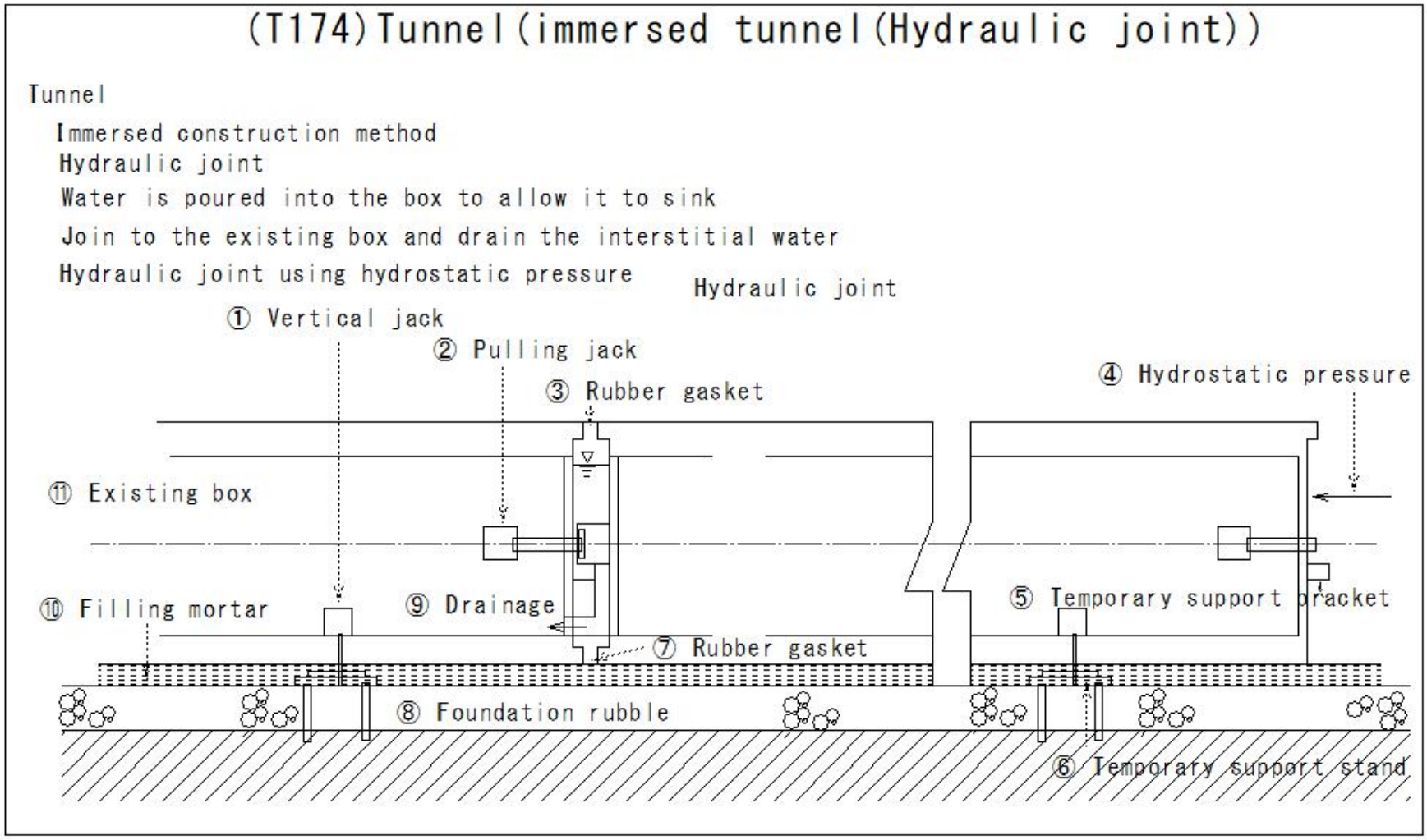
Install interior lighting, pavement, and disaster prevention equipment

Backfilling of sides and top with rubble completed

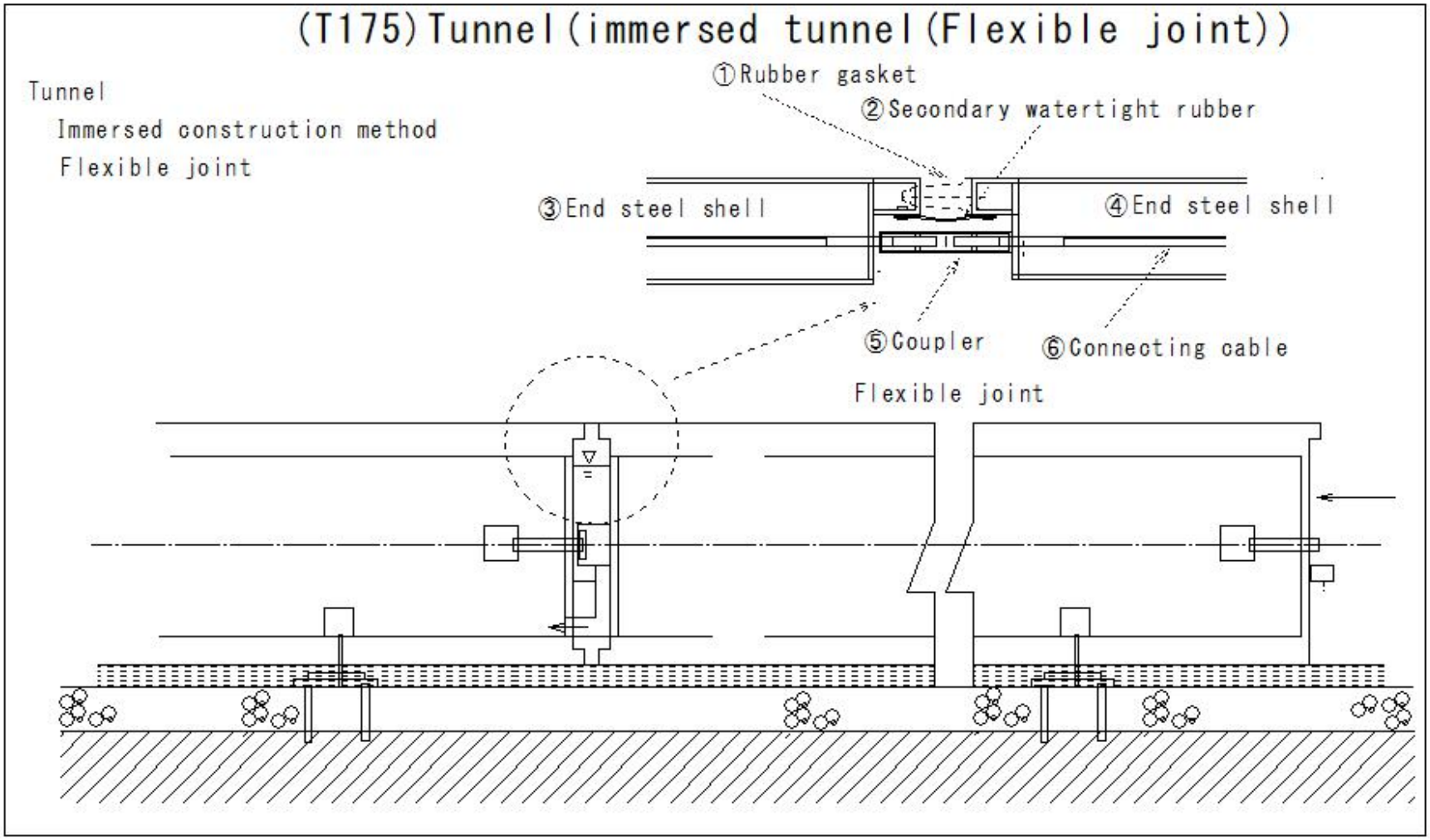
⑤ Internal construction and completion



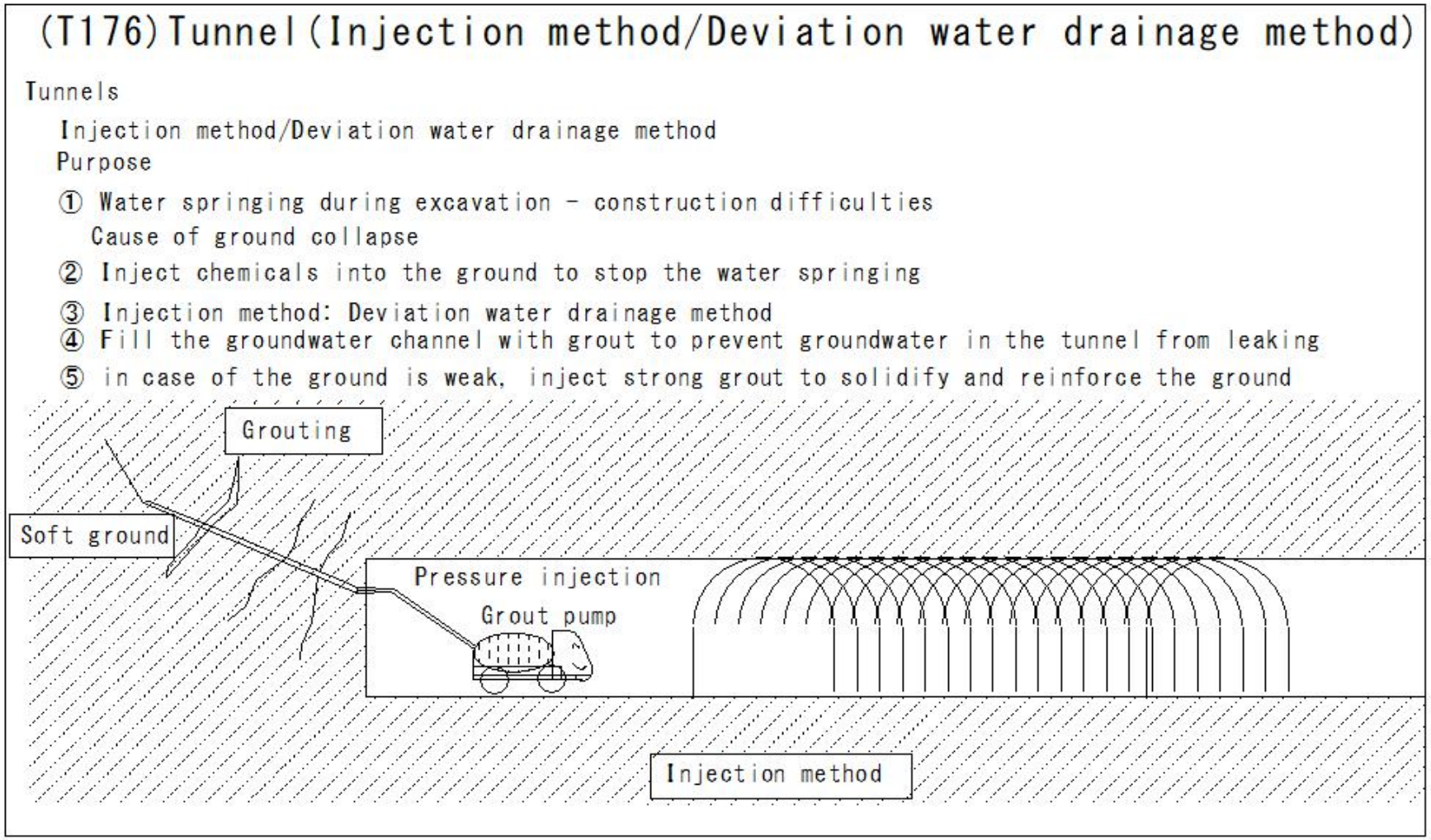
(T174)Tunnel(immersed tunnel(Hydraulic joint))



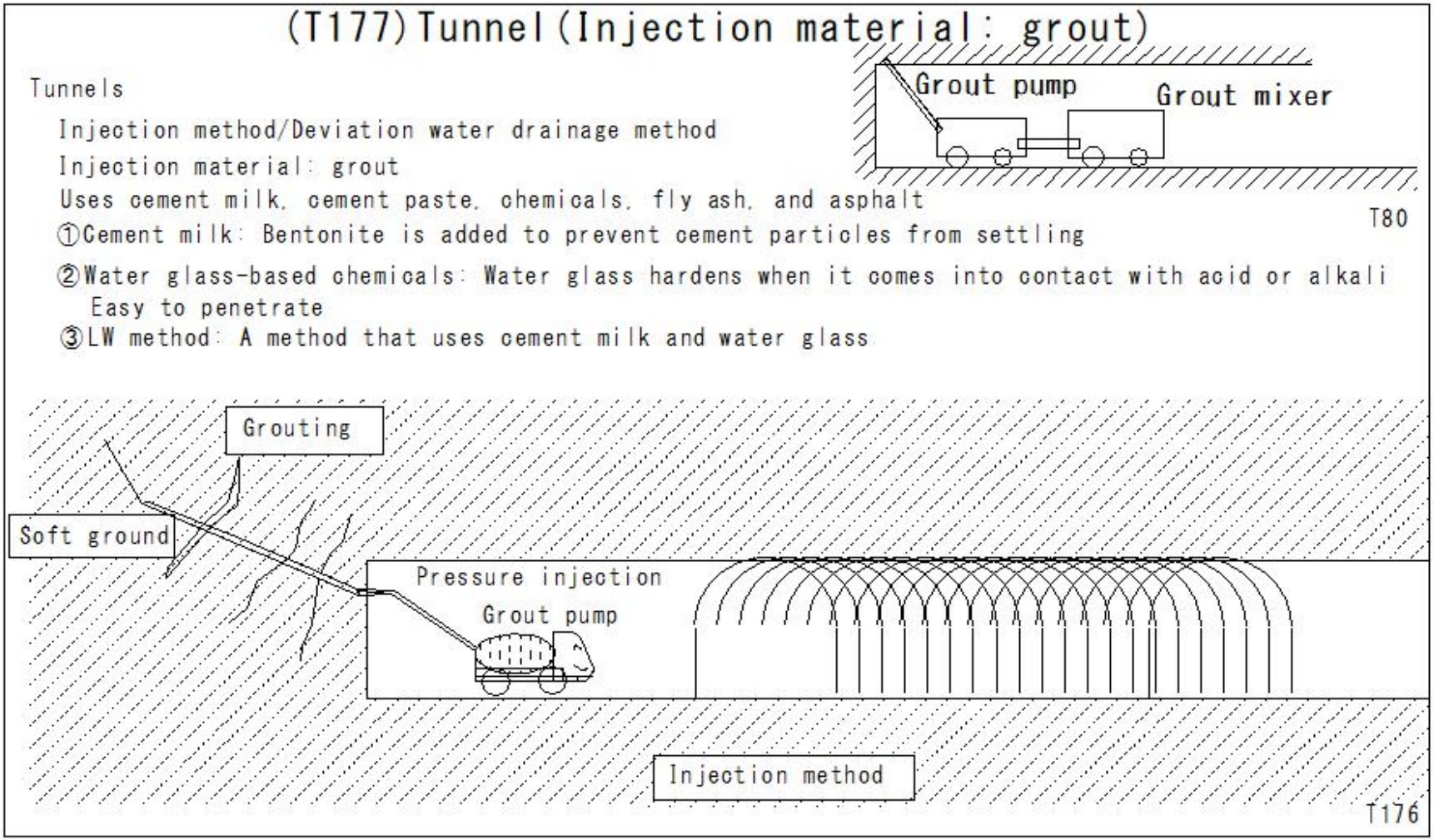
(T175)Tunnel(immersed tunnel(Flexible joint))



(T176)Tunnel(Injection method/Deviation water drainage method)



(T177)Tunnel(Injection material: grout)



(T178)Tunnel(Grouting)

(T178)Tunnel(Grouting)

Tunnels

Injection method/Deviation water drainage method

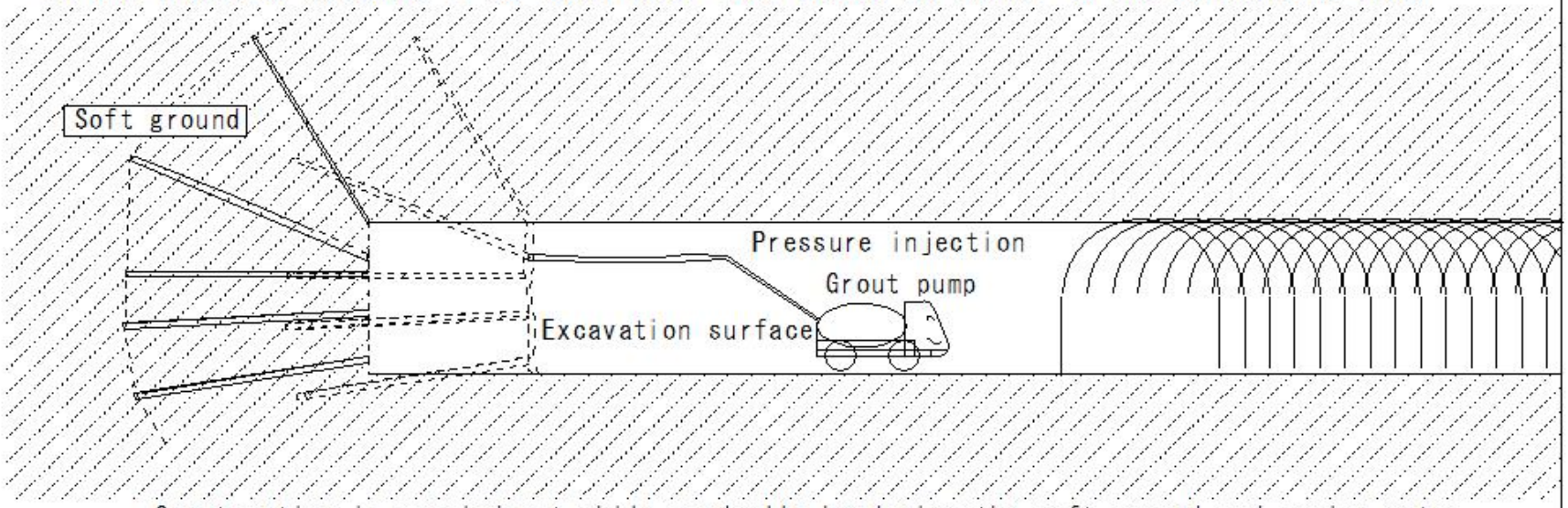
Grouting

① In order to prevent soft ground or water leakage, injection agents (cement paste, etc.) are injected to fill voids in the ground.

② Injection holes are arranged so that the grout penetration ranges overlap each other.

③ The thickness of the injection zone is usually 1.5-3 times the radius of the tunnel.

④ The injection sequence is to expel water from inside the tunnel to the surrounding area.



Construction is carried out while gradually hardening the soft ground and spring water.

(T179)Tunnel(Grouting)

(T179)Tunnel(Grouting)

Tunnels

Injection method/Deviation water drainage method

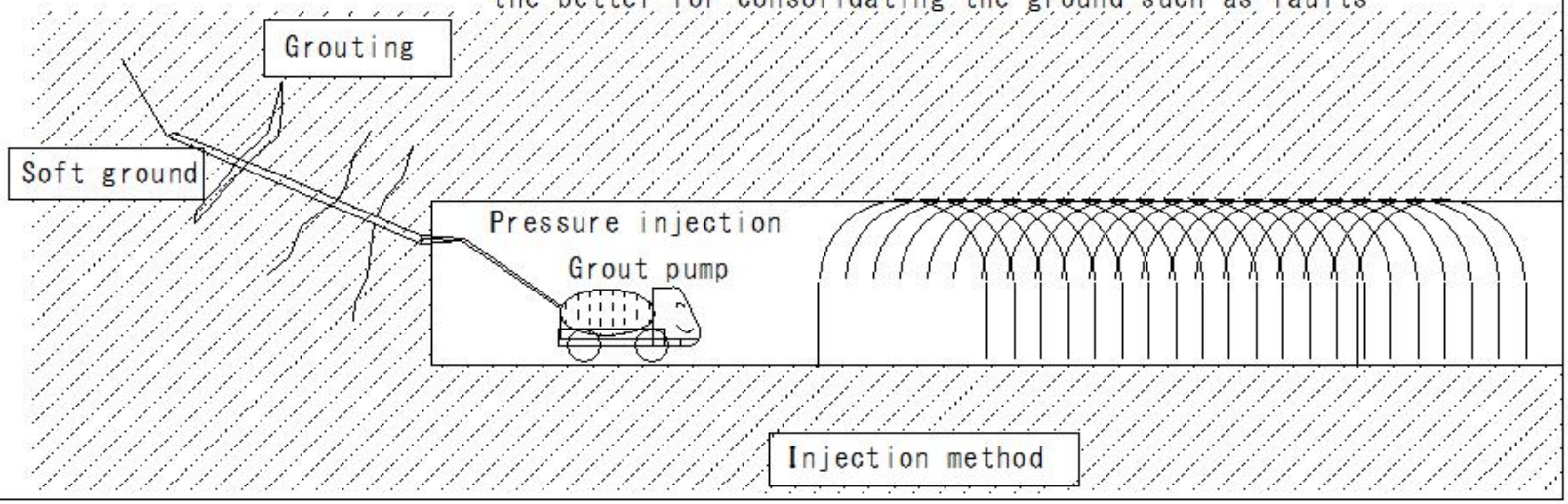
Checking injection

①End of injection: Determine the final injection pressure, consider the injection amount and perform check boring

②in case of necessary, perform sampling and water injection tests to make a judgment

③Final injection pressure: When suppressing spring water, inject at a pressure 2-3 times the spring water pressure

④Fracture zone: The higher the injection pressure, the better for consolidating the ground such as faults



(T180)Tunnel(Injection method/Detour drainage method)

(T180)Tunnel(Injection method/Detour drainage method)

Tunnels

Injection method/Detour drainage method

Checking injection

Detour drainage method

①in case of a lot of spring water during tunnel excavation, dig a drainage shaft separate from the main shaft to drain groundwater and then perform excavation work

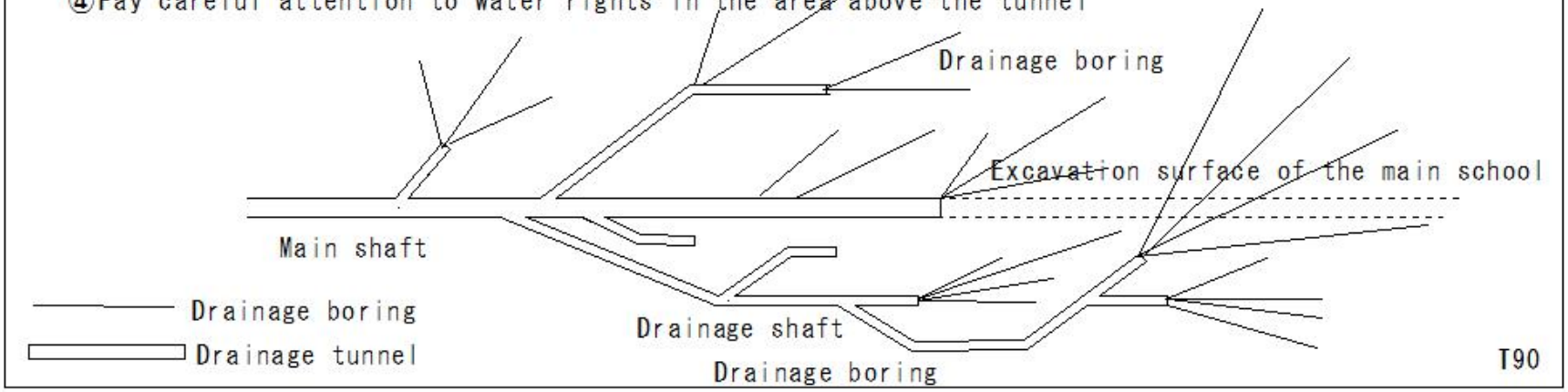
②An effective method in case of a fractured zone is encountered during tunnel excavation

③Procedure: Drill a drainage hole from the side to the front in front of the cutting edge

Drill just before the fractured zone

Discharge water from the borehole through the drainage hole and the main tunnel shaft to the outside of the tunnel

④Pay careful attention to water rights in the area above the tunnel



T90

(T181)Tunnel(Pipe parallel /Messer method)

(T181)Tunnel(Pipe parallel /Messer method)

Tunnels

Special construction methods

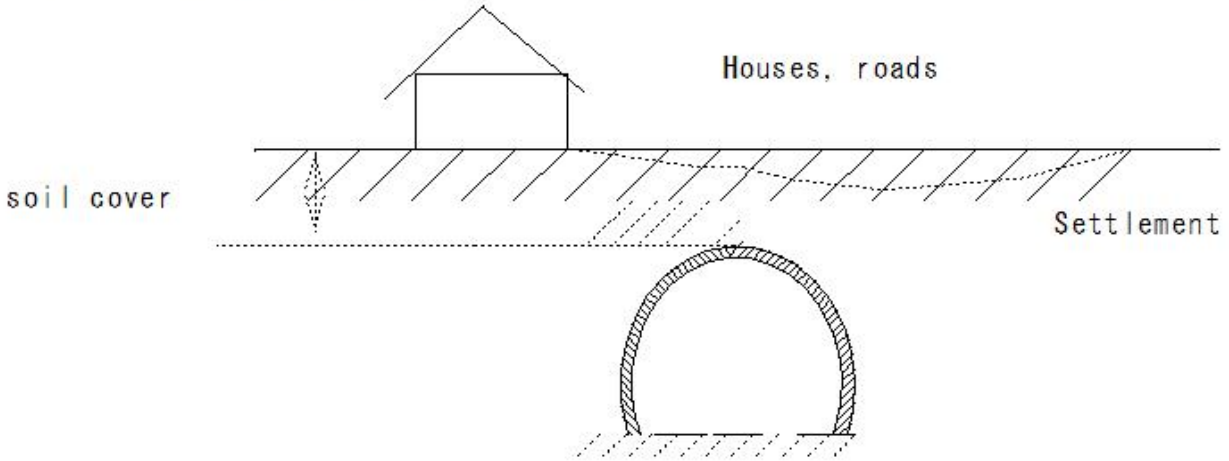
Tunnels with thin soil cover

Houses, roads, etc. exist on the ground

Loosening of the ground and Settlement of the ground surface due to tunnel excavation are avoided as much as possible

① Pipe parallel construction method

② Messer construction method



(T182)Tunnel(Pipe parallel method)

(T182)Tunnel(Pipe parallel method)

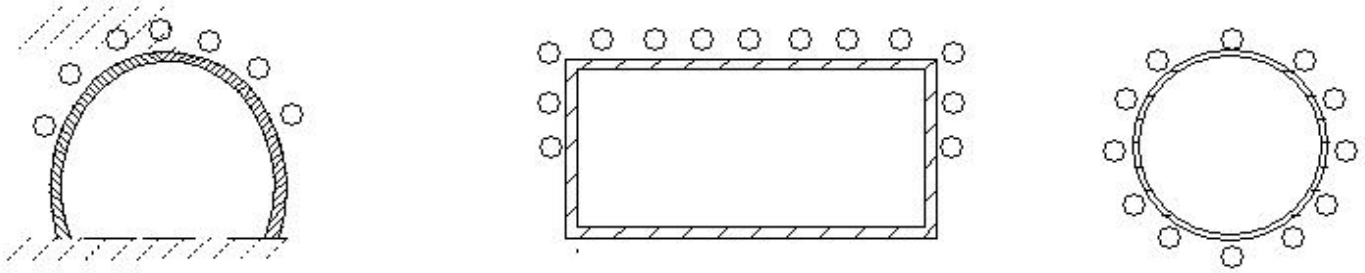
Tunnels

Special methods

①Pipe parallel method

Steel pipe diameter 100-900mm

Steel arch support

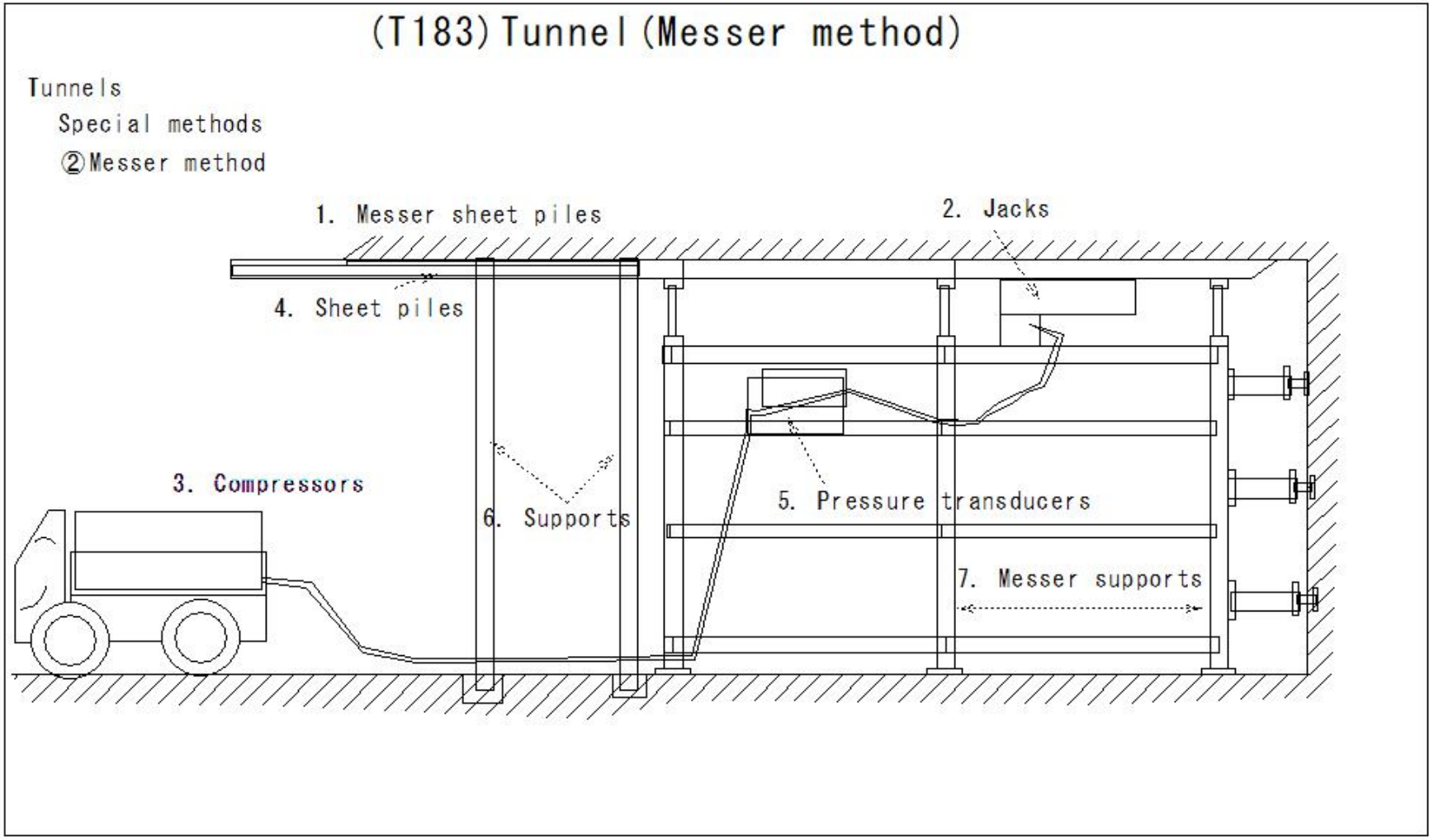


○ Pipe roof

Pipe roof methods

T92

(T183)Tunnel(Messer method)



(T184)Tunnel(Freezing methods)

(T184)Tunnel(Freezing methods)

Tunnels

Special methods

Freezing methods

Soft ground, for ground with high water content

Temporarily freeze and solidify the ground to strengthen and watertighten it

① Applicable conditions

Moisture content 8% or more

Groundwater flow: Direct method 10m/day or less

Indirect method 1m/day or less

② Volume expansion

Silt/clay: Large

Gravel/sand: No expansion

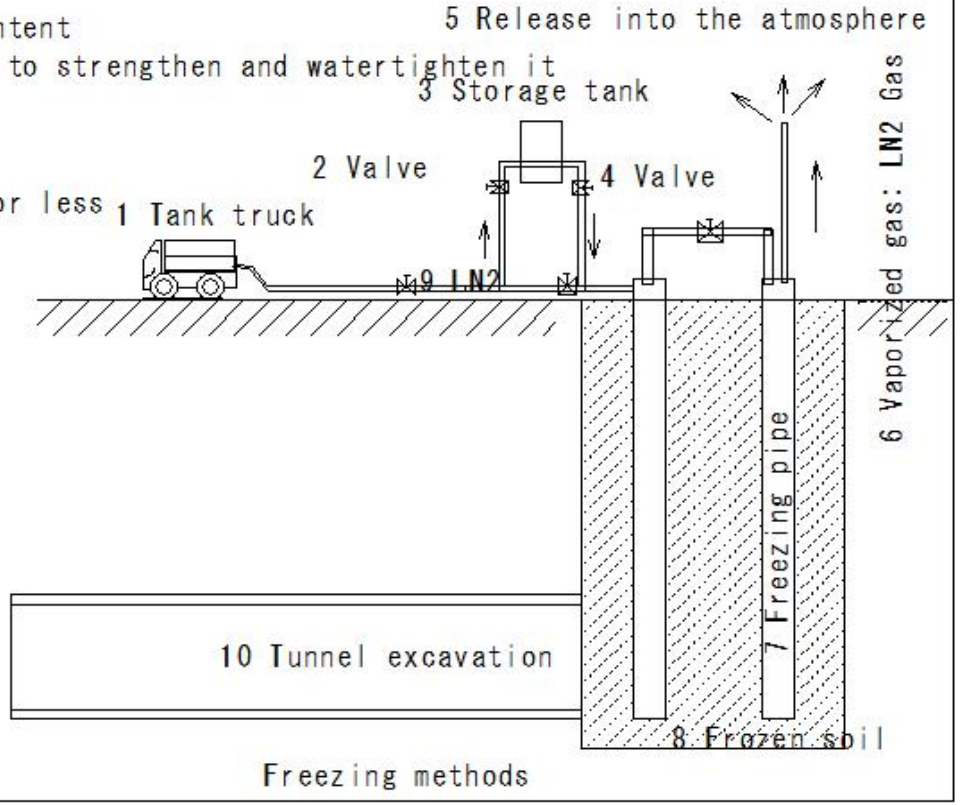
Artificially frozen soil 5% or less

③ Strength of frozen soil

Clay < sand < gravel (4.9-15.7N/mm2)

④ Freezing temperature

-20 to -30℃



Freezing methods

(T185)Tunnel(Freezing methods)

(T185)Tunnel(Freezing methods)

Tunnels

Special methods

Freezing methods

○Effective locations

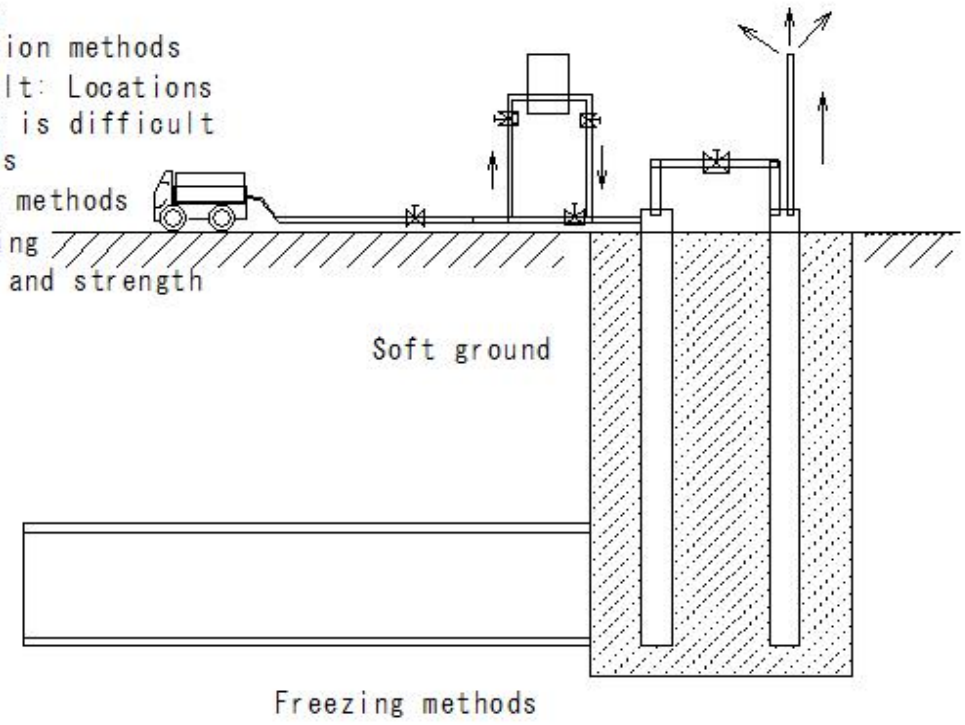
①Soft ground: Locations where excavation is not possible even with chemical injection methods

②Locations where pile driving is difficult: Locations where Underpinning of structures is difficult

③Locations where the groundwater level is difficult to lower even with dehydration methods

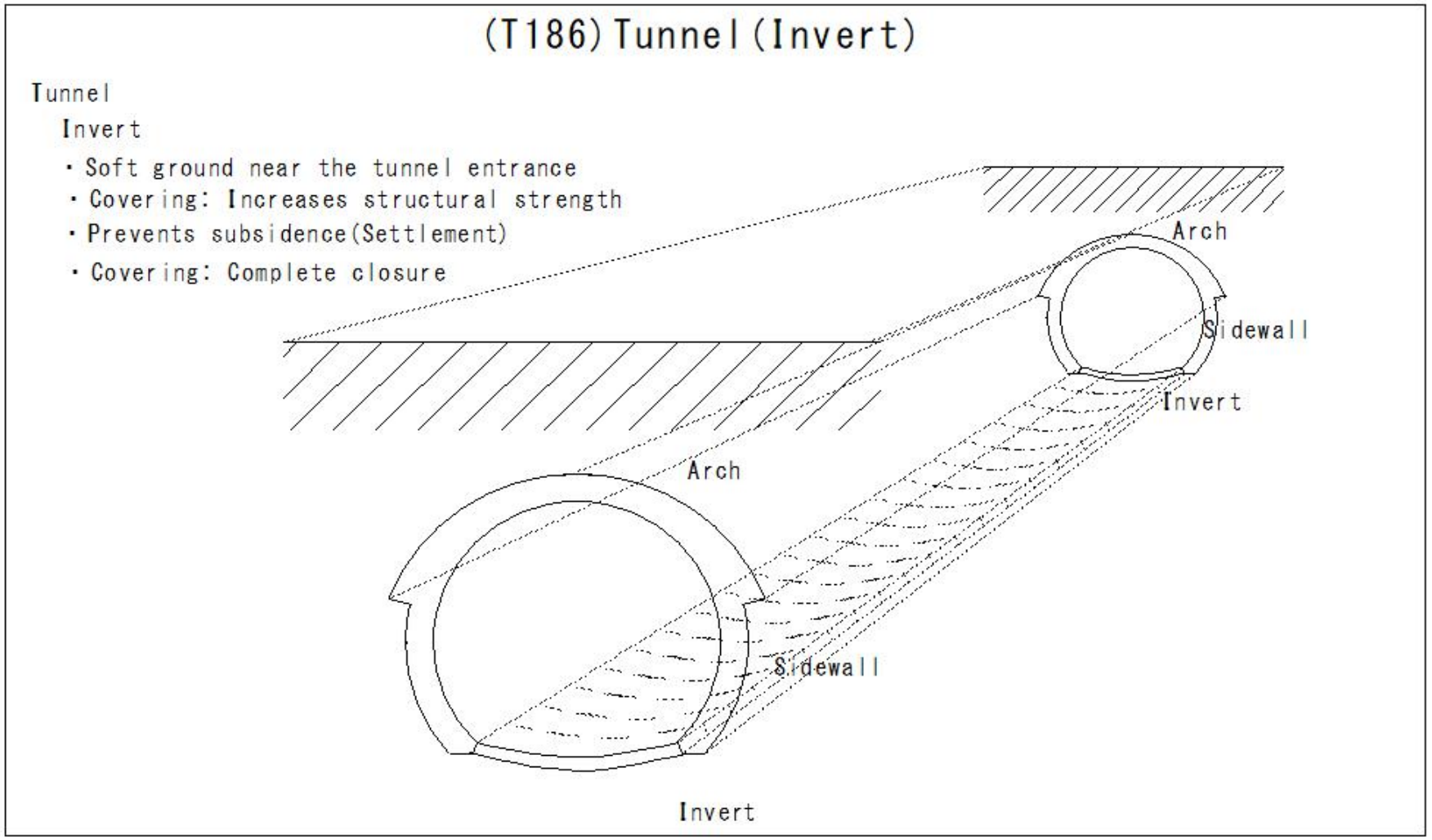
Caution: Volume expansion during freezing

Pay attention to changes in ice volume and strength



Freezing methods

(T186)Tunnel(Invert)



(T187)Tunnel(Return packing)

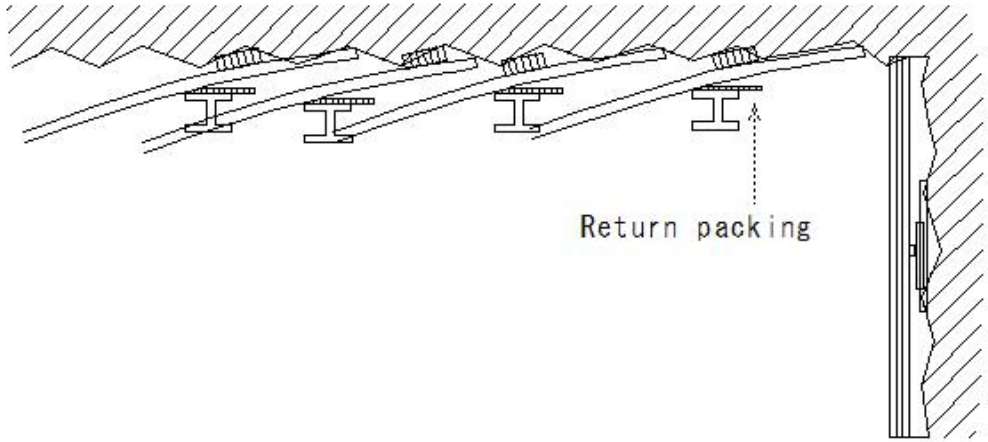
(T187)Tunnel(Return packing)

Tunnels

Return packing

Prevents loosening of sheet piles

Prevents twisting of supports(timbering)



(T188)Tunnel(Payment line)

(T188)Tunnel(Payment line)

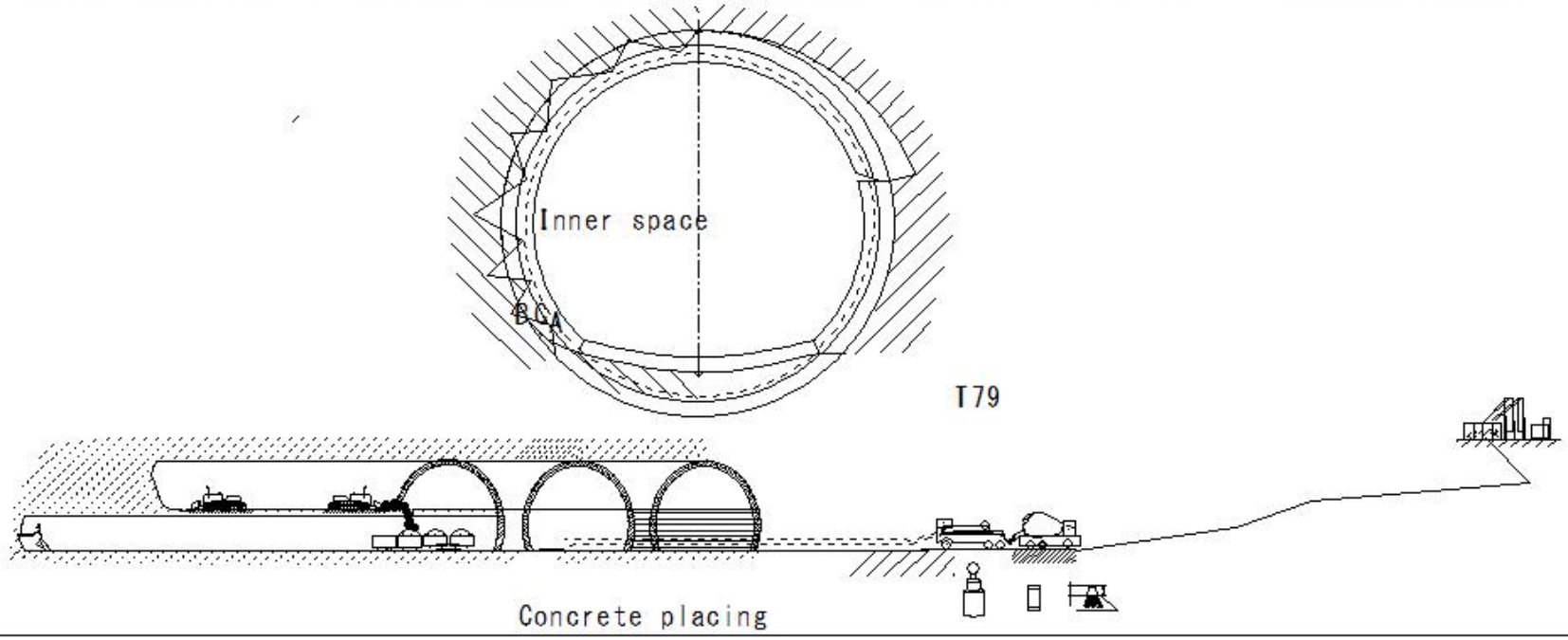
Tunnel

Payment line

A: Minimum coverings (lining) thickness line: Inside the edge, completely filled with concrete, nothing else should be in it

B: Payment line: Payment subject

C: Design coverings (lining) thickness line: Hard rock and steel may be in it, wood: not allowed



(T189)Tunnel(bracing)

(T189)Tunnel(bracing)

Tunnel

bracing

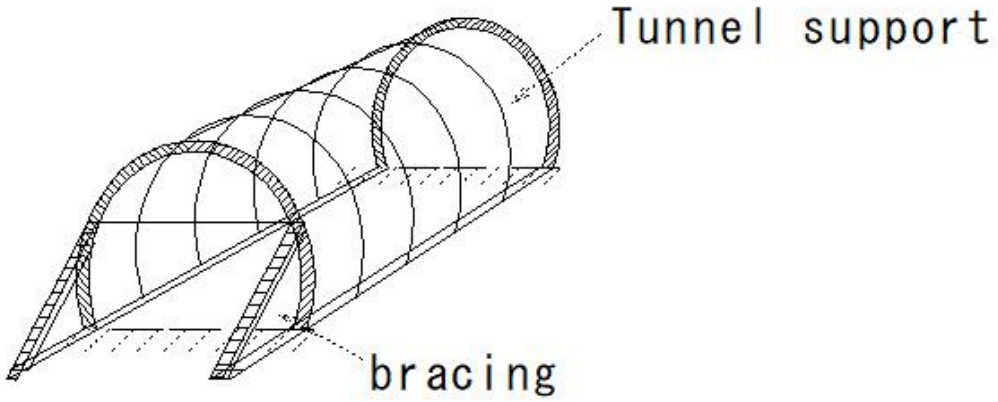
Collapse prevention

Support

facing

Cutting edge (facing)

Entrance



(T190)Tunnel(Upper half section advanced construction method)

(T190)Tunnel(Upper half section advanced construction method)

Tunnel

Upper half section advanced construction method

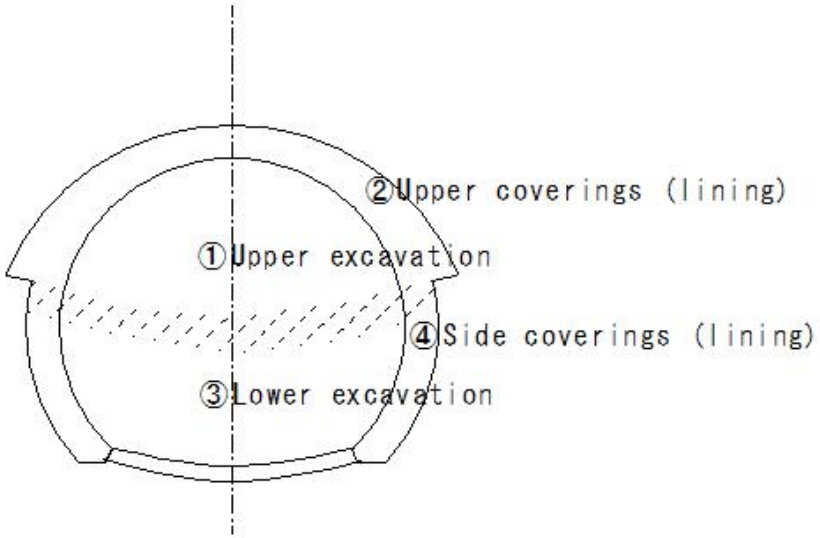
・Geological conditions - Good

・Low spring water volume - Tunnel

Upper half excavation

Upper coverings (lining)

Lower construction



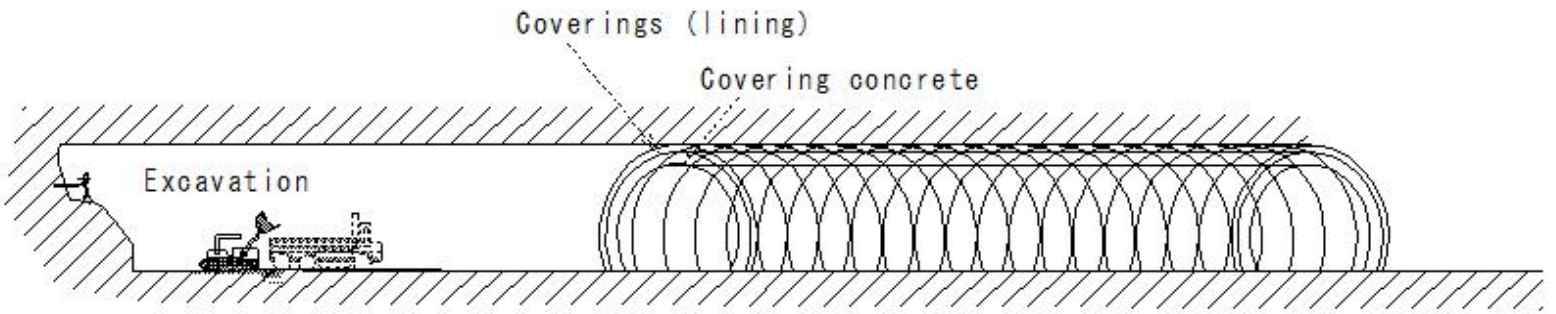
(T191)Tunnel(Full-section advanced construction method)

(T191)Tunnel(Full-section advanced construction method)

Tunnels

Full-section advanced construction method

- Simultaneous excavation of all sections
- Rock foundation - Good
- Used for small and medium sections
- Excavation speed - Fast



Full-section excavation work

T29

(T192)Tunnel(Side wall heading(Pilot) tunnel excavation work advanced upper half section method)

(T192)Tunnel(Side wall heading(Pilot) tunnel excavation work advanced upper half section method)

Tunnel

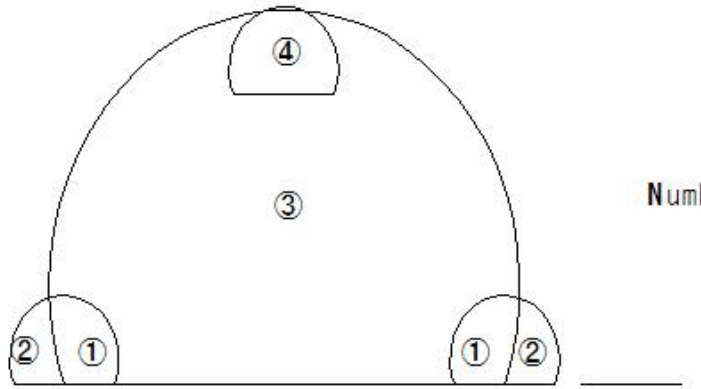
Side wall heading(Pilot) tunnel excavation work advanced upper half section method
Side wall heading(guiding) work advanced

Concrete placing

Upper half section -Excavation cover work

Ground - poor

Reverse arch:Lack of bearing capacity



Number: Construction sequence

Side wall heading(Pilot) tunnel excavation work advanced upper half section method

T30

(T193)Tunnel(Enlarged sidewall concrete)

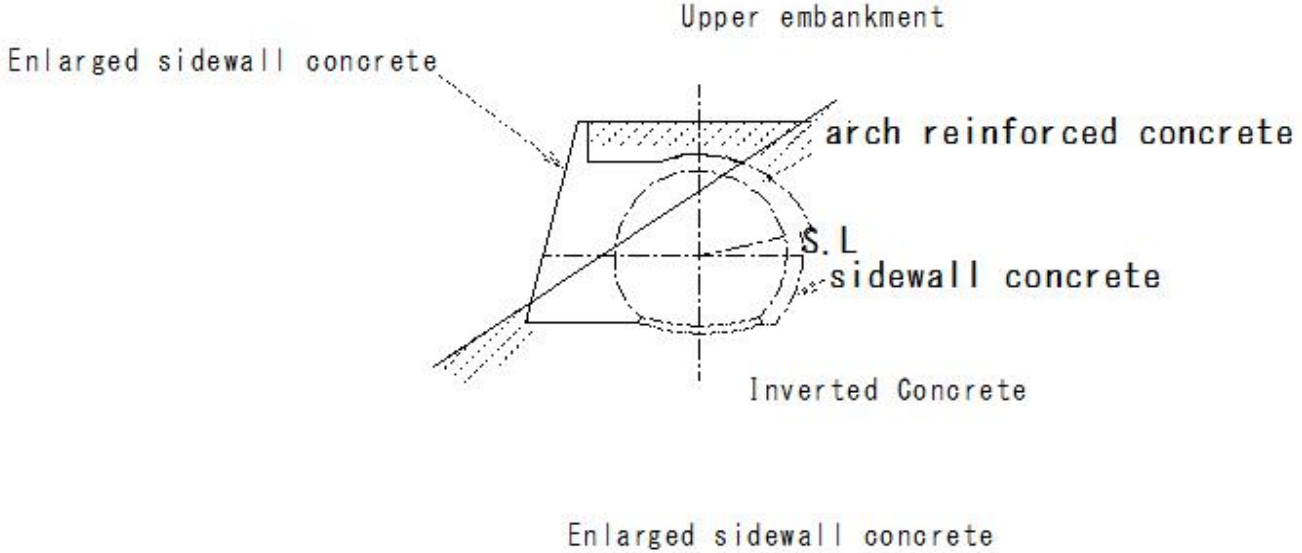
(T193)Tunnel(Enlarged sidewall concrete)

Tunnel

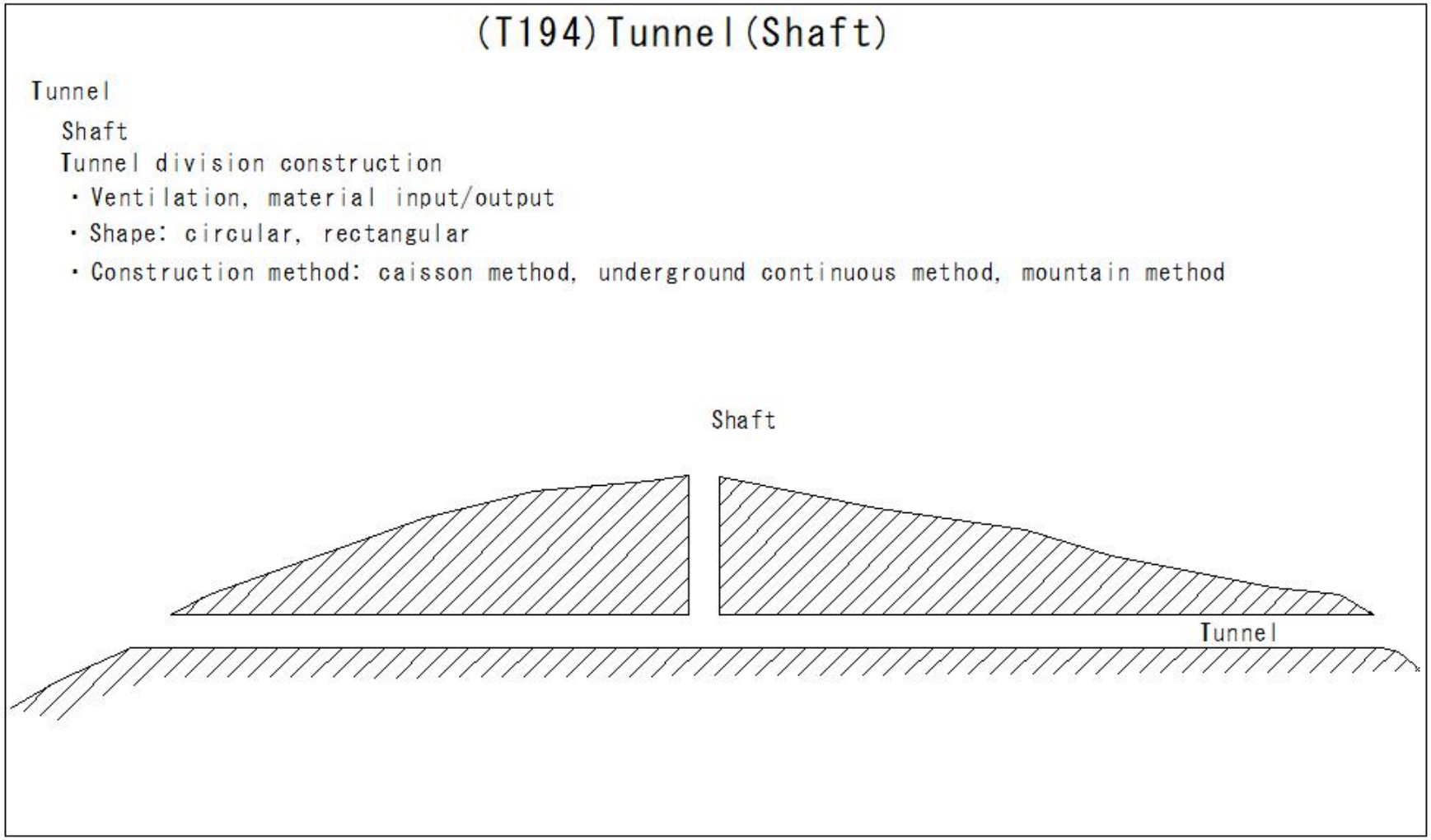
Enlarged sidewall concrete

Near the tunnel entrance where there is a little soil covering

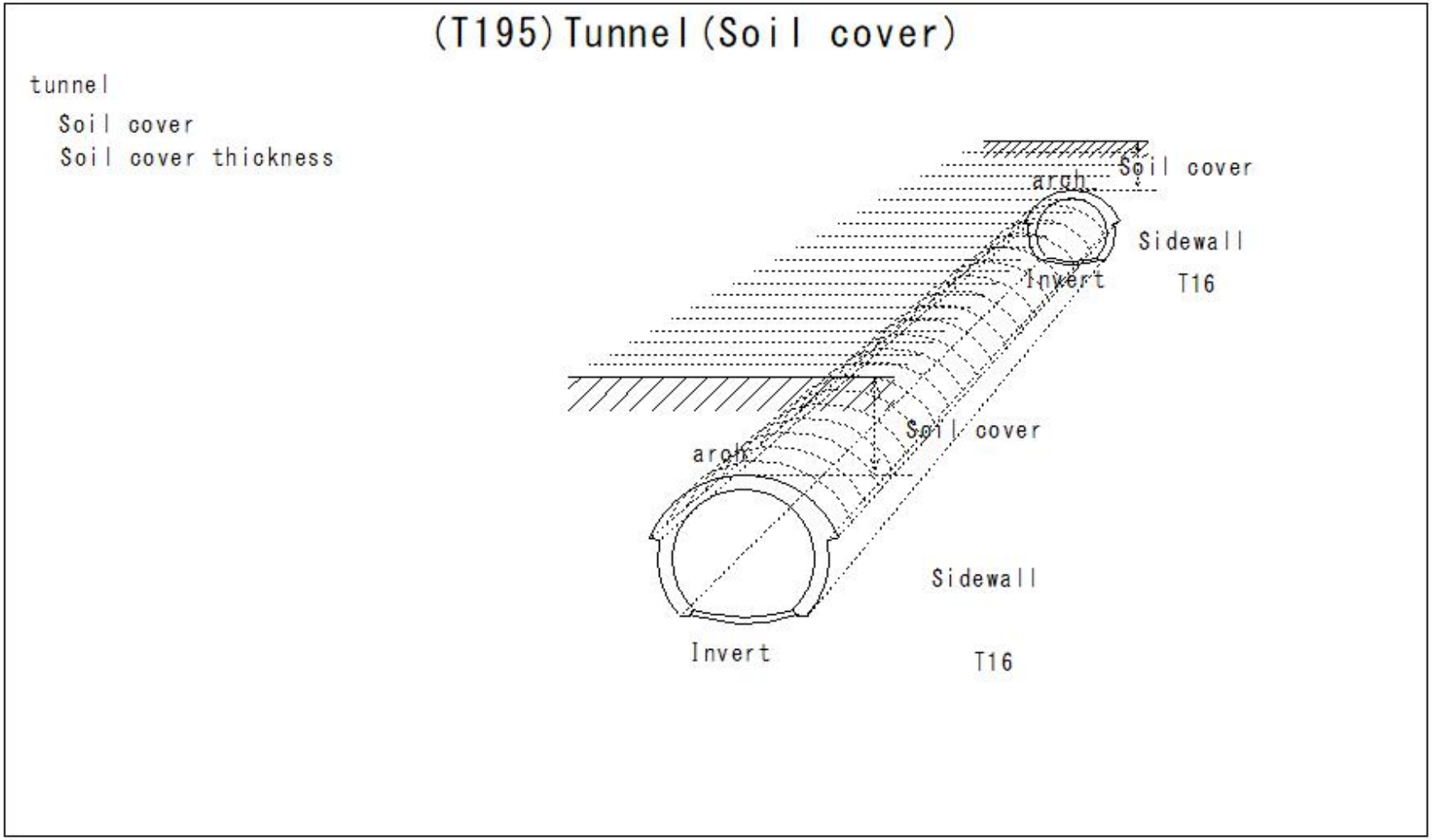
Areas where side walls are prone to deformation due to uneven pressure



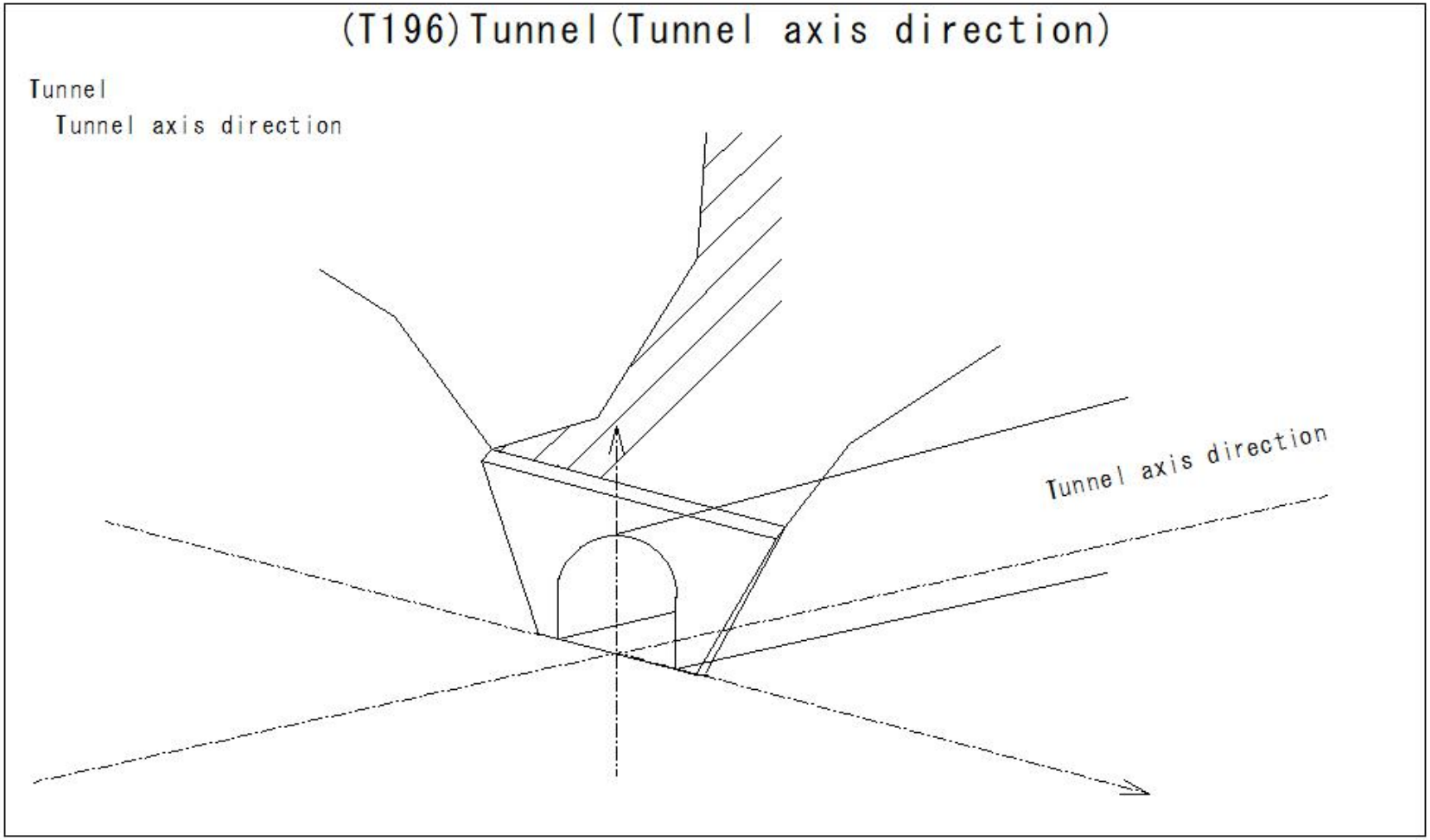
(T194)Tunnel(Shaft)



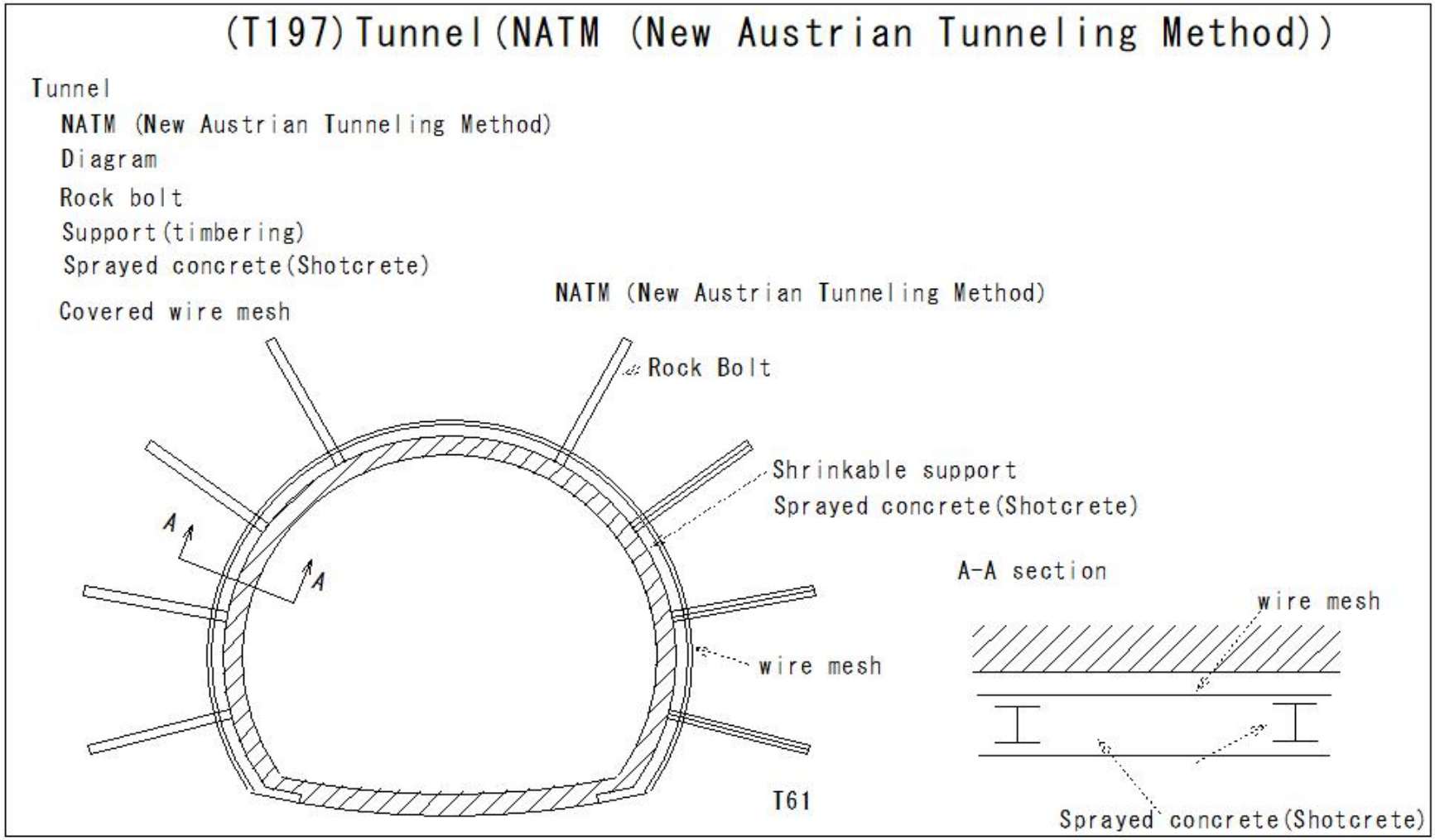
(T195)Tunnel(Soil cover)



(T196)Tunnel(Tunnel axis direction)



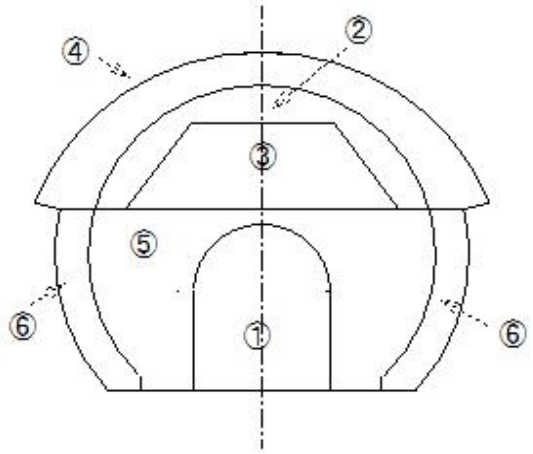
(T197)Tunnel(NATM (New Austrian Tunneling Method))



(T198)Tunnel(Bottom heading(pilot) tunnel advance ring cut method)

(T198)Tunnel(Bottom heading(pilot) tunnel advance ring cut method)

Tunnel
Ring cut method



Number: Construction sequence

Bottom heading(pilot) tunnel advance
ring cut method

Ring cut method

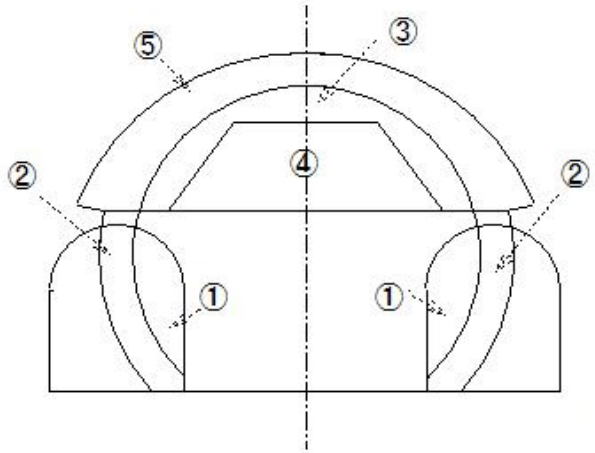
T34

(T199)Tunnel(Sidewall heading tunnel advanced ring cut construction method)

(T199)Tunnel(Sidewall heading tunnel advanced ring cut construction method)

Tunnel

Ring cut method



Number: Construction sequence

Sidewall heading tunnel advanced
ring cut construction method

(T200)Tunnel(Full cross-section method)

(T200)Tunnel(Full cross-section method)

Tunnels

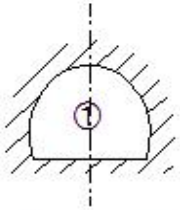
Steel arch support(timbering)

Mountain tunnel construction method

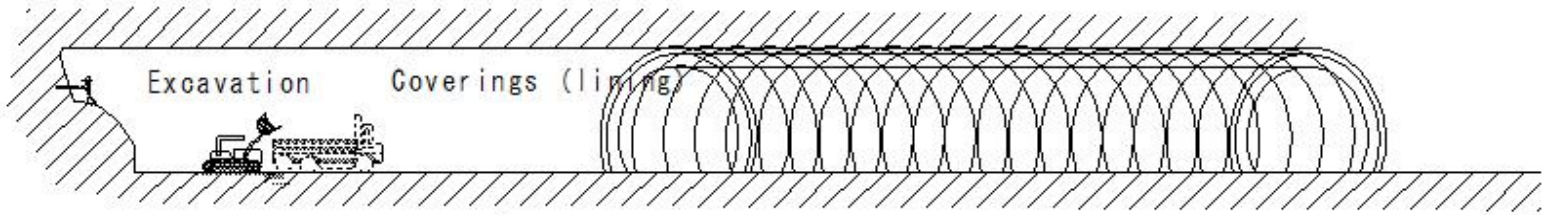
①Full cross-section method

Coverings (lining) concrete

support(timbering)



a: Full section method T35



①Full-section excavation method T29

(T201)Tunnel(Upper half section ring excavation method)

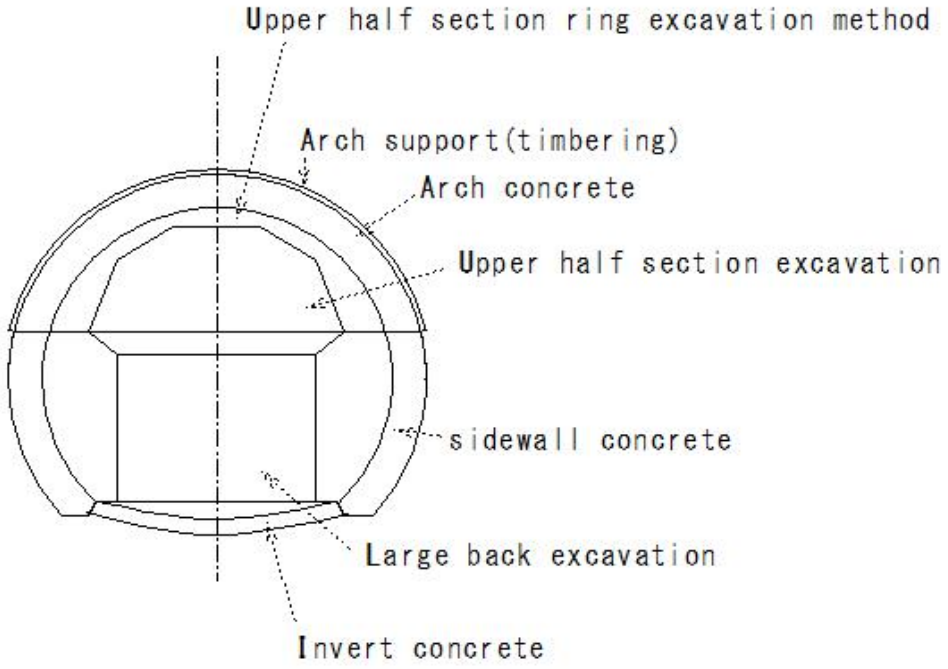
(T201)Tunnel(Upper half section ring excavation method)

Tunnels

Steel arch support(timbering)

Mountain tunnel construction method

②Upper half section ring excavation method



②Upper half section ring excavation method

(T202)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)

(T202)Tunnel(Bottom-heading tunnel advanced upper half section excavation method)

Tunnels

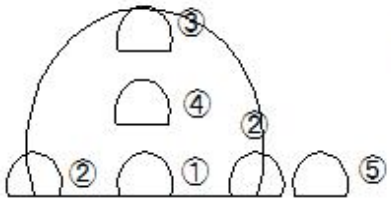
Steel arch support

Mountain tunnel construction methods

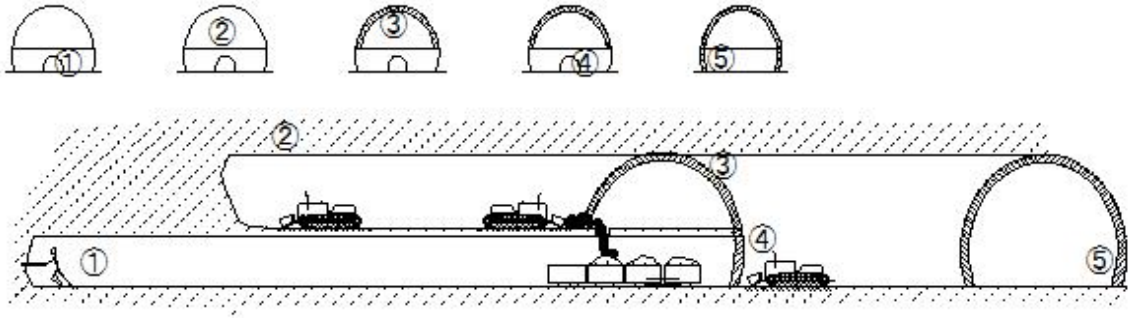
Bottom-heading tunnel advanced upper half section excavation method

Types of heading(pilot)

① Bottom heading(pilot) - Center bottom



T30



T31

(T203)Tunnel(Side wall guide shaft advanced upper half section construction method)

(T203)Tunnel(Side wall guide shaft advanced upper half section construction method)

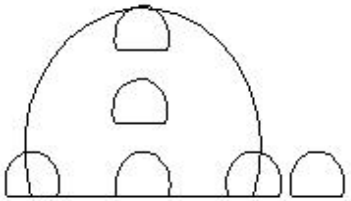
Tunnels

Steel arch support

Mountain tunnel construction methods

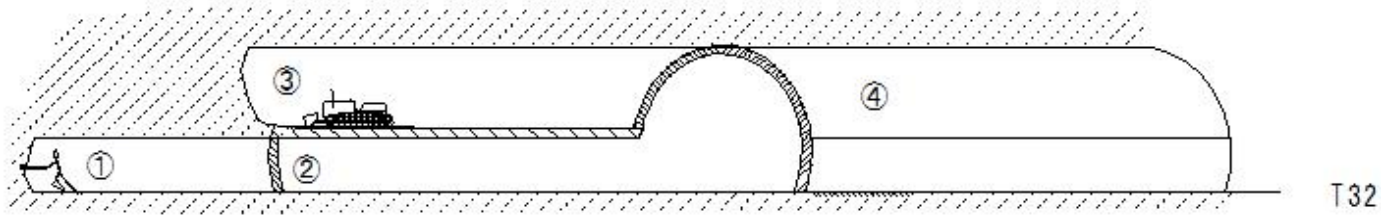
Side wall guide shaft advanced upper half section construction method

Types of heading(pilot)



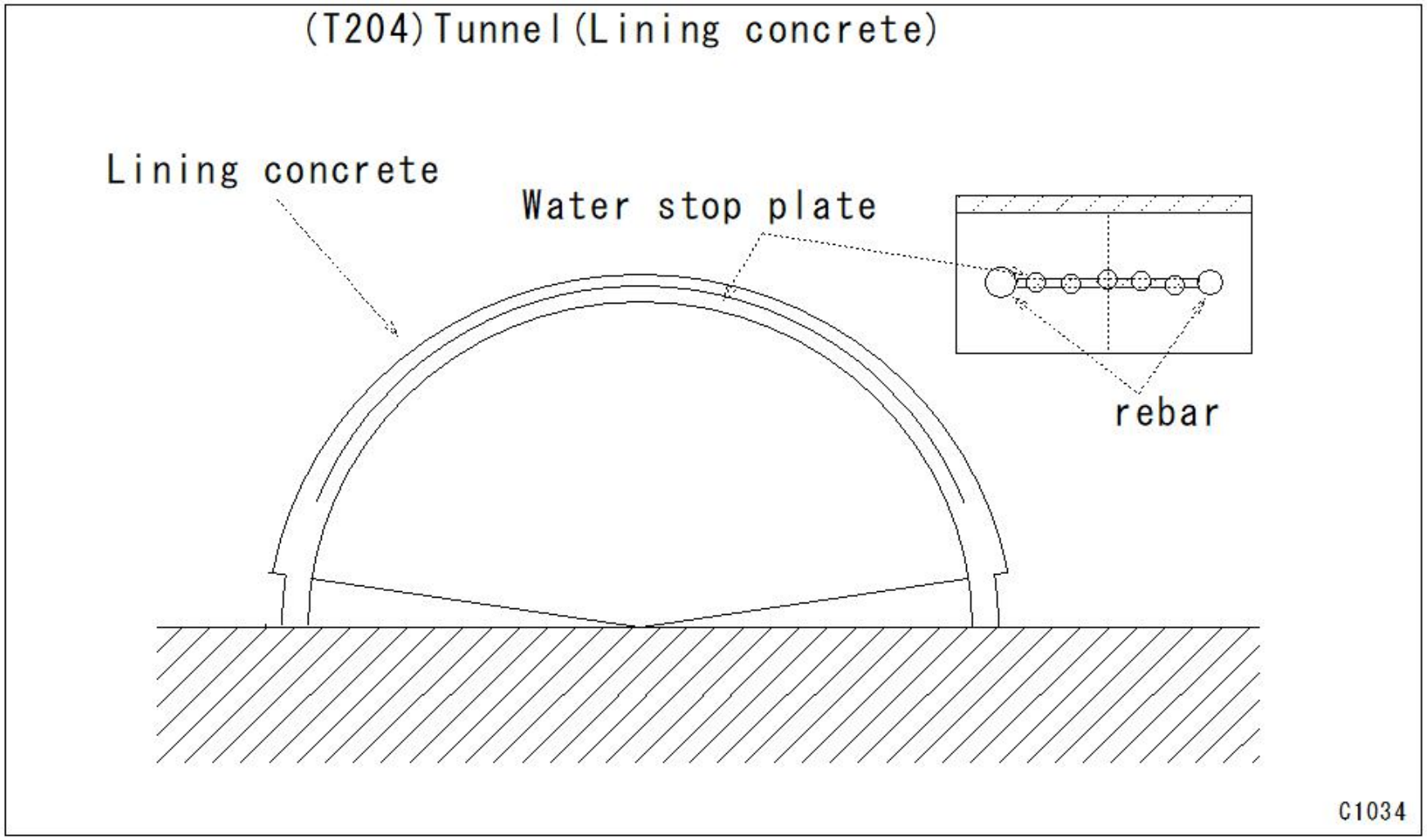
Side wall heading(pilot) - Both sides of the bottom

T30



T32

(T204)Tunnel(Lining concrete)



(T205)Tunnel(payment lines)

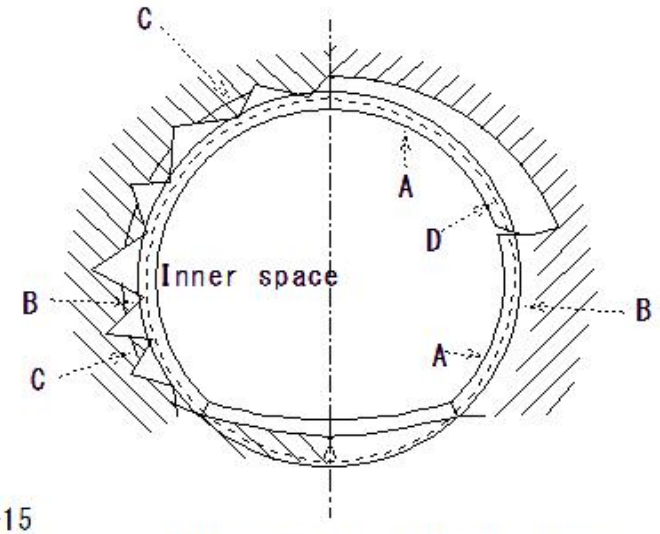
(T205)Tunnel(payment lines)

Tunnels

Examples of payment lines

A: Coverings (lining) work finish line
B: Design Coverings (lining) thickness line: Design excavation line
C: Excavation payment line
D: Minimum winding thickness line

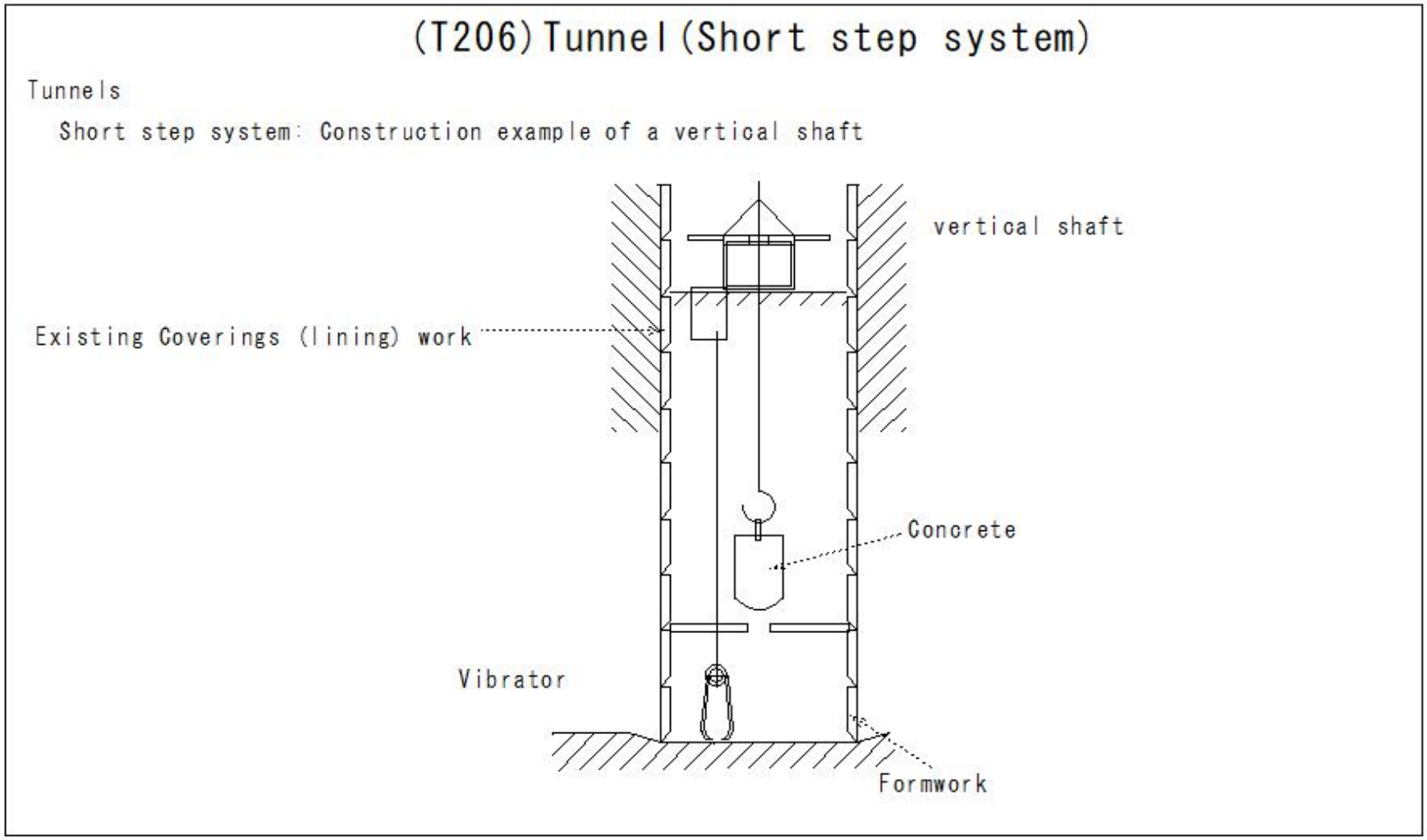
Backfill injection is performed when ground conditions are poor



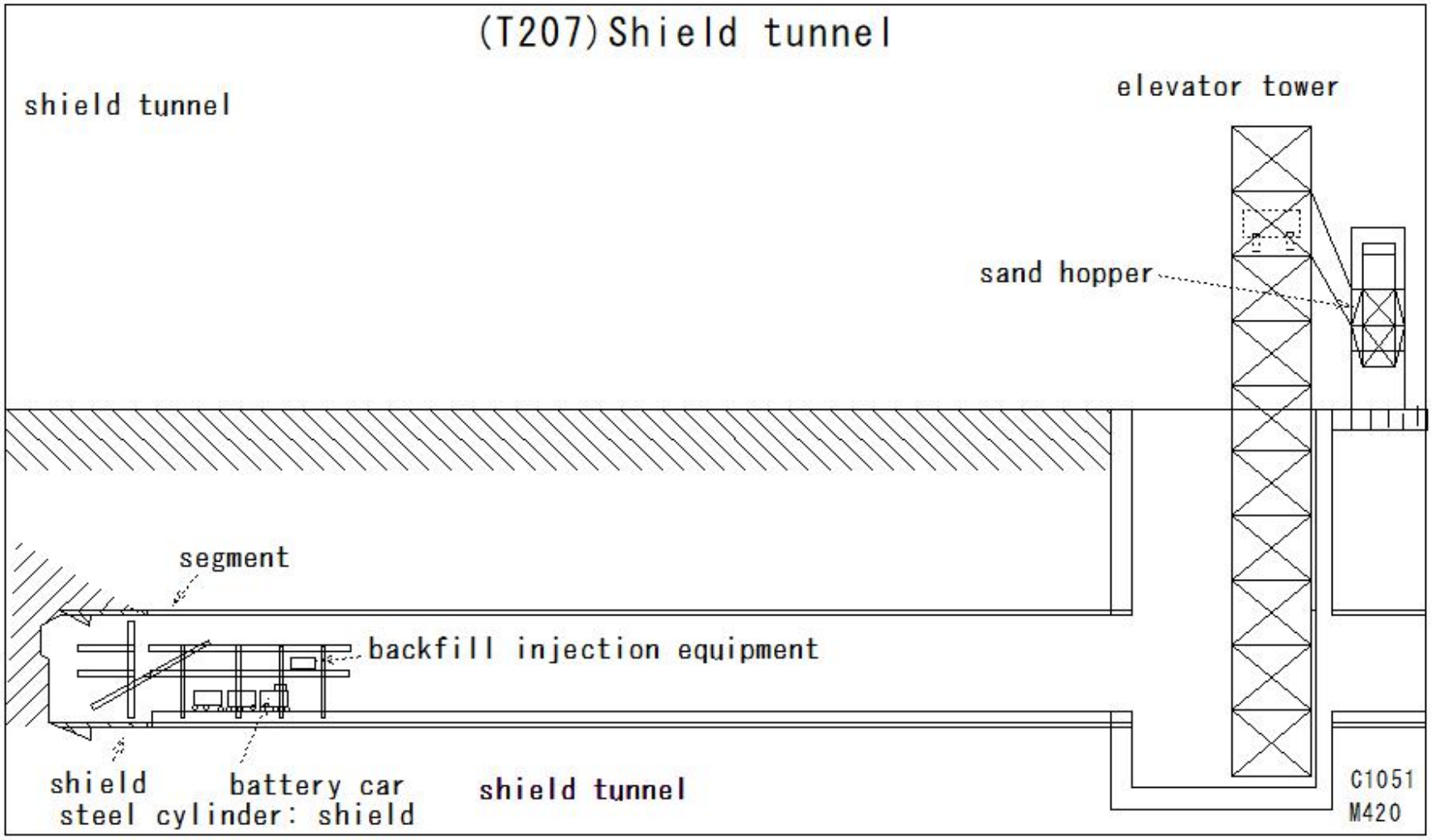
Type of work: Payment line

Type of work: Payment line
Excavation: Design excavation line +15-20
Coverings (lining) work: Design winding thickness line +10-15

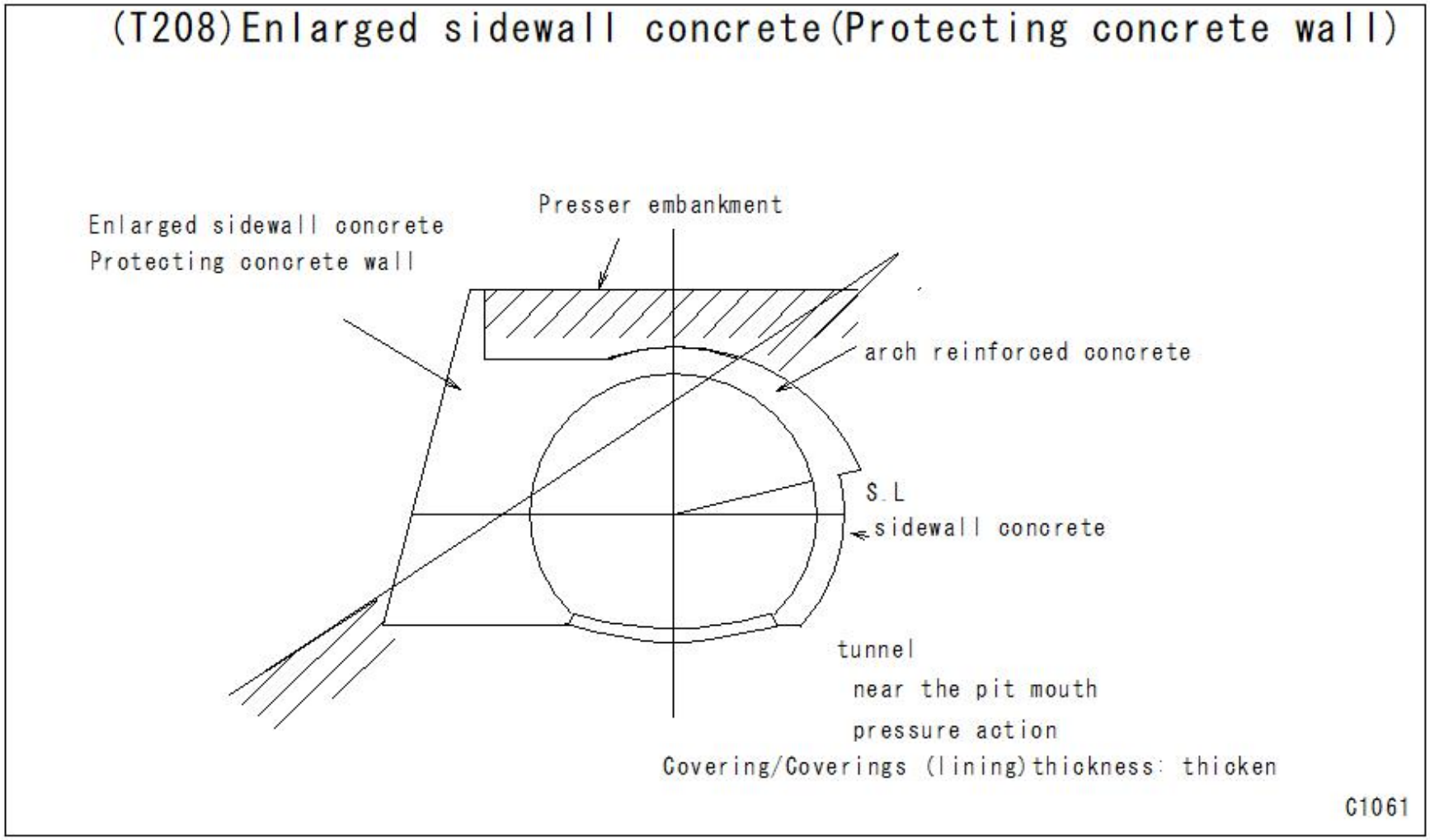
(T206)Tunnel(Short step system)



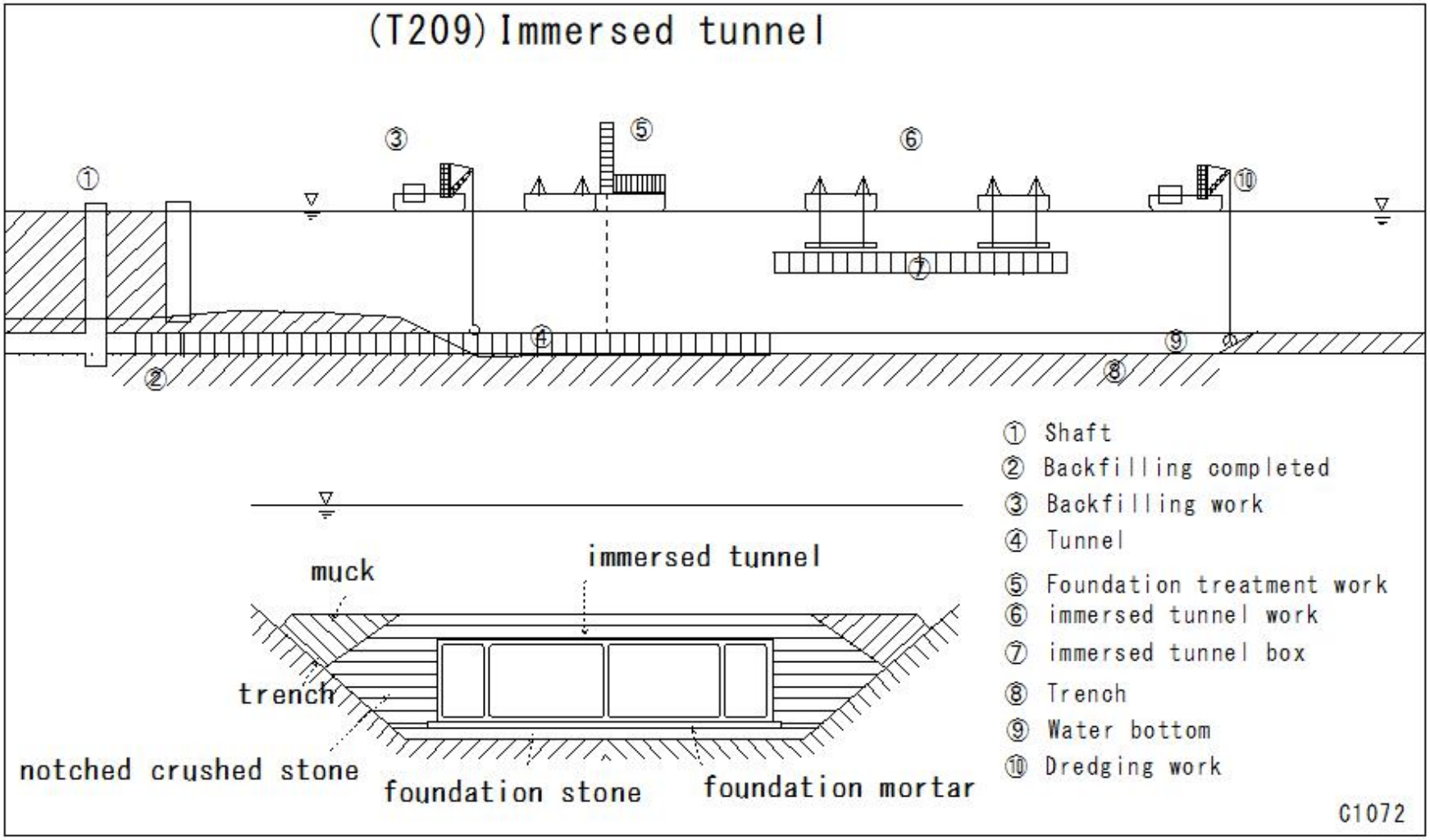
(T207)Shield tunnel



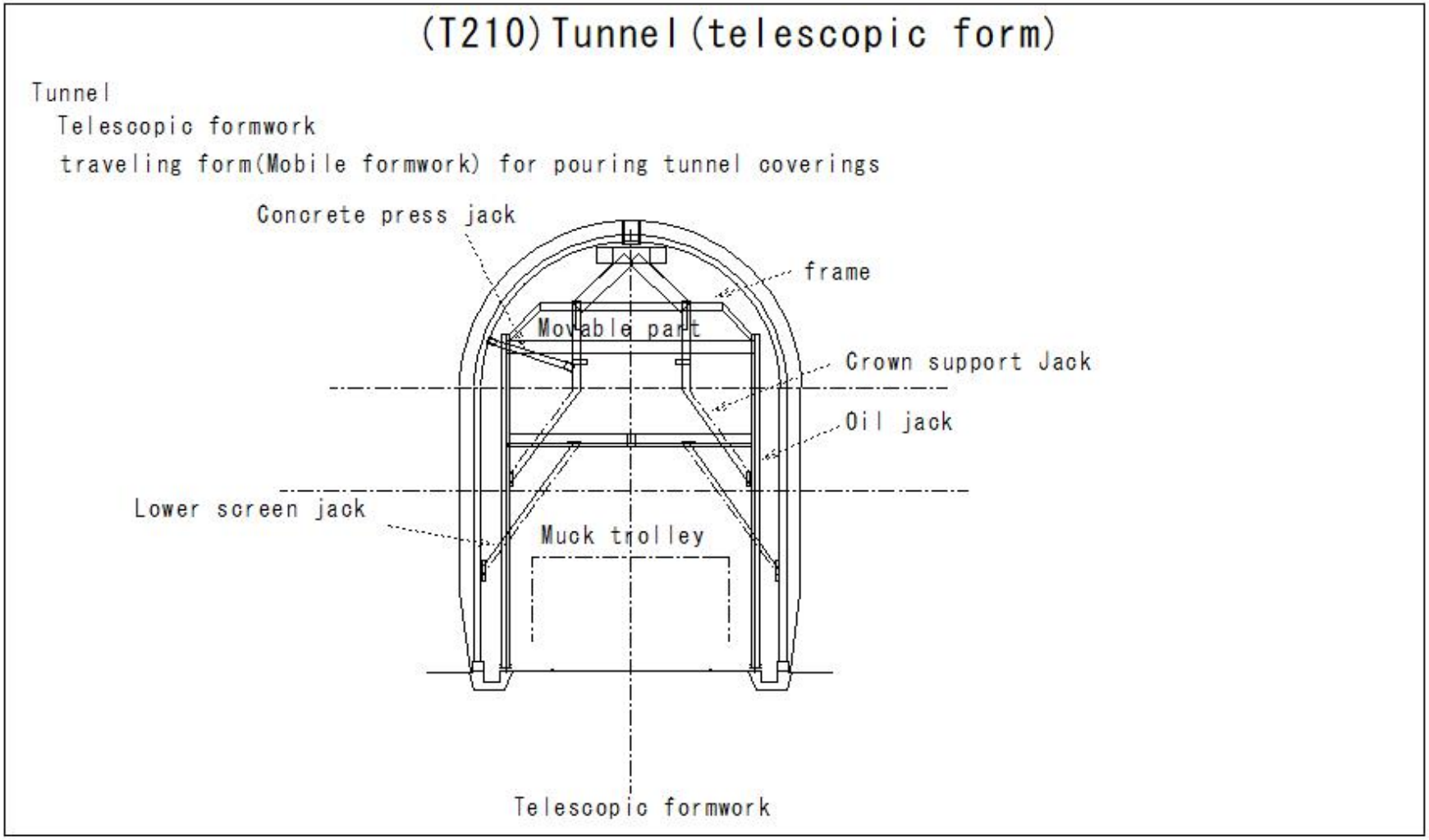
(T208)Enlarged sidewall concrete(Protecting concrete wall)



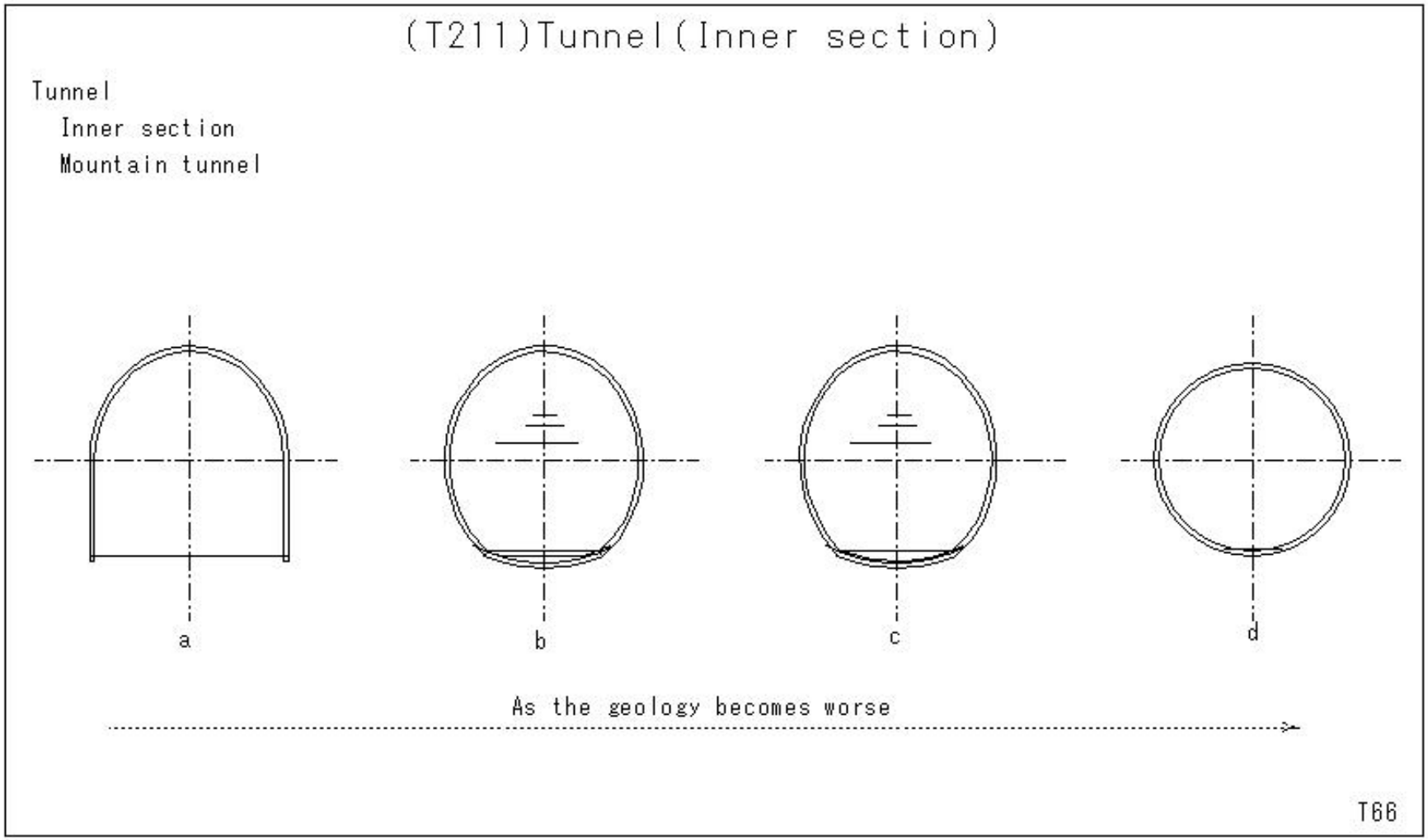
(T209)Immersed tunnel



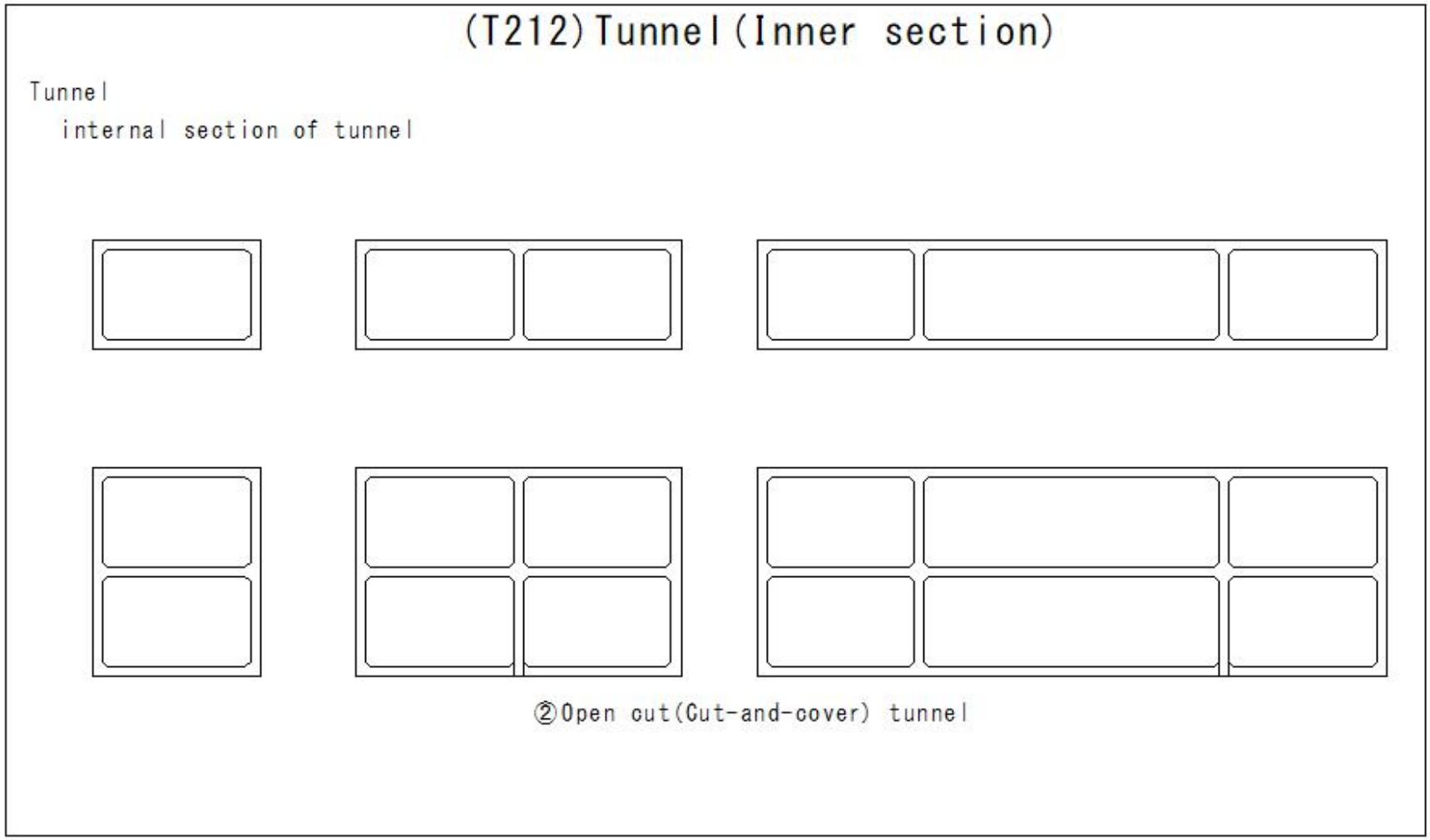
(T210)Tunnel(telescopic form)



(T211)Tunnel(Inner section)



(T212)Tunnel(Inner section)



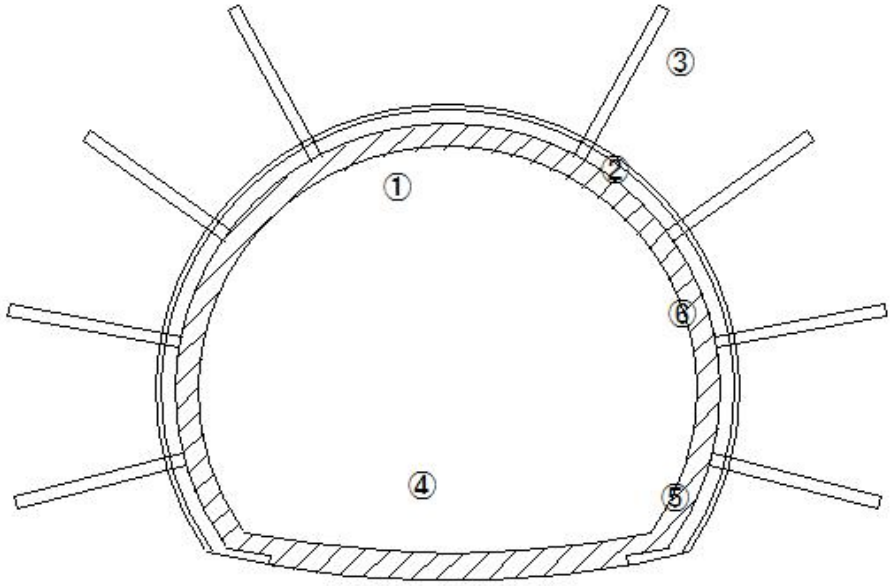
(T213)Tunnel(NATM（New Austrian Tunneling Method）)

(T213)Tunnel(NATM (New Austrian Tunneling Method))

Tunnels

NATM (New Austrian Tunneling Method)

Bench cut construction method

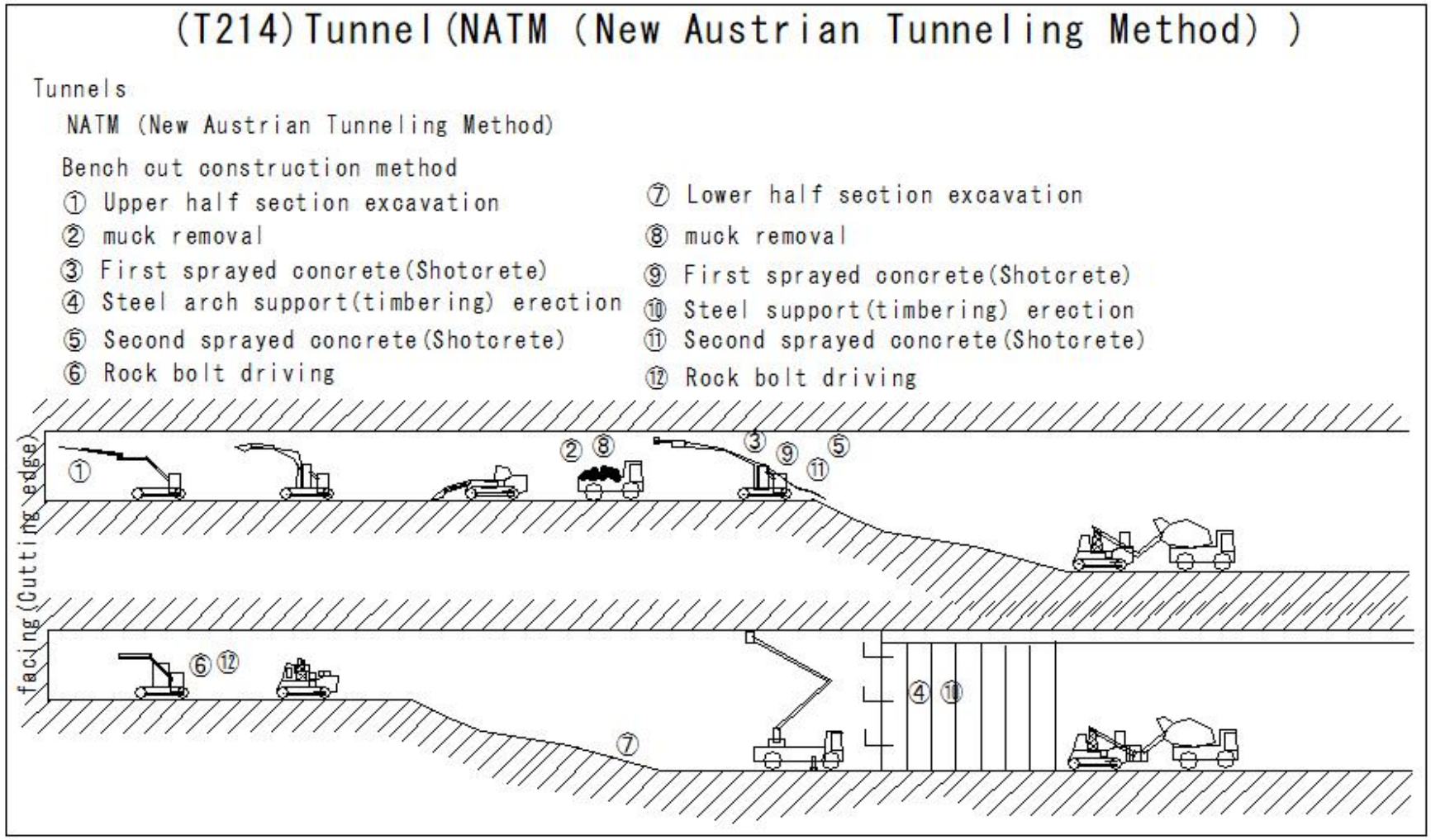


① Upper excavation
② Sprayed concrete
③ Rock bolts
④ Lower excavation
⑤ Sprayed concrete
⑥ Concrete covering

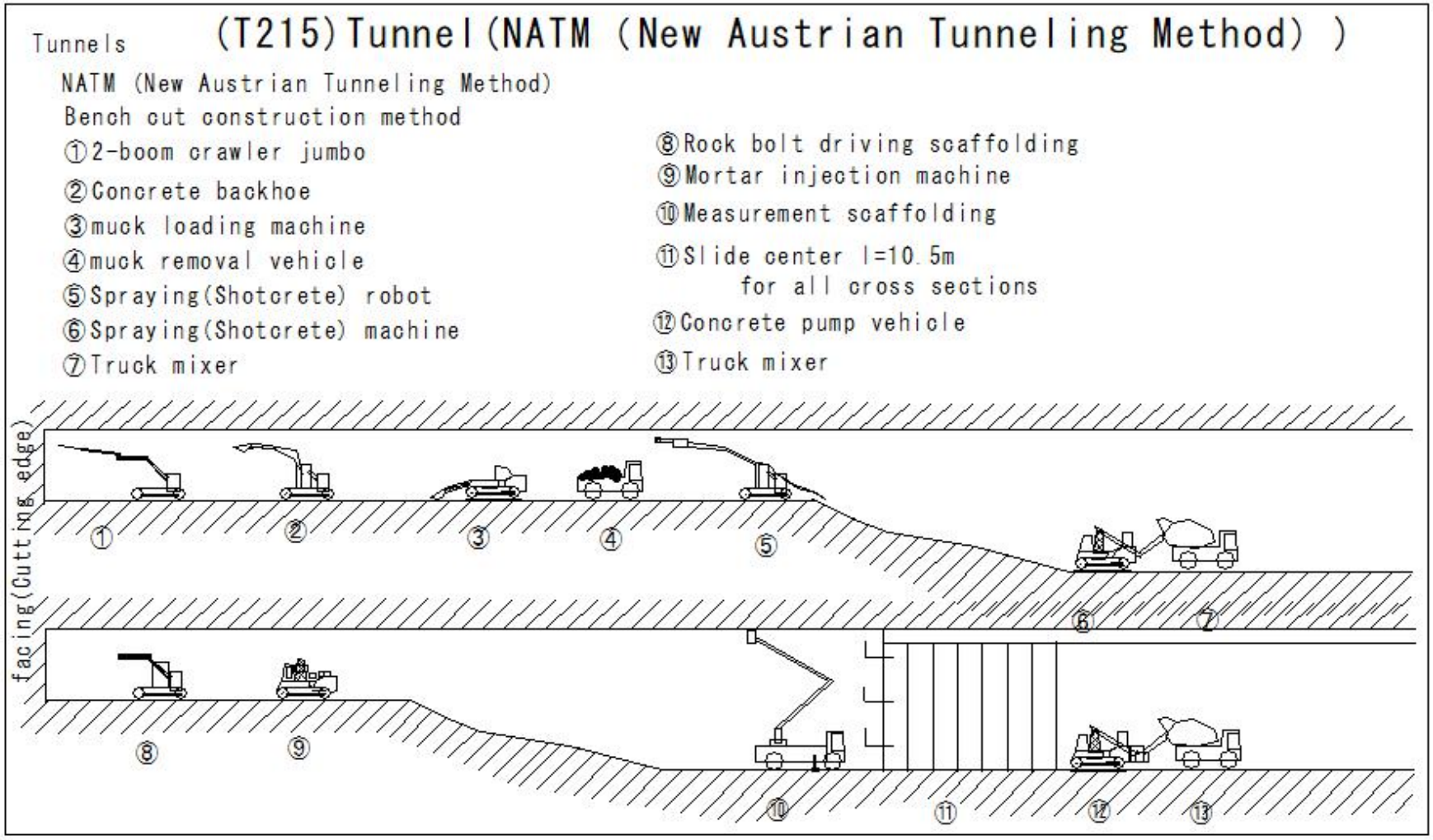
NATM (New Austrian Tunneling Method)

T61
T62

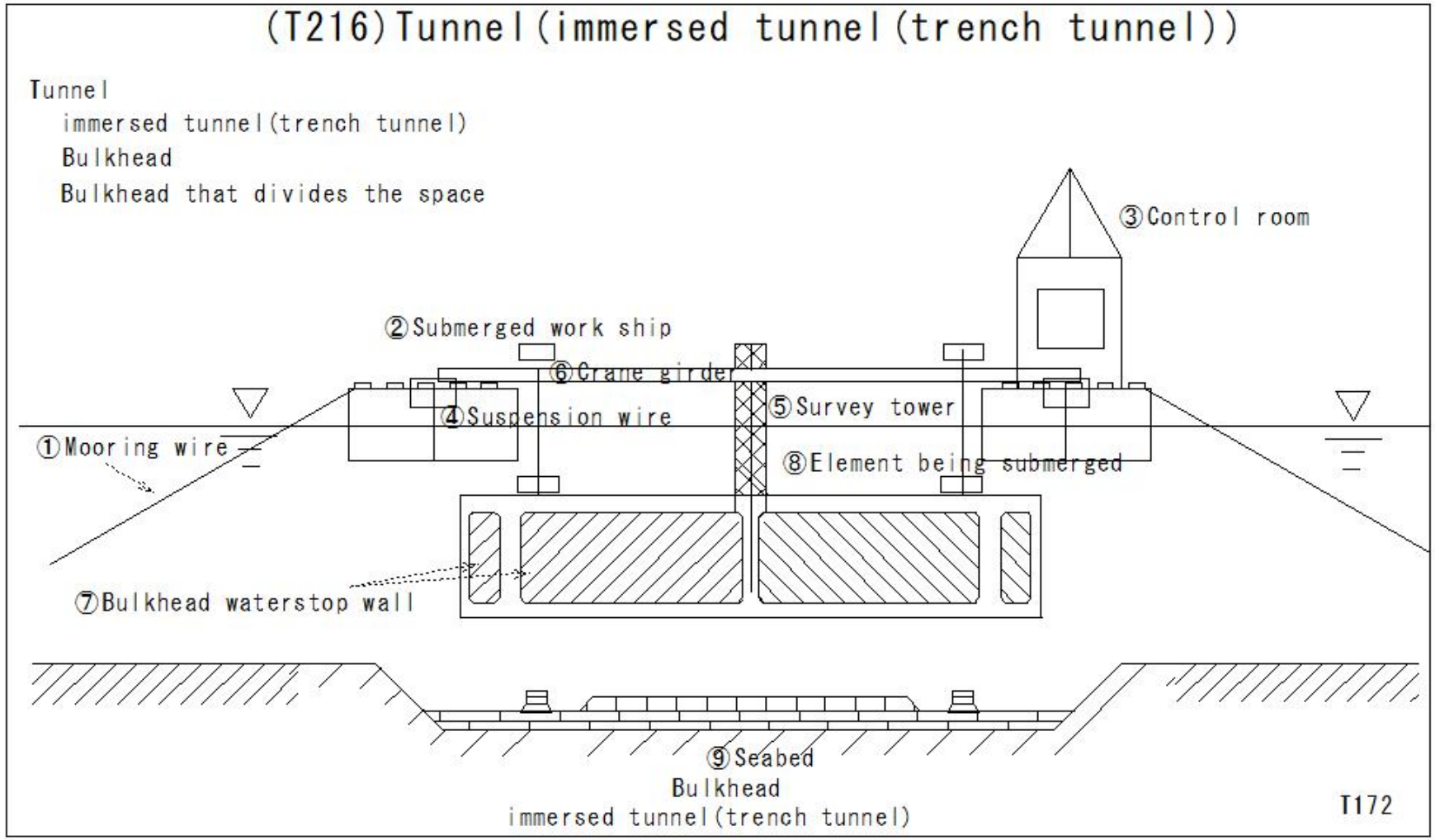
(T214)Tunnel(NATM（New Austrian Tunneling Method）)



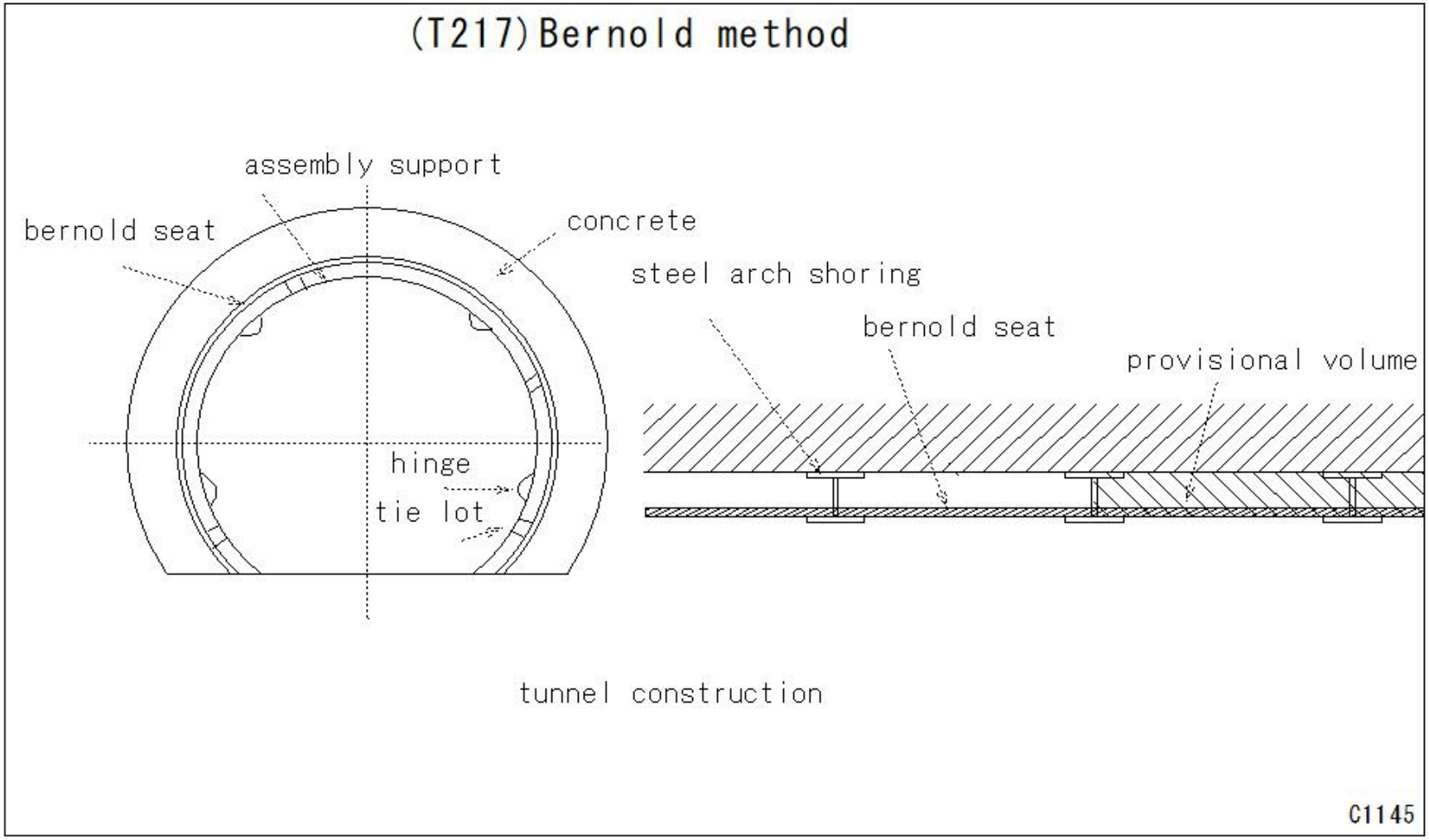
(T215)Tunnel(NATM（New Austrian Tunneling Method）)



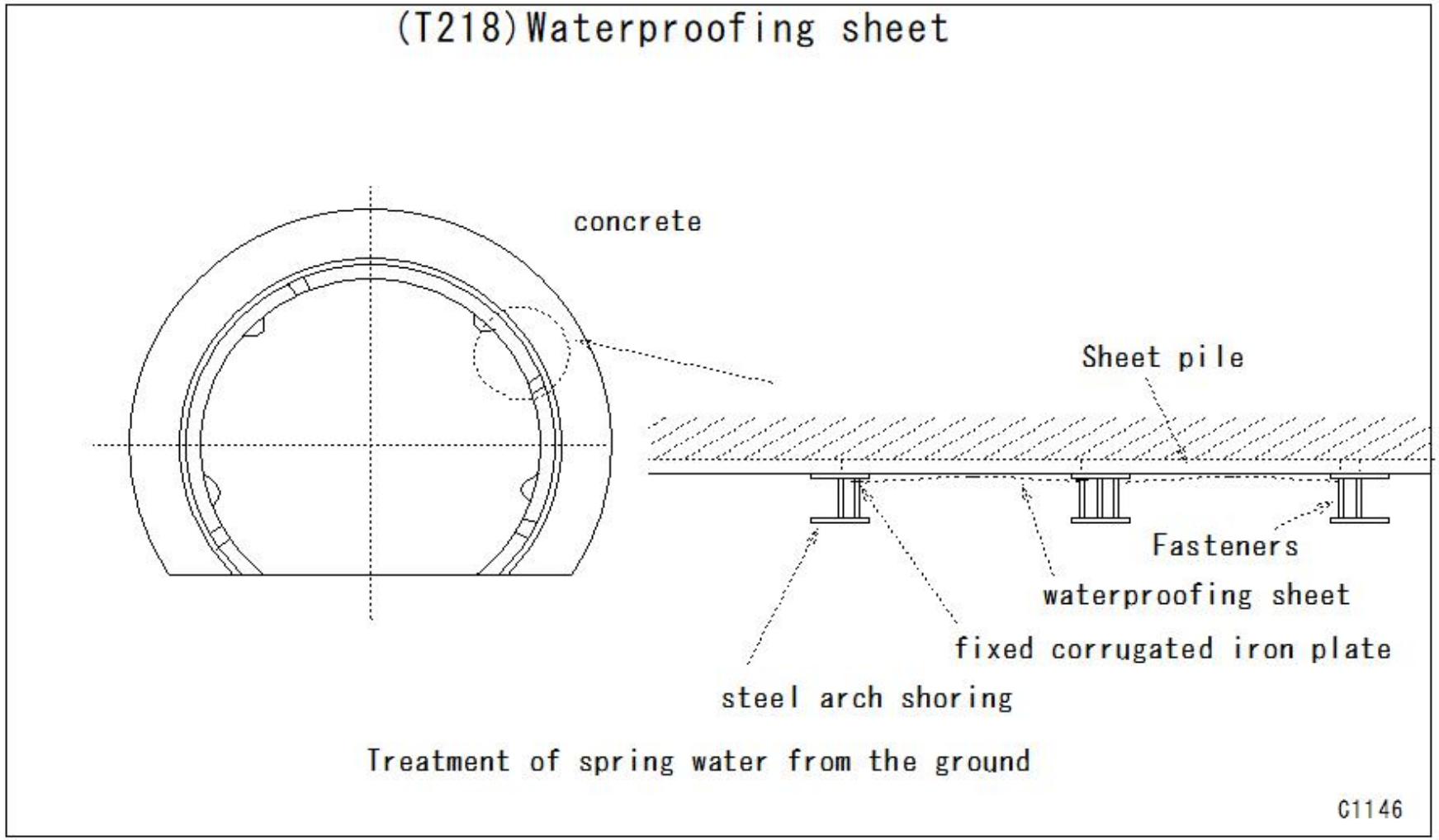
(T216)Tunnel(immersed tunnel(trench tunnel))



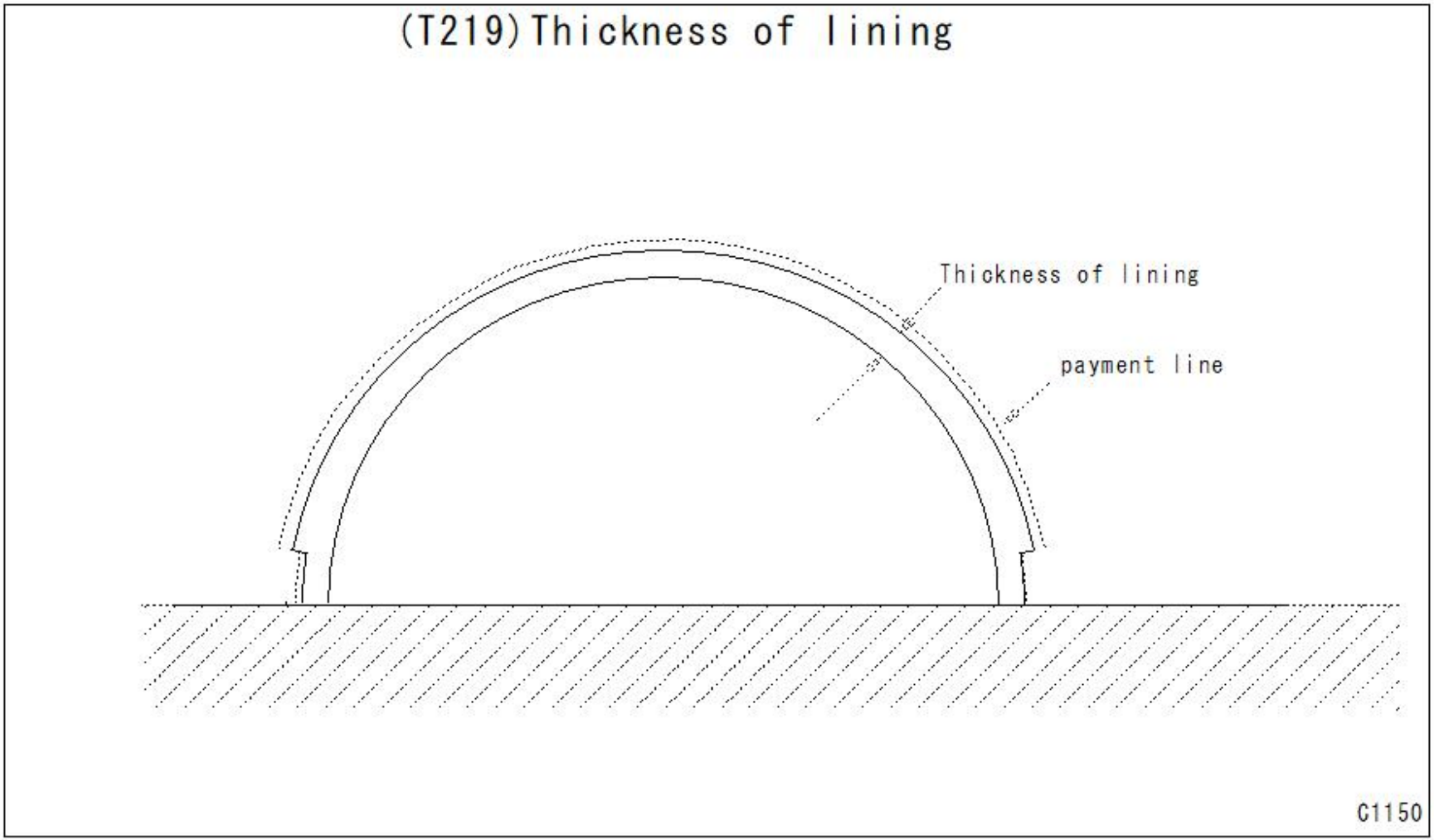
(T217)Bernold method



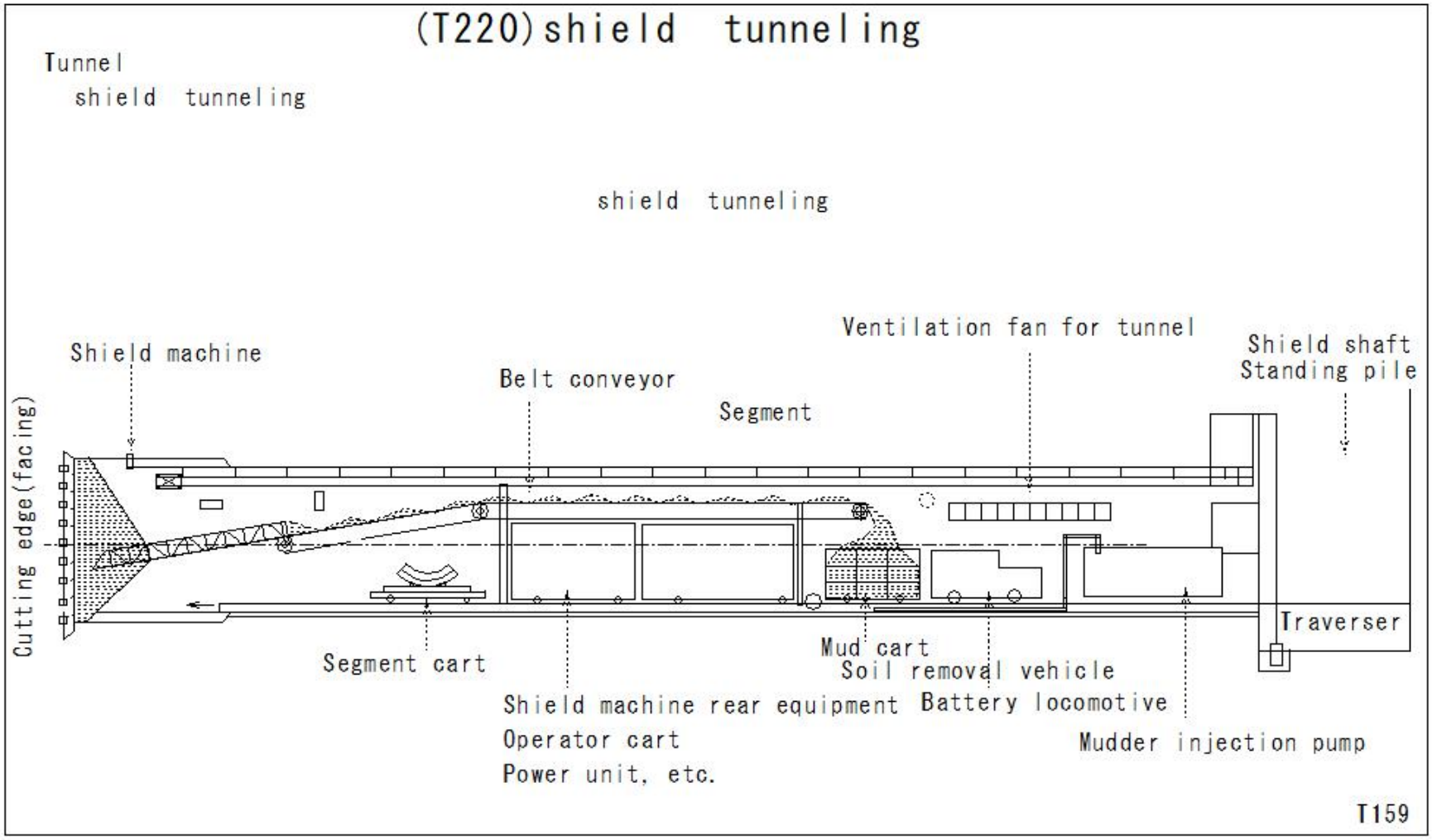
(T218)Waterproofing sheet



(T219)Thickness of lining



(T220)shield tunneling



(T221)support(timbering)

(T221)support(timbering)

Tunnel

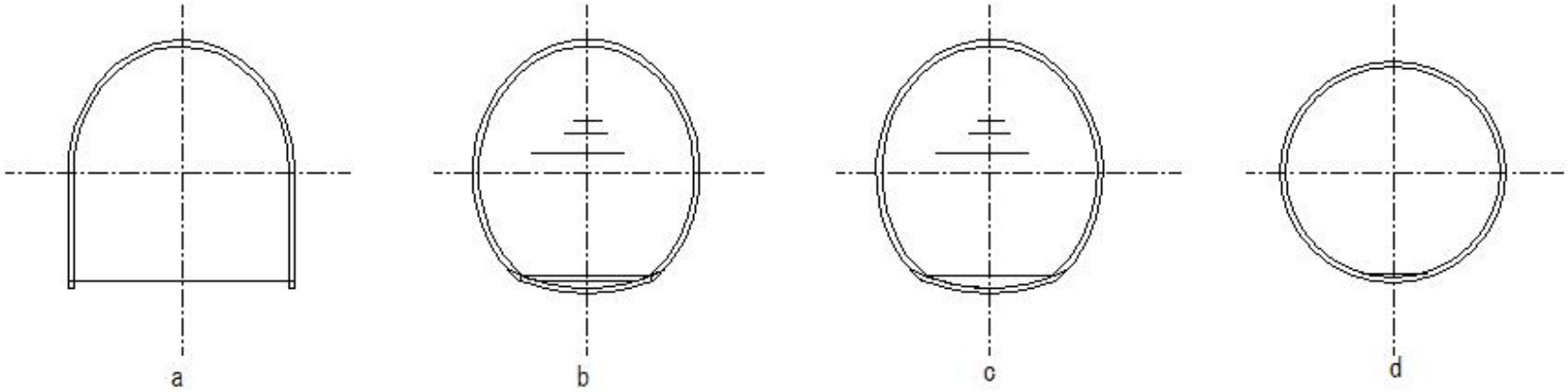
support(timbering)

Shape of steel arch support(timbering) for tunnel

①Temporary structure

②Tunnel support(timbering)

③Earth retaining support(timbering)



Shape of steel arch support(timbering) for tunnel

T66

(T222)inclined adit :inclined shaft

(T222)inclined adit :inclined shaft

Tunnel

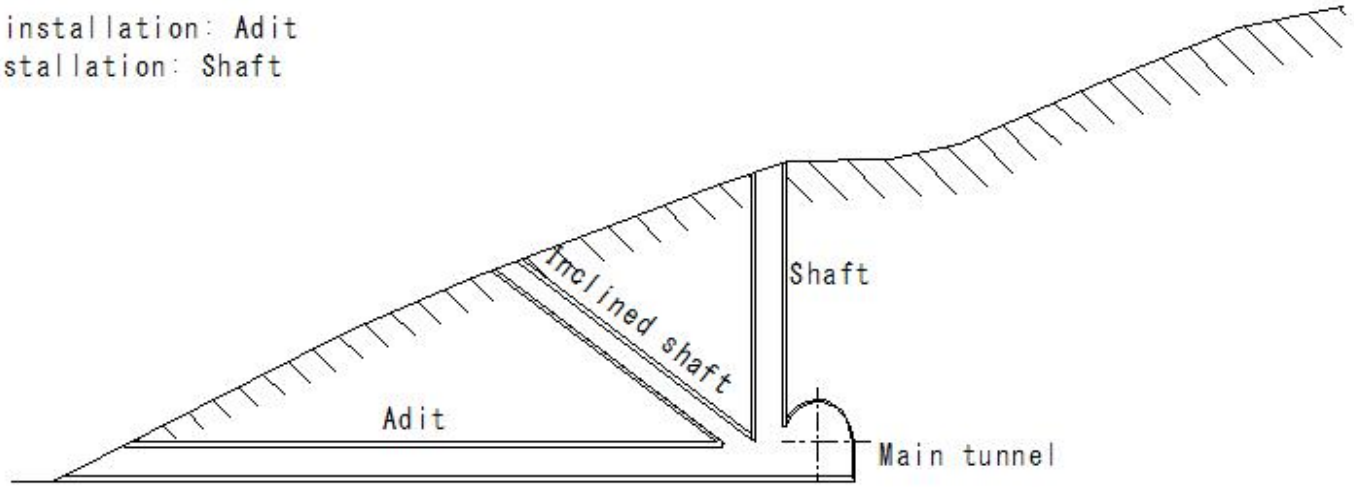
Inclined shaft
Steep tunnel

Connects the surface and the main tunnel

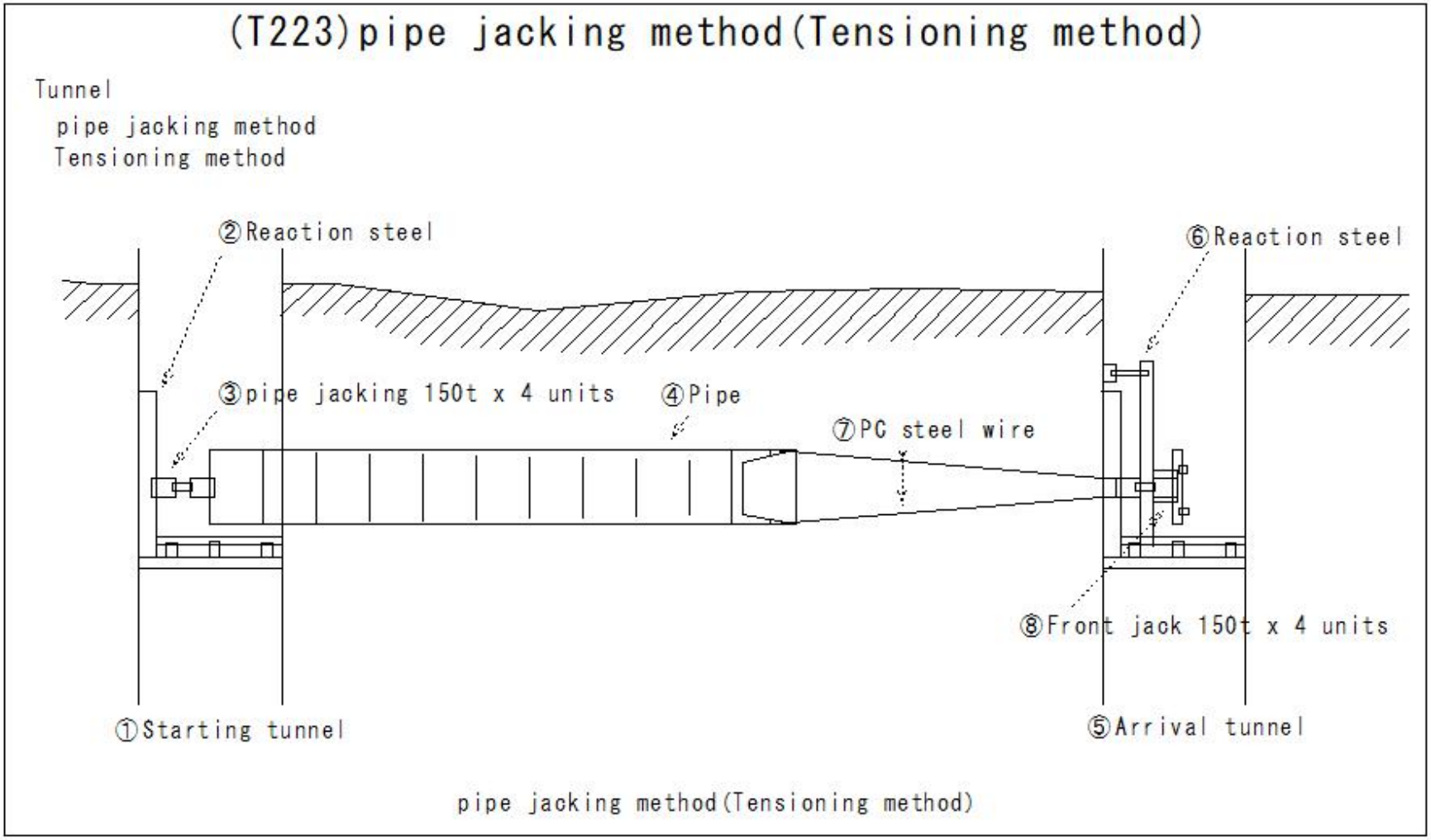
Work tunnel for removing muck and transporting materials

Inside the tunnel: Install an incline

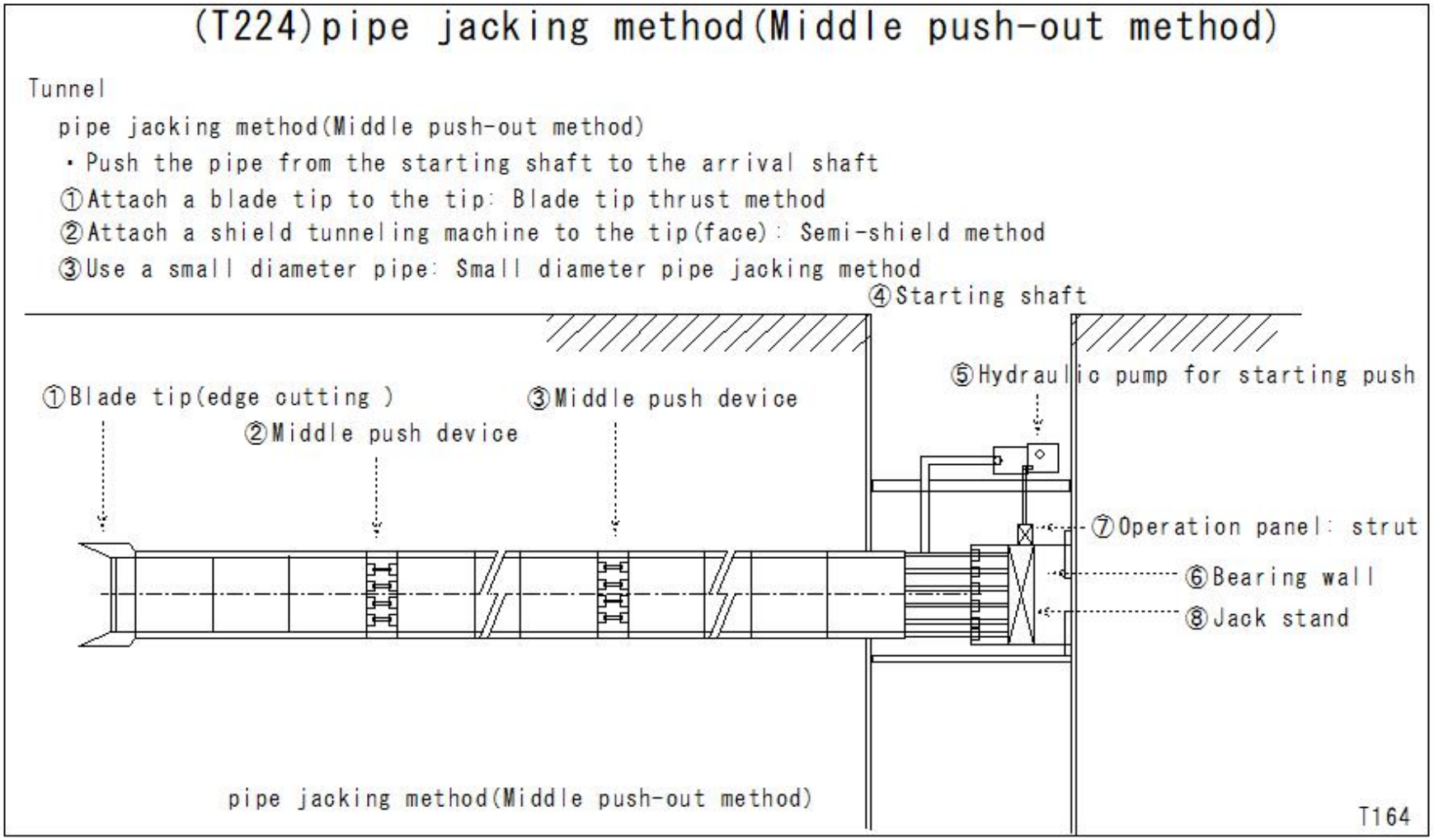
Horizontal installation: Adit
Vertical installation: Shaft



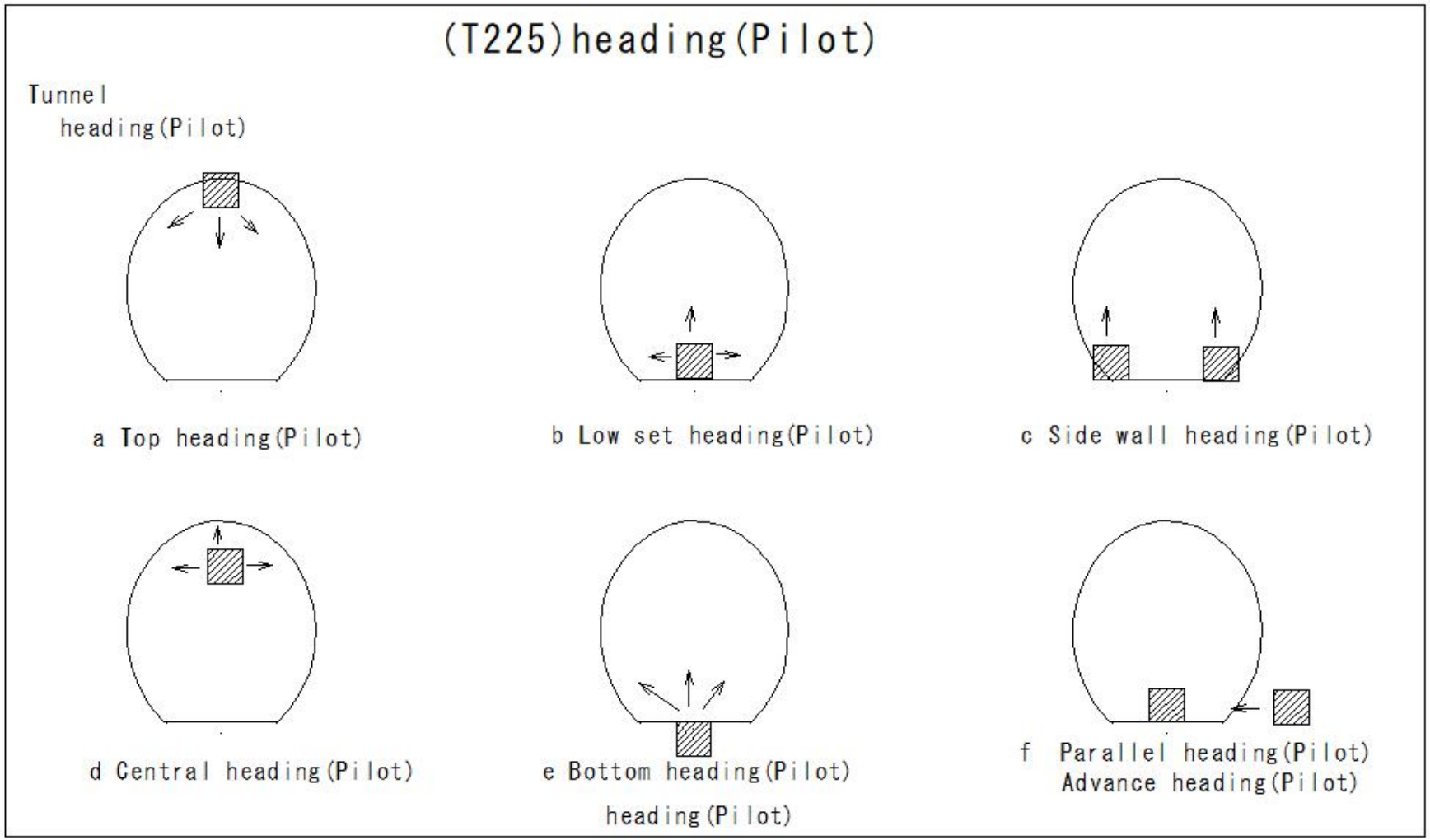
(T223)pipe jacking method(Tensioning method)



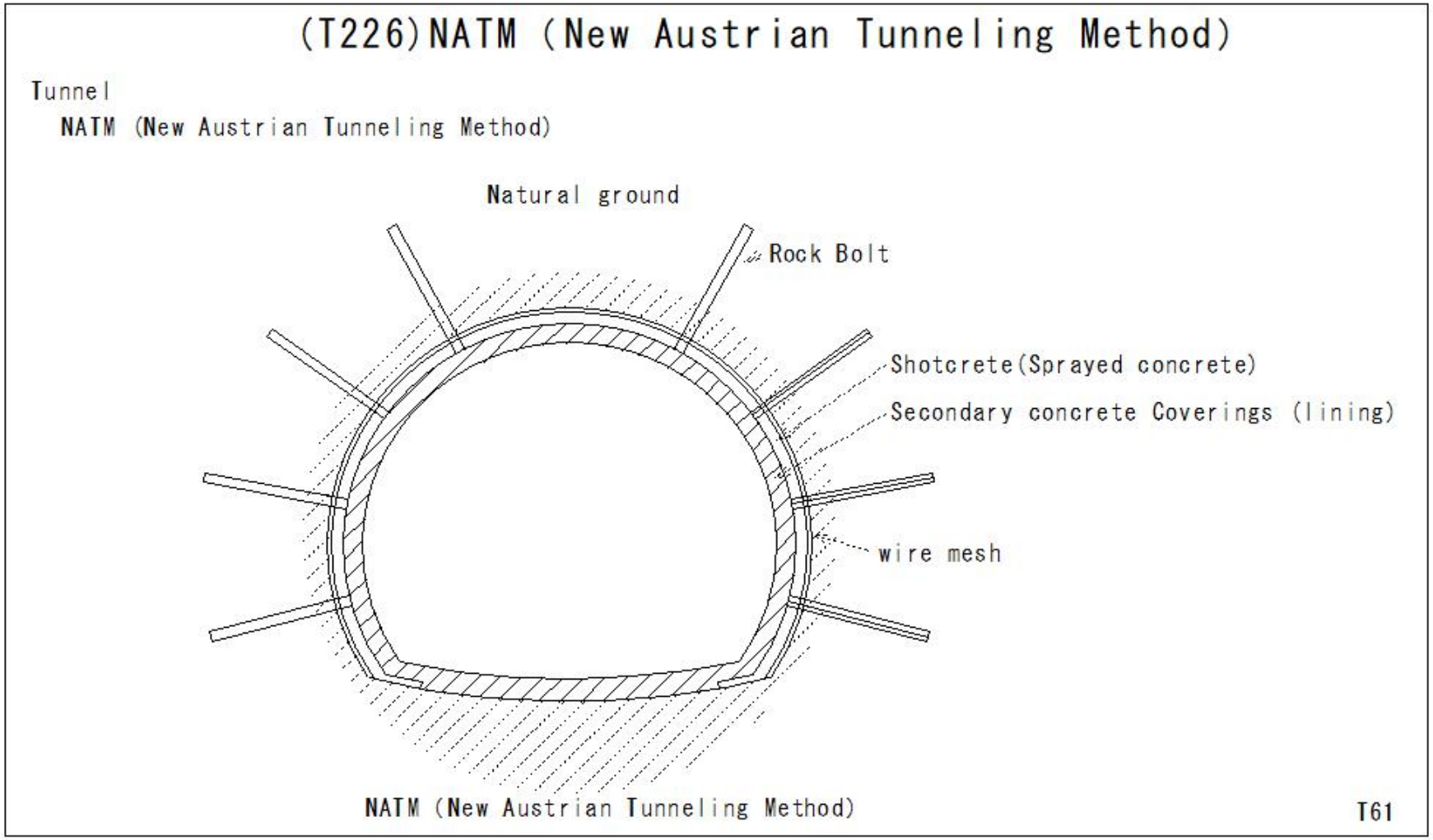
(T224)pipe jacking method(Middle push-out method)



(T225)heading(Pilot)



(T226)heading(Pilot)



(T227)Tunnel(swelling heaving)

(T227)Tunnel(swelling heaving)

Tunnel

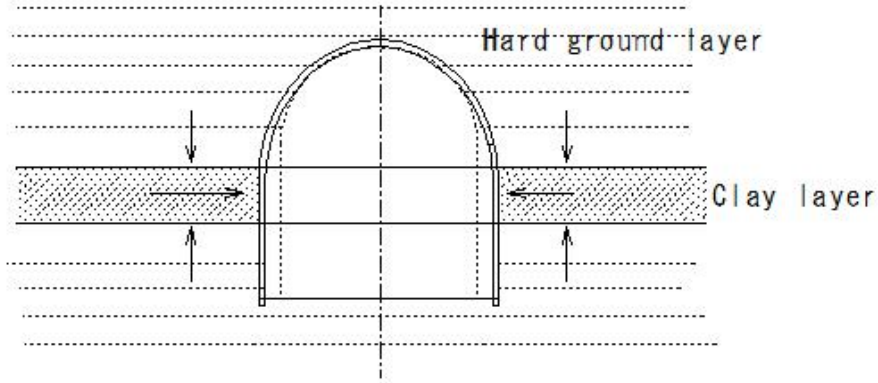
Ground swelling

in case of excavating a tunnel, the ground pushes inward over time

The tunnel space shrinks as the rock absorbs water and expands

Large earth pressure acts on the tunnel support(timbering) and Coverings (lining)

① Clay layer pushes out



① Clay layer pushes out

Ground swelling

(T228)Tunnel(swelling heaving)

(T228)Tunnel(swelling heaving)

Tunnel

Ground swelling

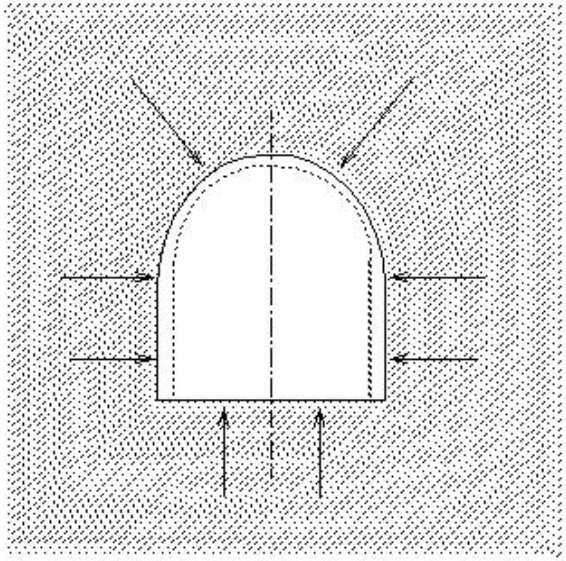
in case of excavating a tunnel, the ground pushes inward over time

The tunnel space shrinks as the rock absorbs water and expands

Large earth pressure acts on the tunnel support(timbering) and Coverings (lining)

②Due to the swelling heaving clay layer

The clay layer swells



The clay layer swells

②Due to the swelling heaving clay layer

Ground swelling

(T229)Tunnel(swelling heaving)

(T229)Tunnel(swelling heaving)

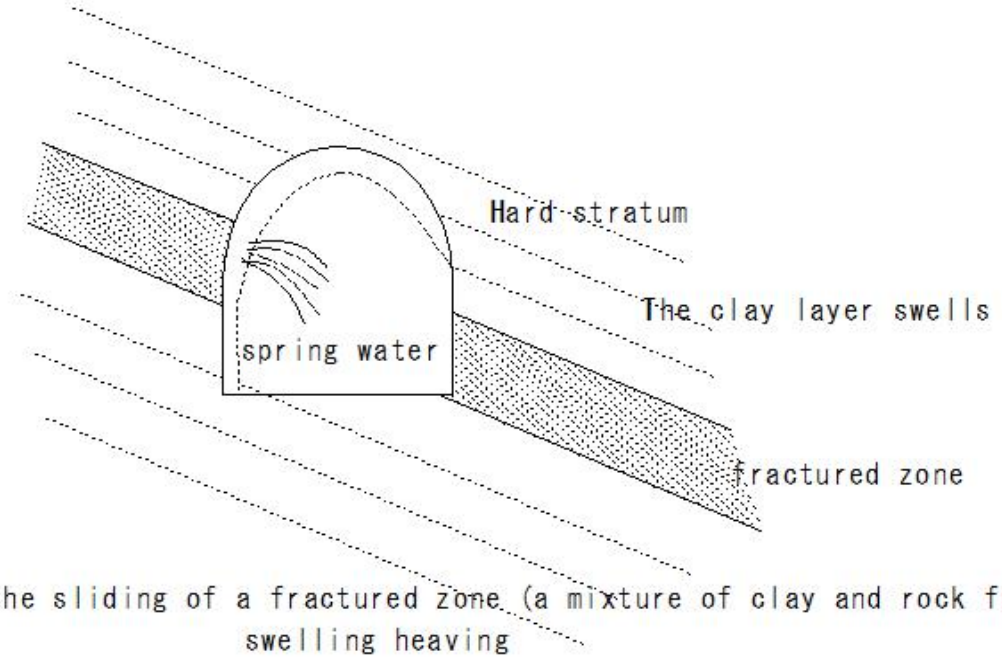
Tunnel

swelling heaving

③ Caused by the sliding of a fractured zone (a mixture of clay and rock fragments)

Drilling is done just before the fractured zone

A place with a lot of spring water



③ Caused by the sliding of a fractured zone (a mixture of clay and rock fragments)
swelling heaving

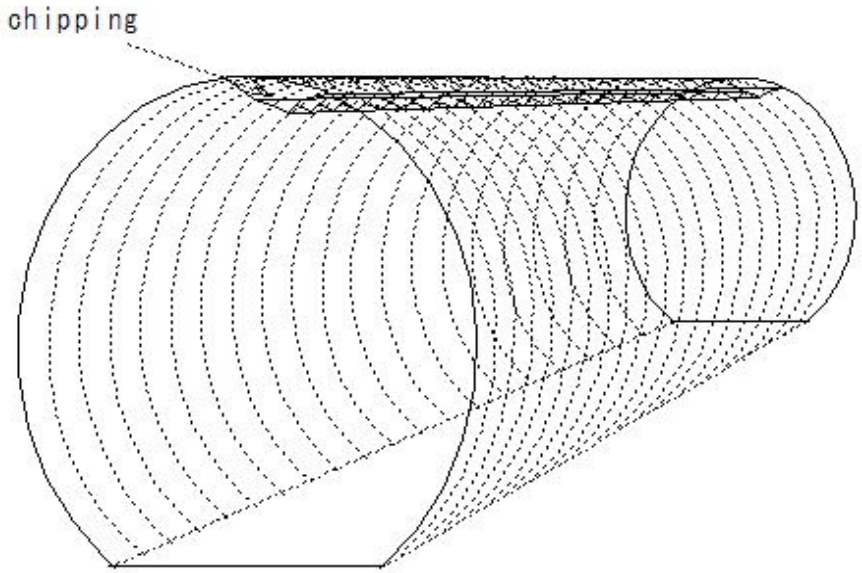
(T230)Tunnel(chipping)

(T230)Tunnel(chipping)

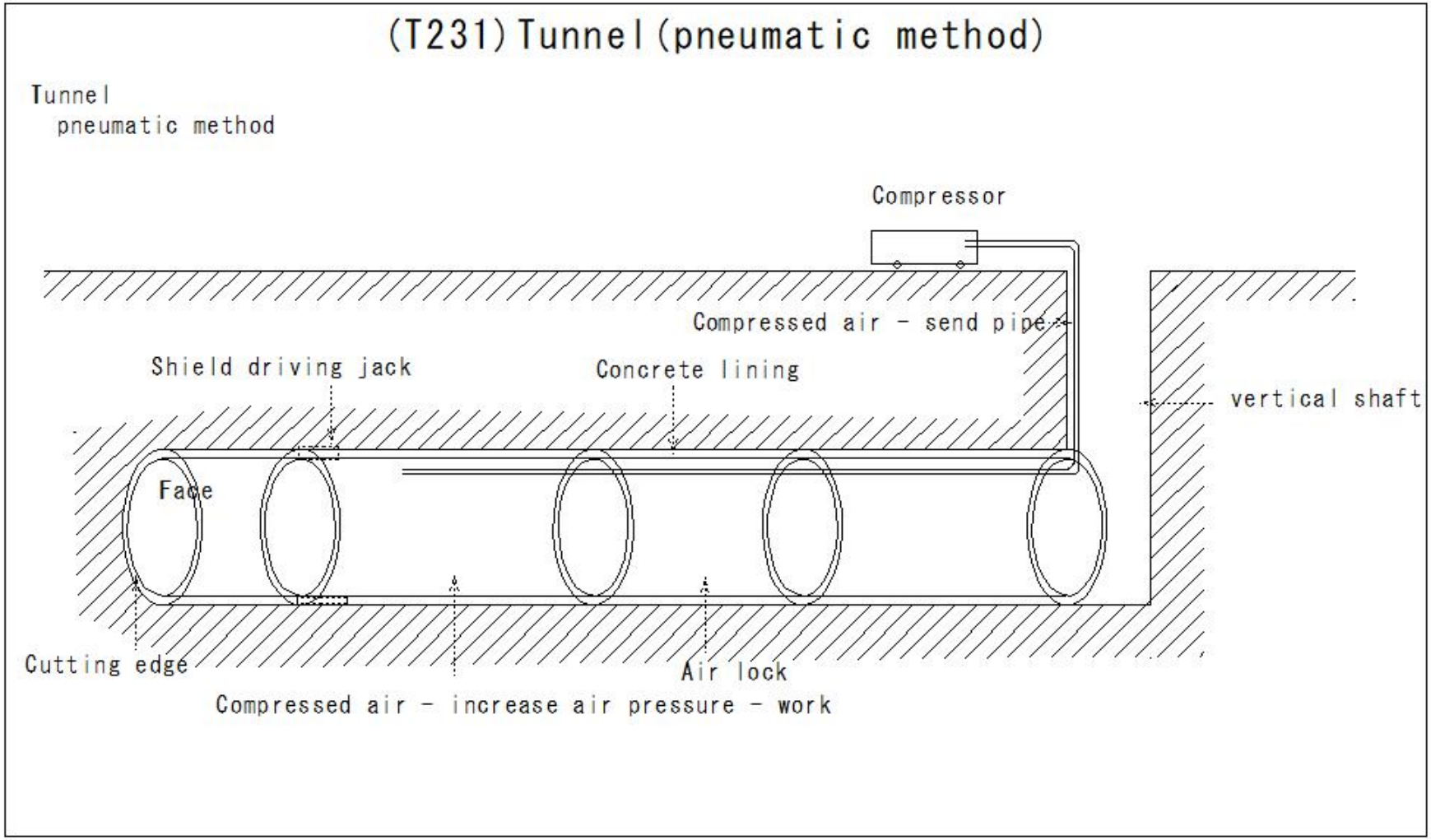
Tunnel

chipping

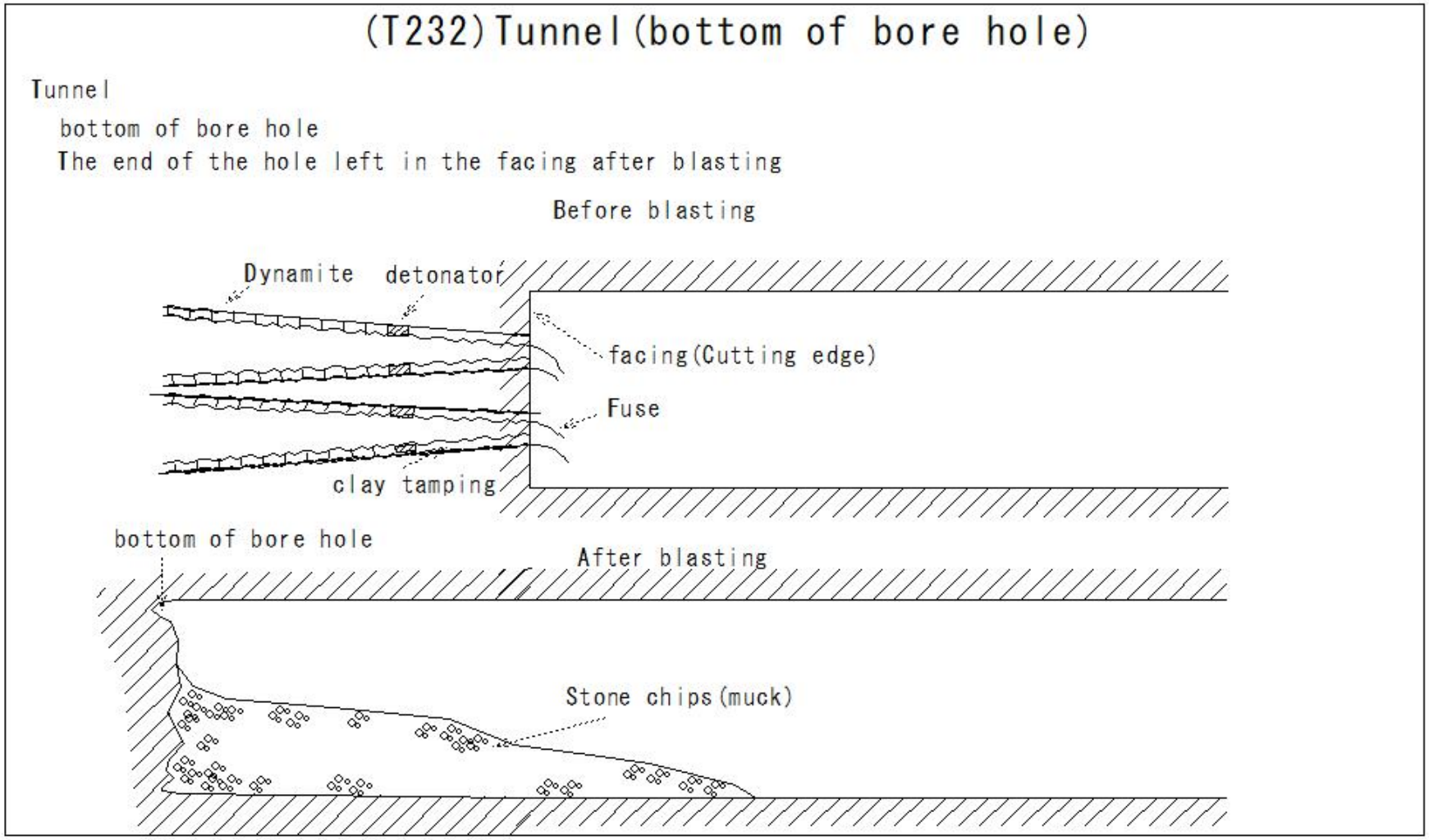
Remove the protruding part that is in the way



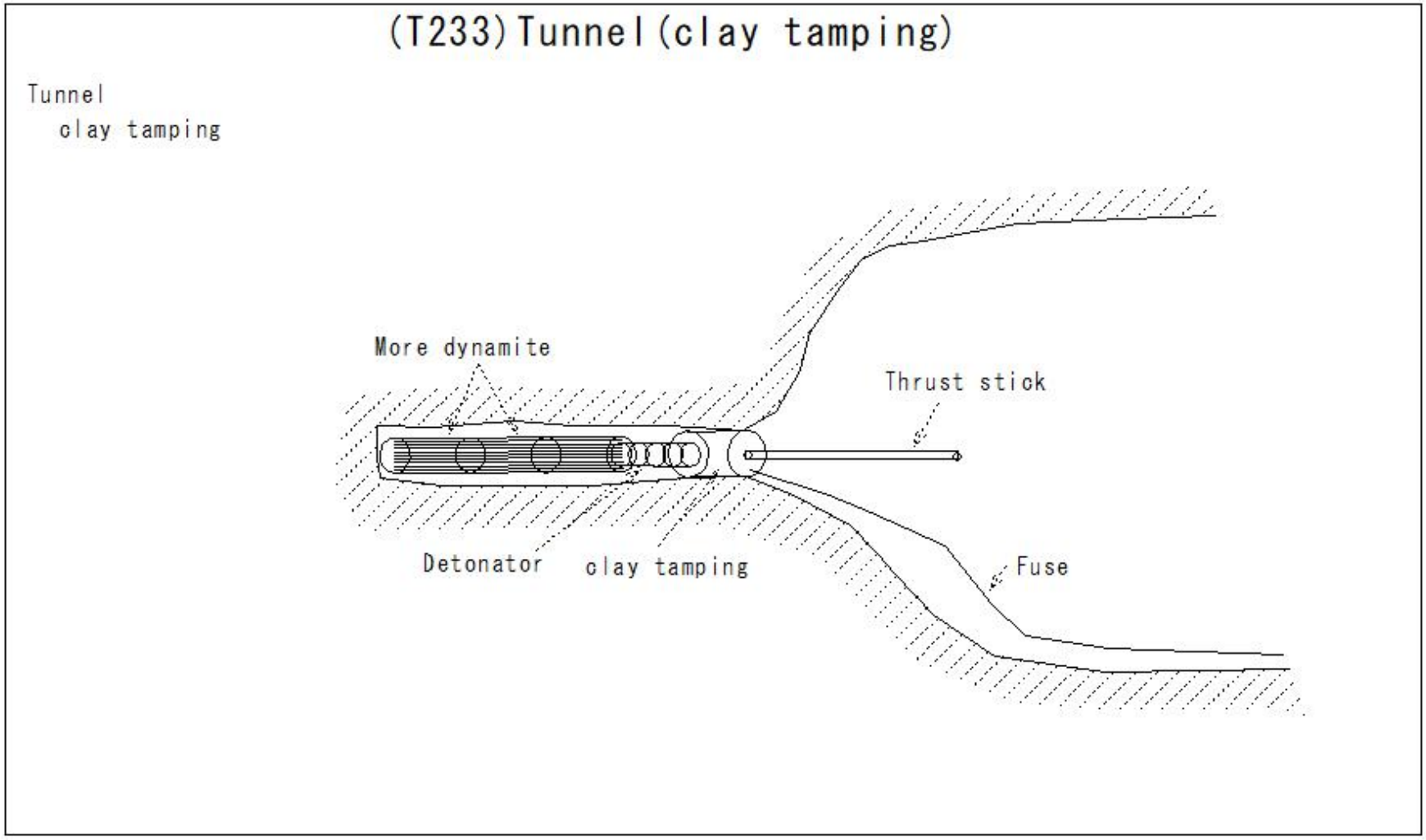
(T231)Tunnel(pneumatic method)



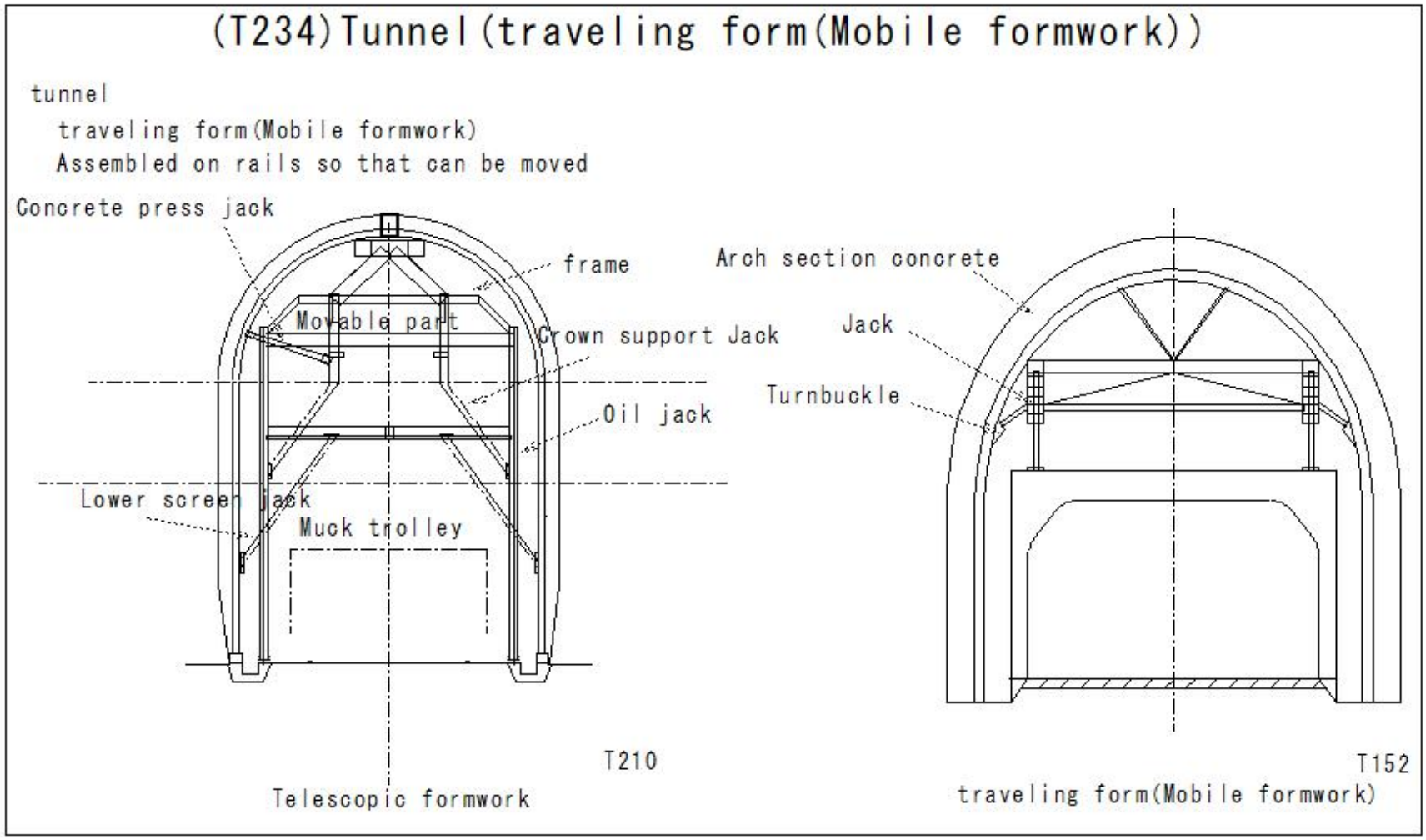
(T232)Tunnel(bottom of bore hole)



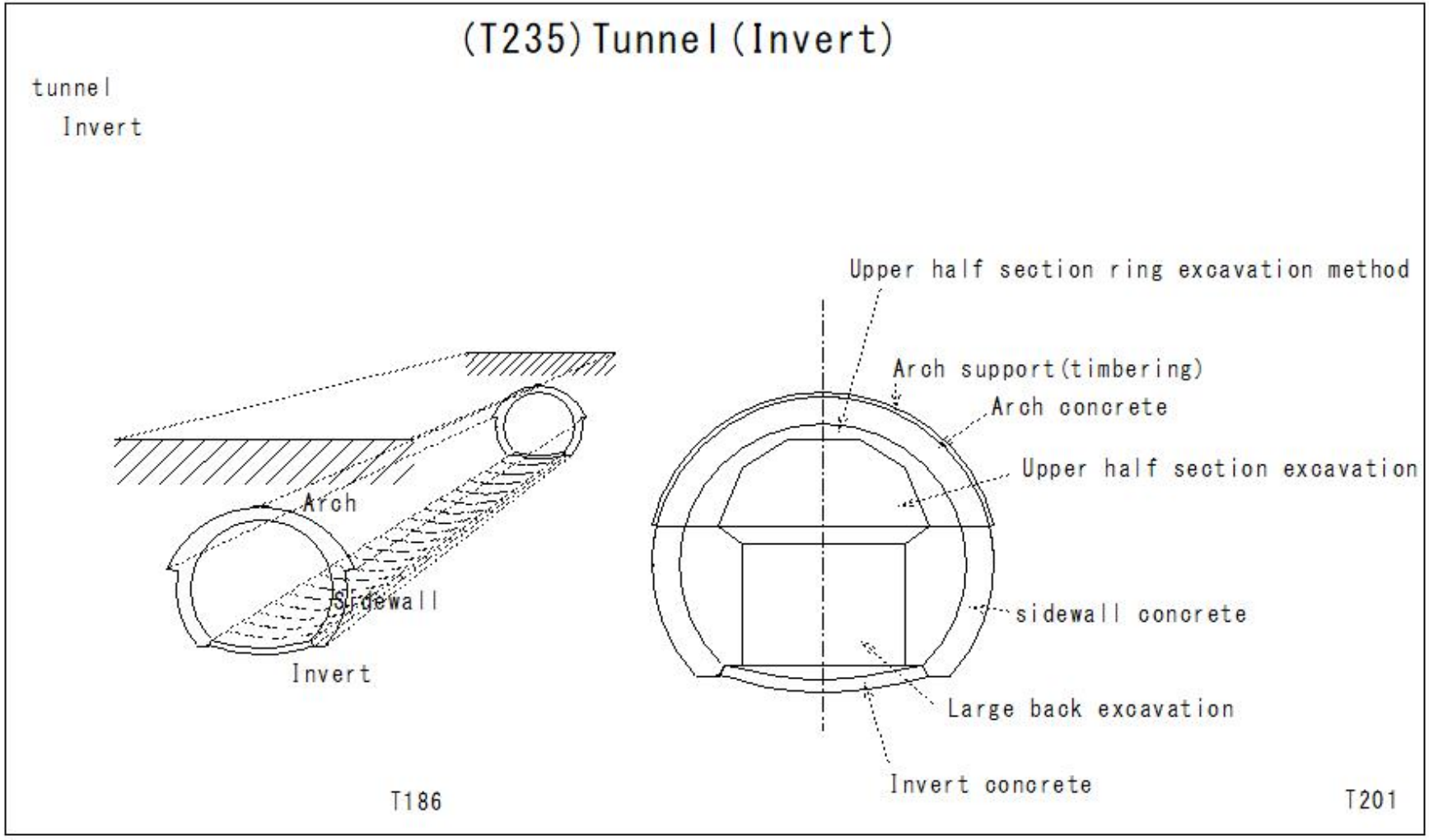
(T233)Tunnel(clay tamping)



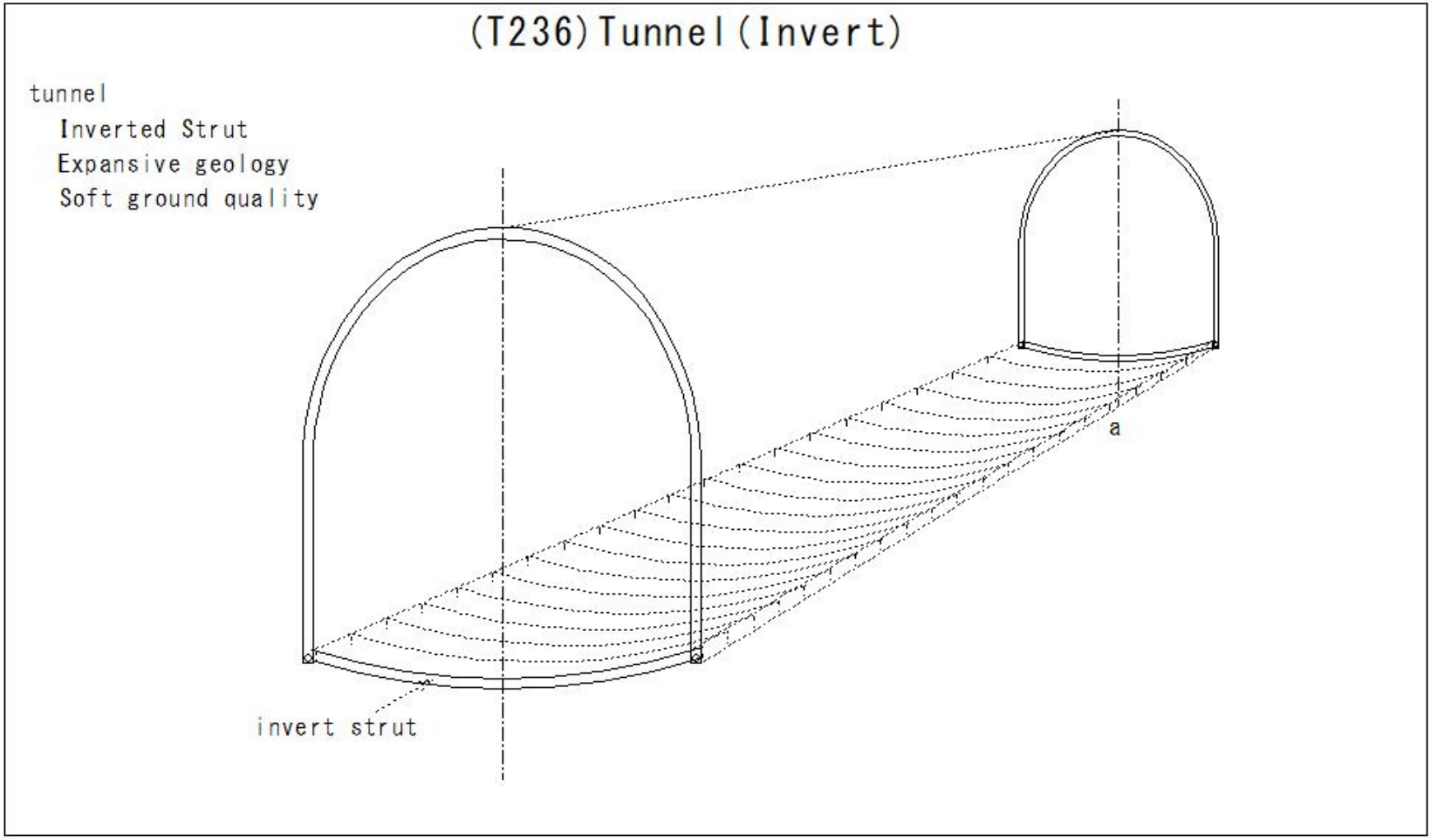
(T234)Tunnel(traveling form(Mobile formwork))



(T235)Tunnel(Invert)



(T236)Tunnel(Invert)



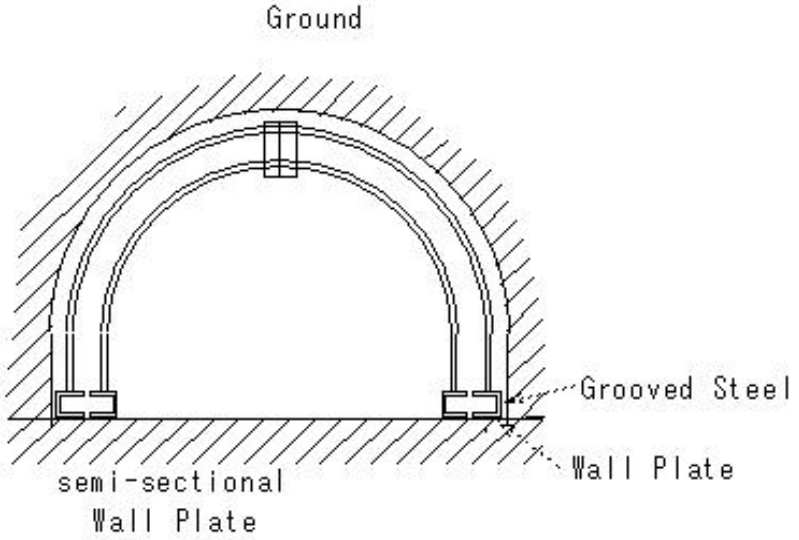
(T237)Tunnel(wall plate)

(T237)Tunnel(wall plate)

tunnel

Wall plate type support(timbering)

The base of the arch member
support(timbering) using wall plates

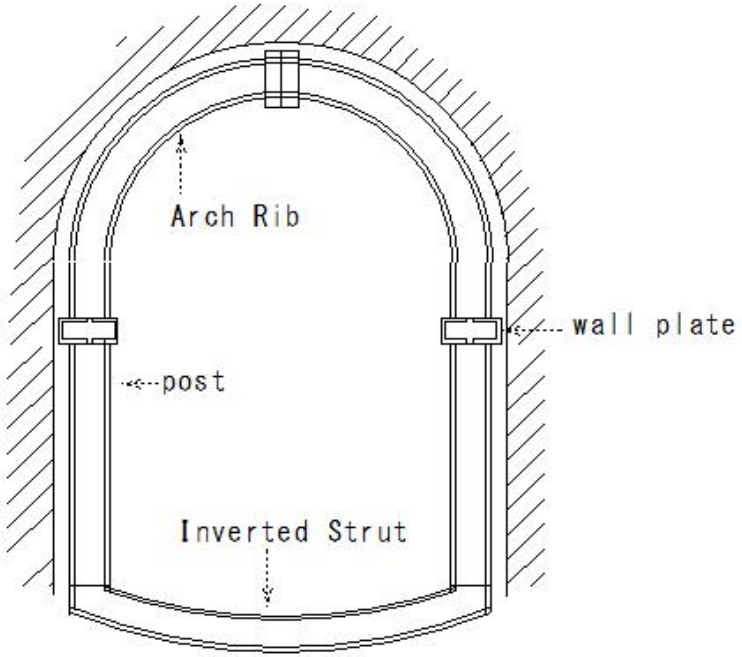


(T238)Tunnel(Wall plate type support(timbering))

(T238)Tunnel(Wall plate type support(timbering))

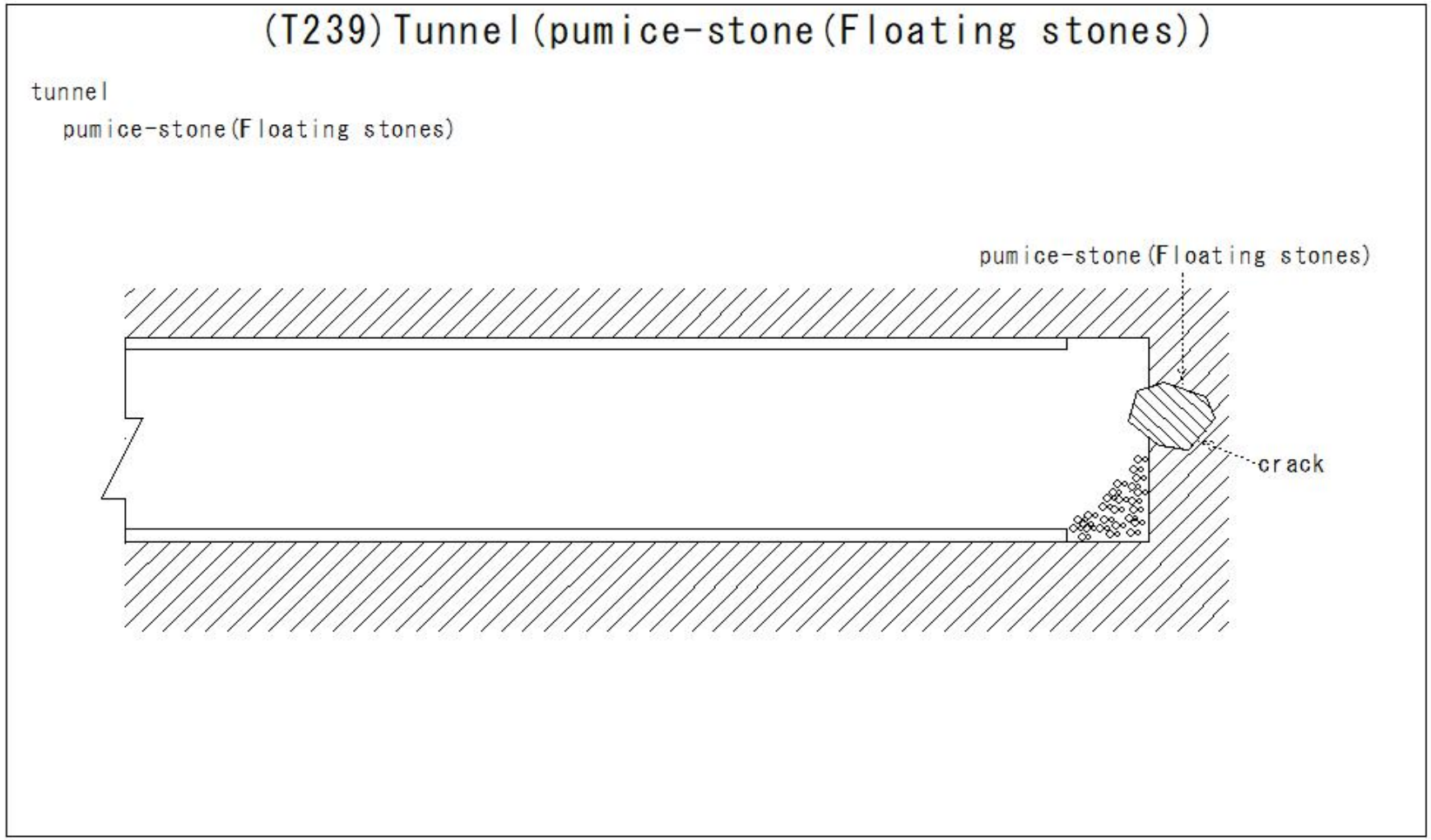
tunnel

Wall plate type support(timbering)

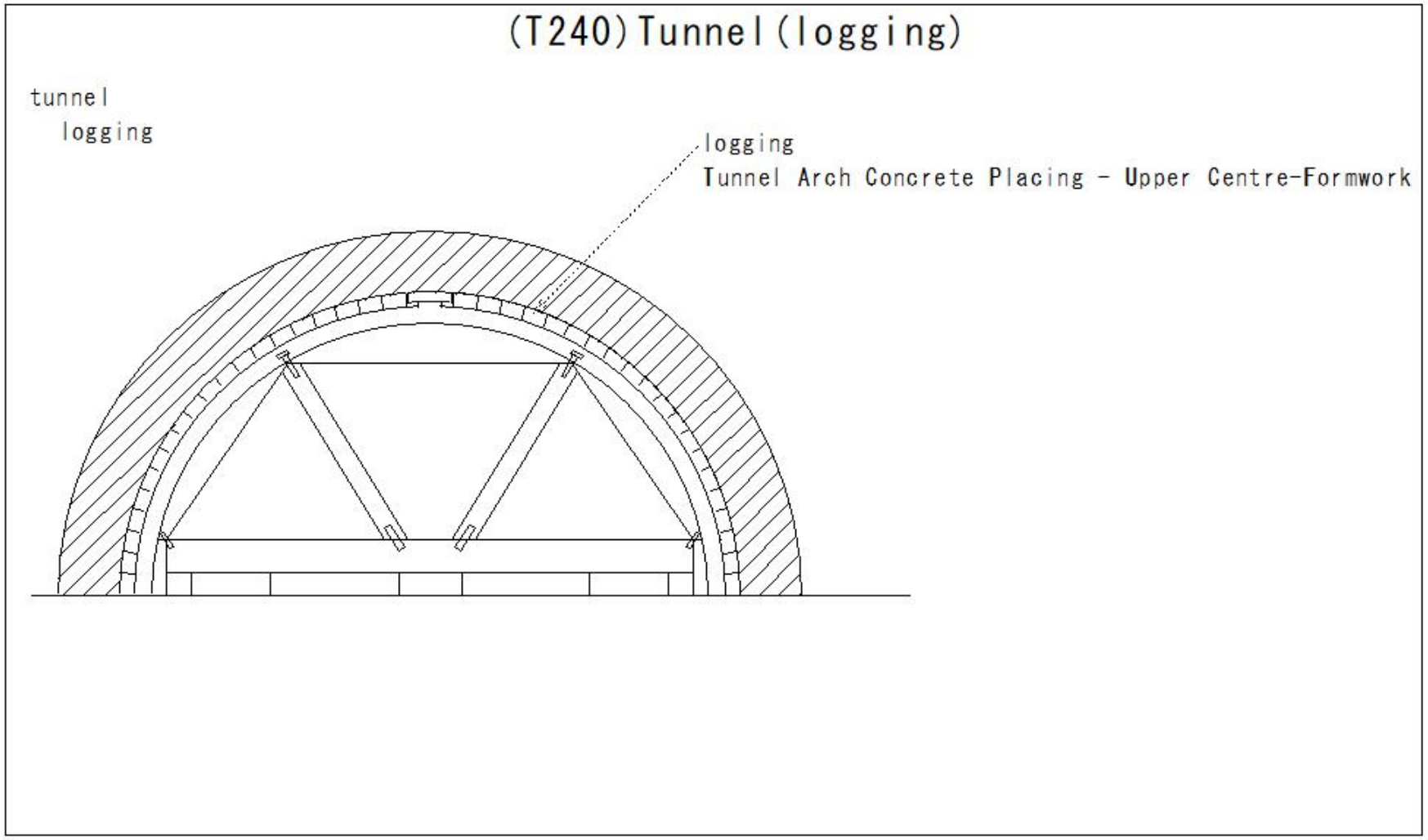


Full-section wall plate

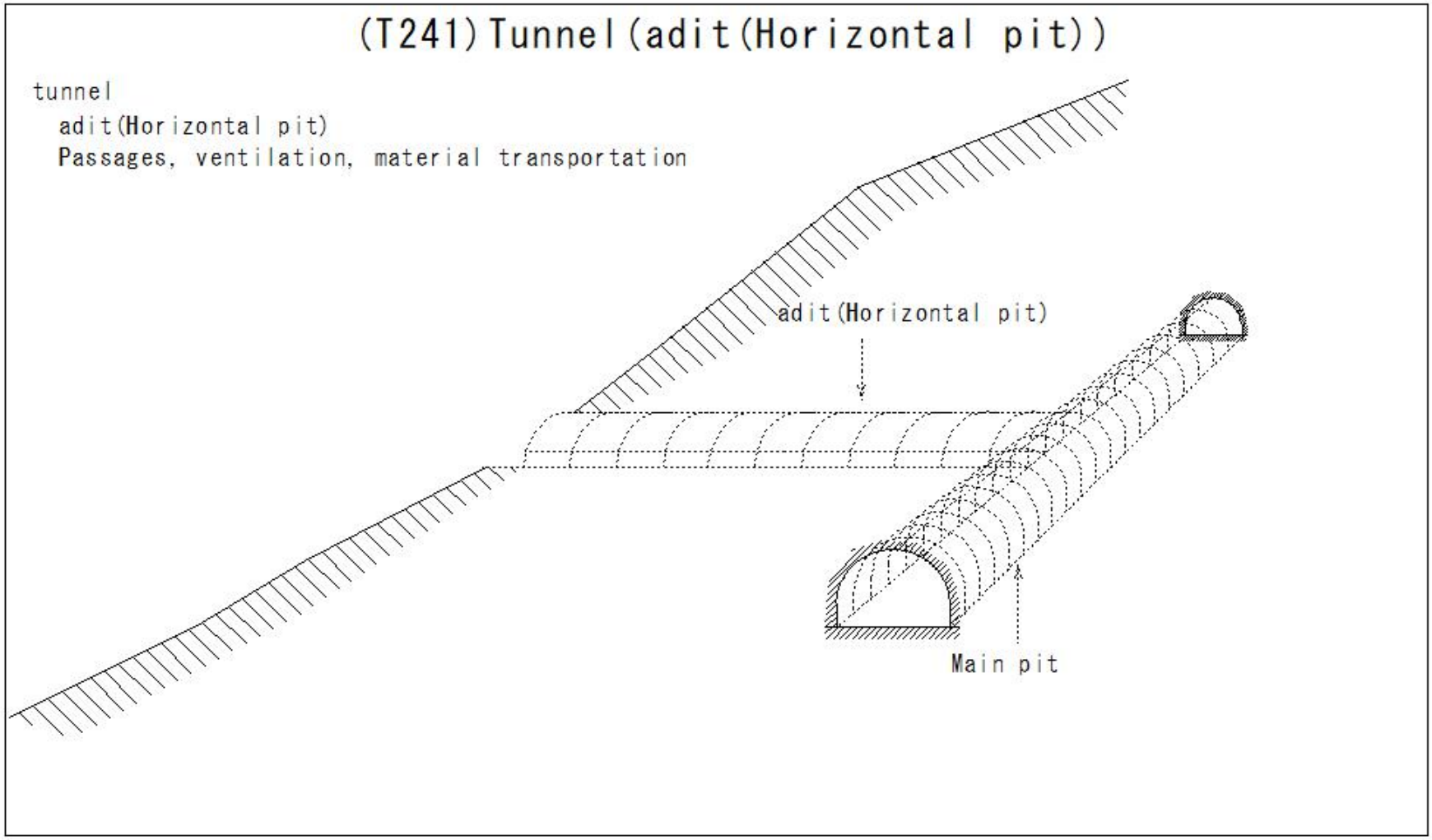
(T239)Tunnel(pumice-stone(Floating stones))



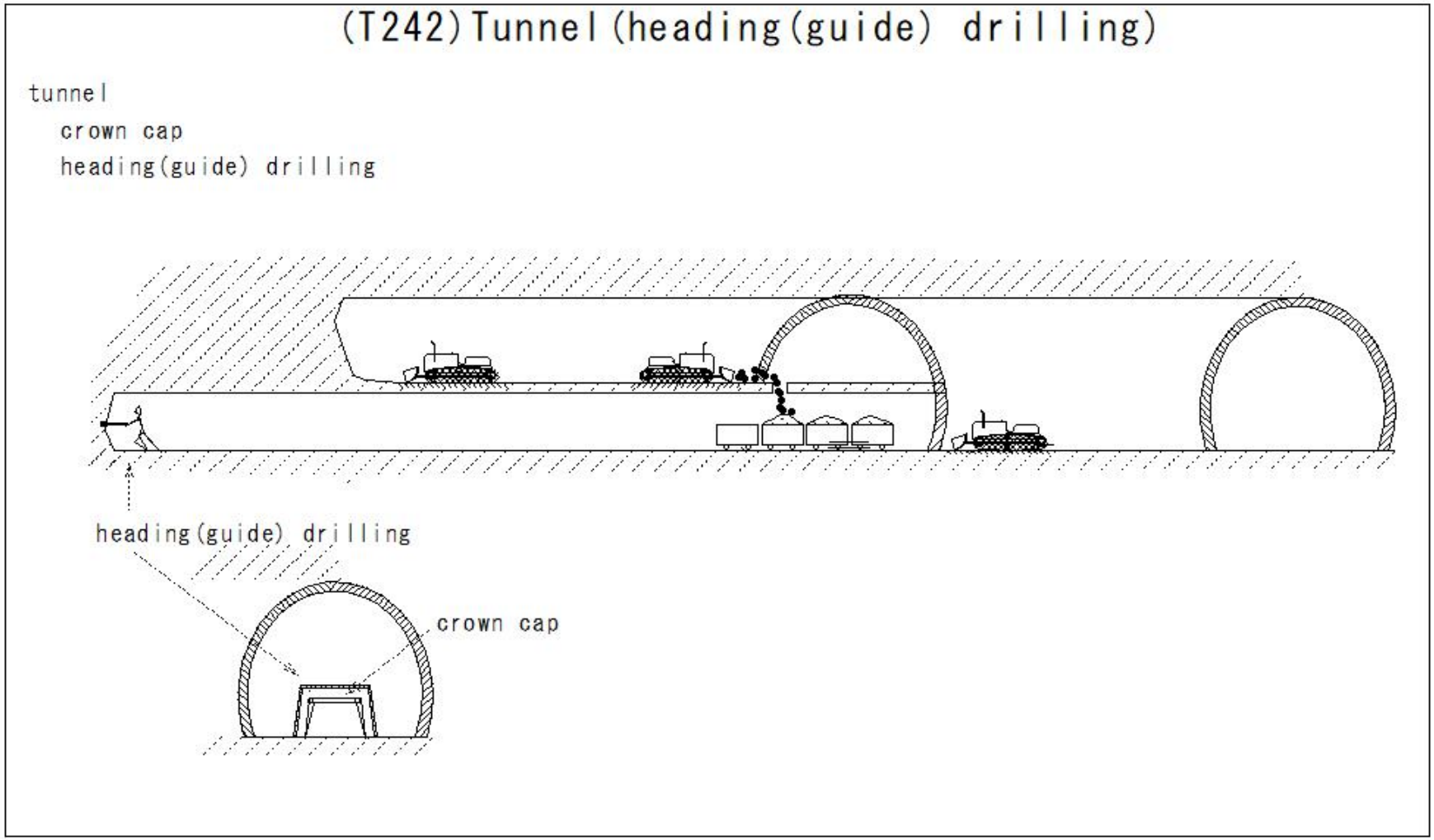
(T240)Tunnel(logging)



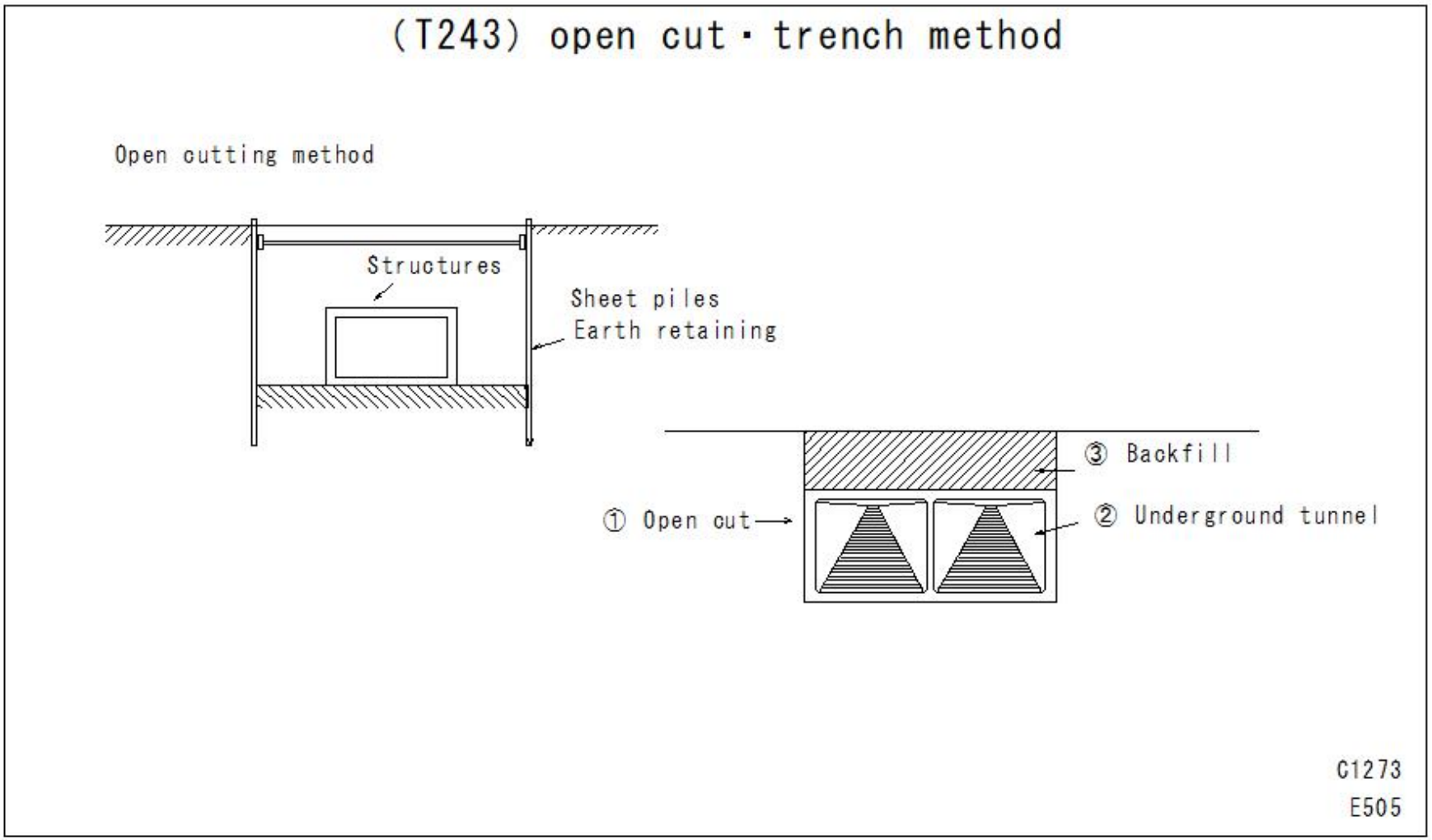
(T241)Tunnel(adit(Horizontal pit))



(T242)Tunnel(heading(guide) drilling)



（T243）open cut・trench method



（T244）erection fixture(Temporary Installations)

(T244) erection fixture(Temporary Installations)

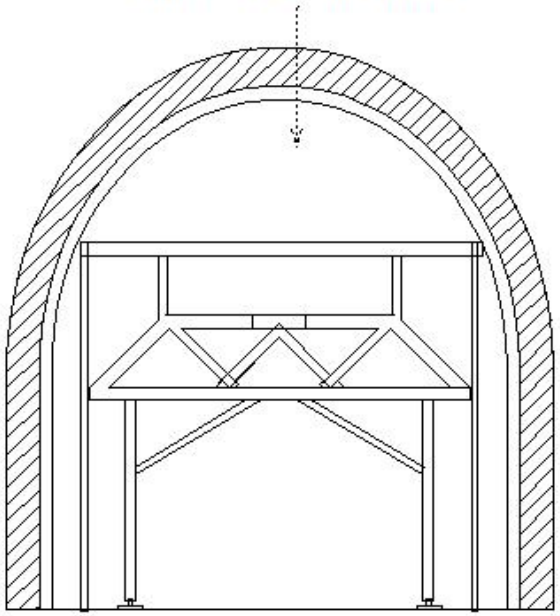
tunnel

erection fixture(Temporary Installations)

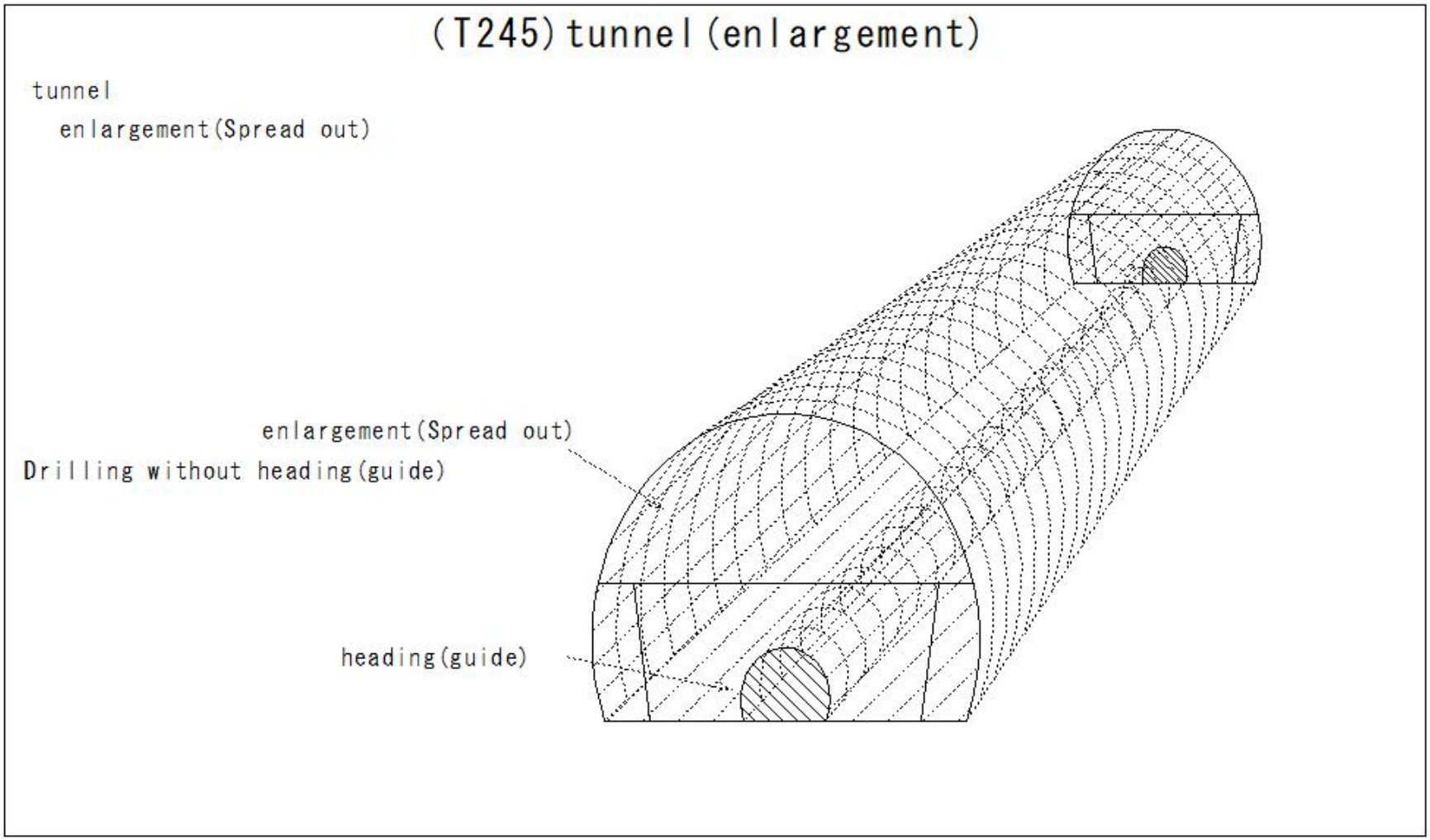
scaffold

Large ground pressure acts on tunnel support(timbering) and Coverings (lining)

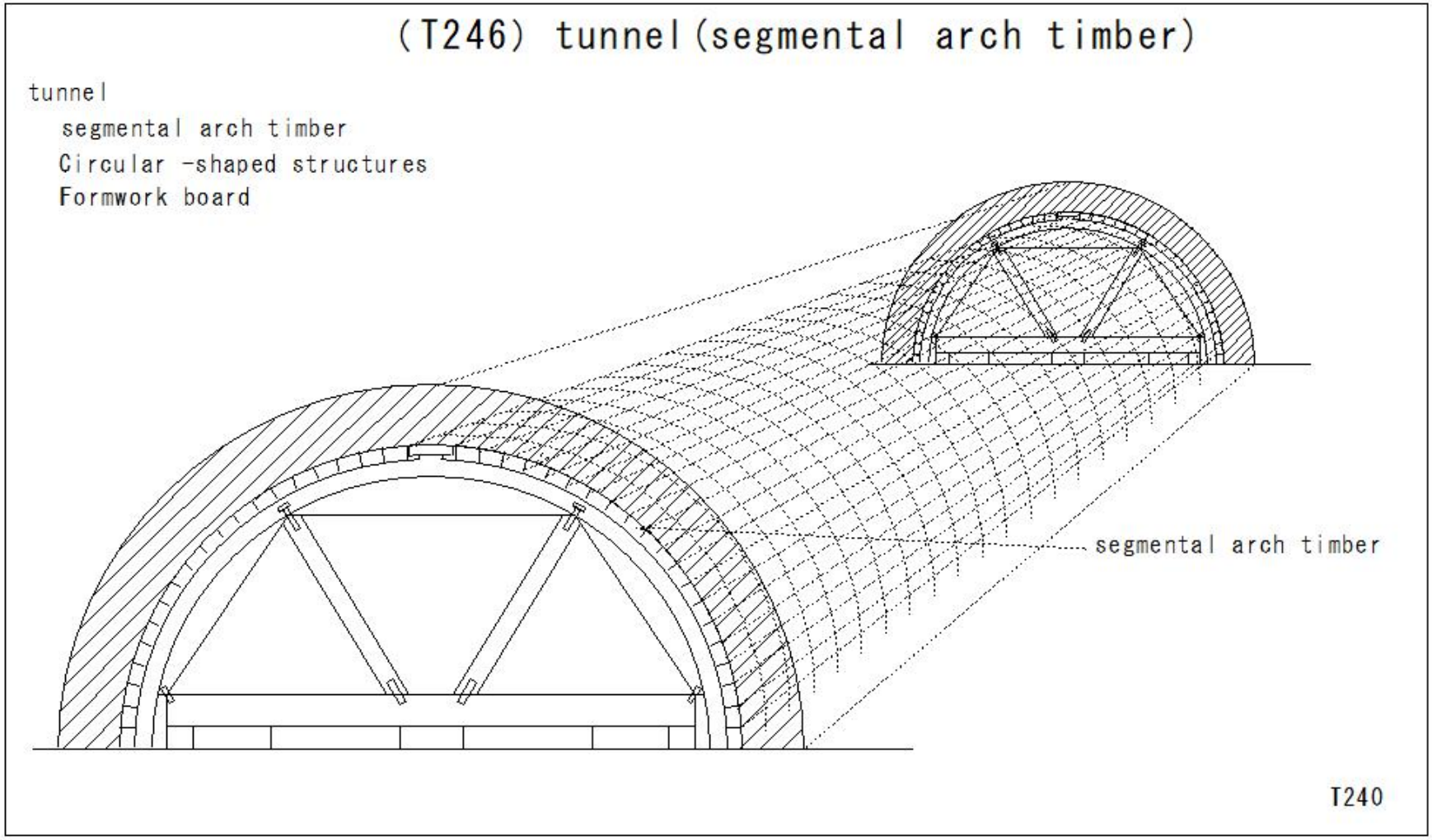
Full Section Central



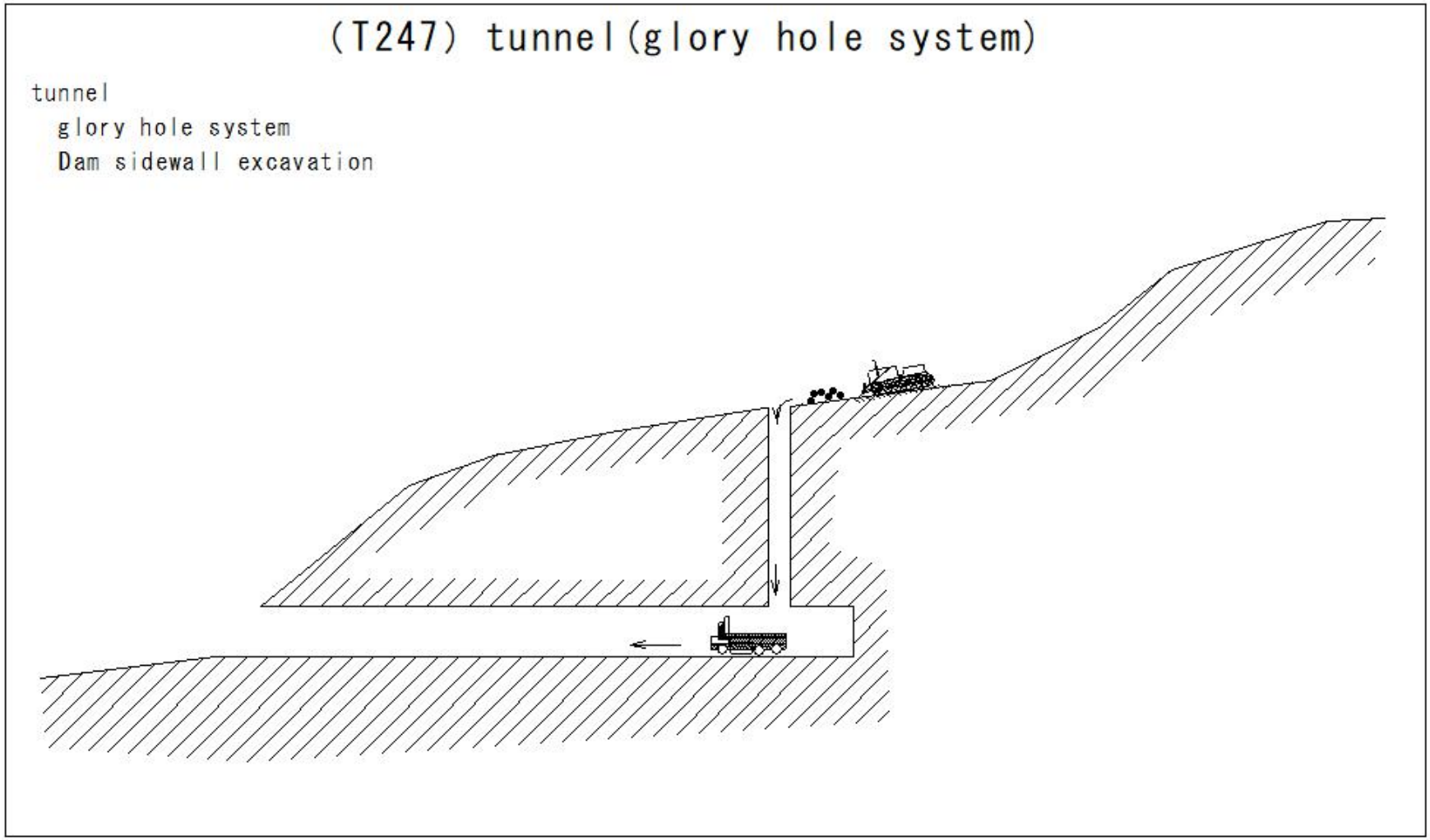
(T245)tunnel(enlargement)



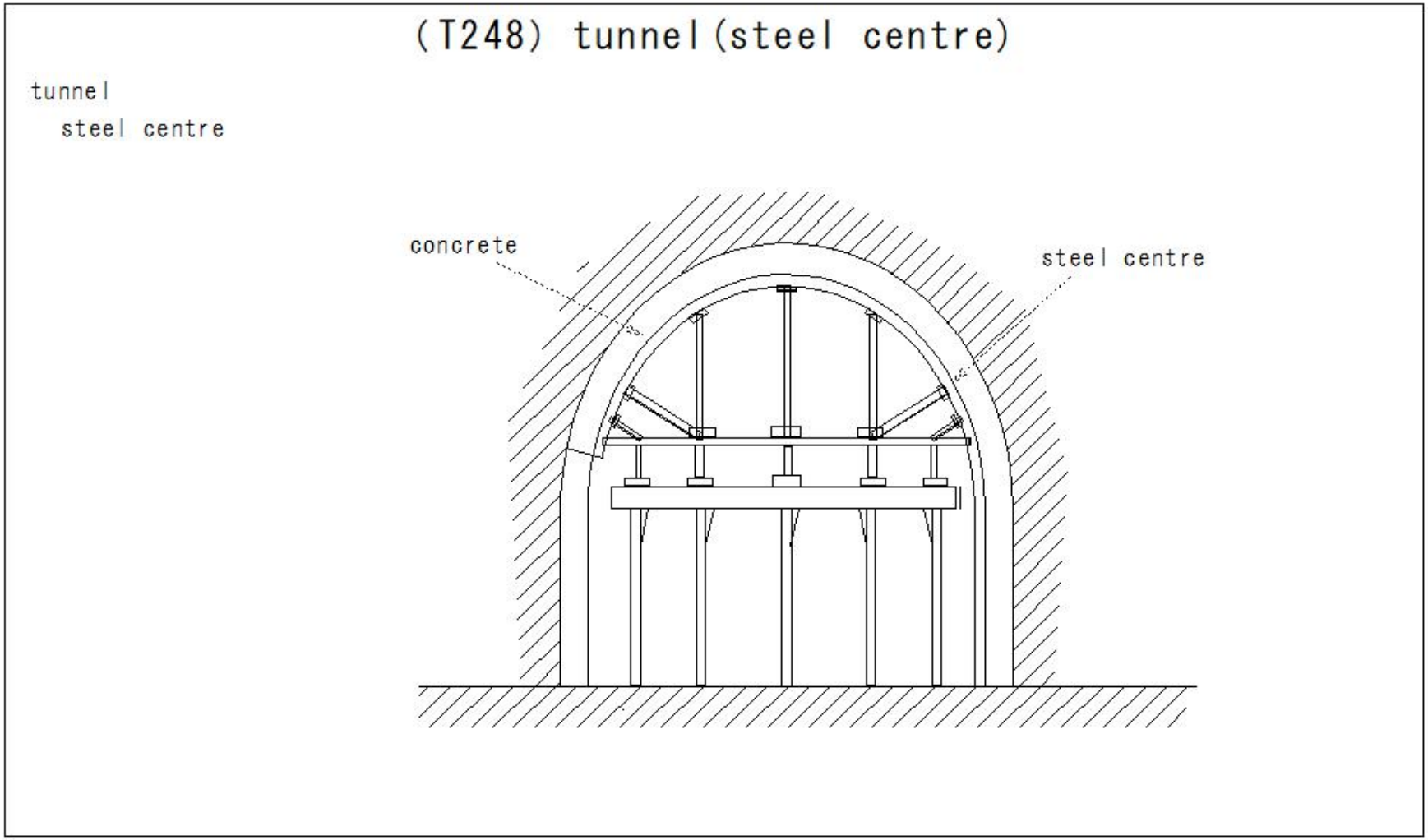
(T246)tunnel(segmental arch timber)



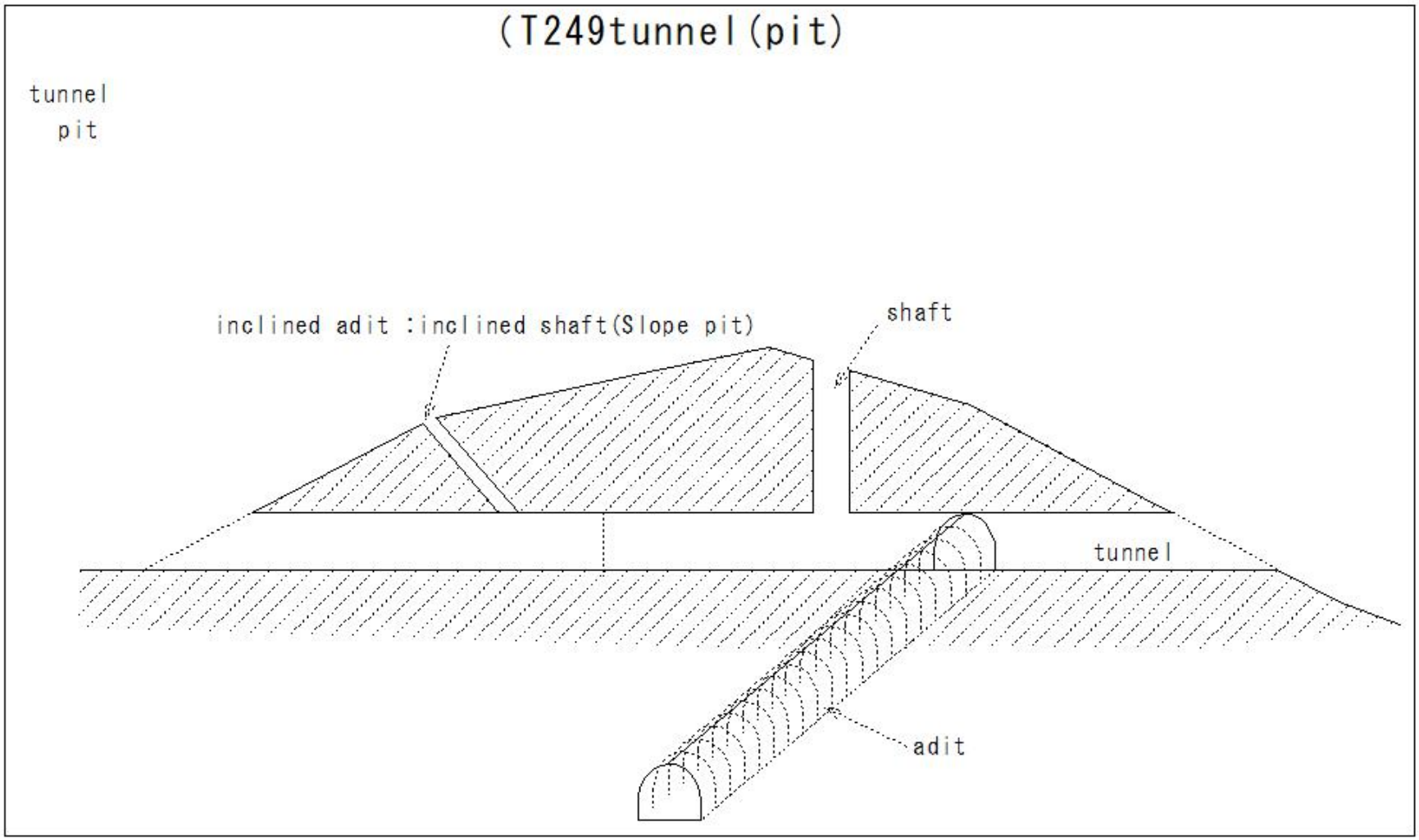
（T247）tunnel(glory hole system)



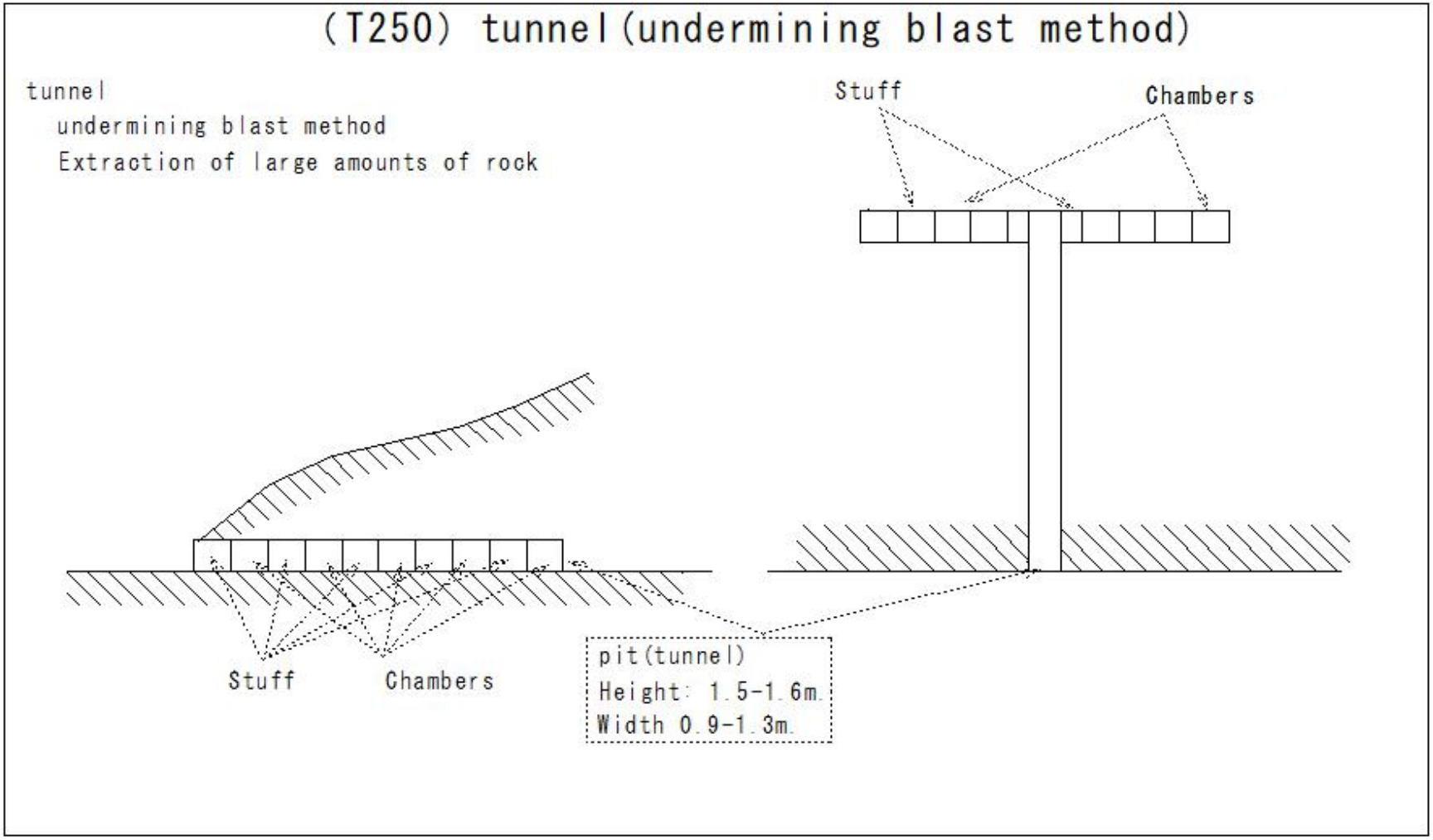
（T248）tunnel(steel centre)



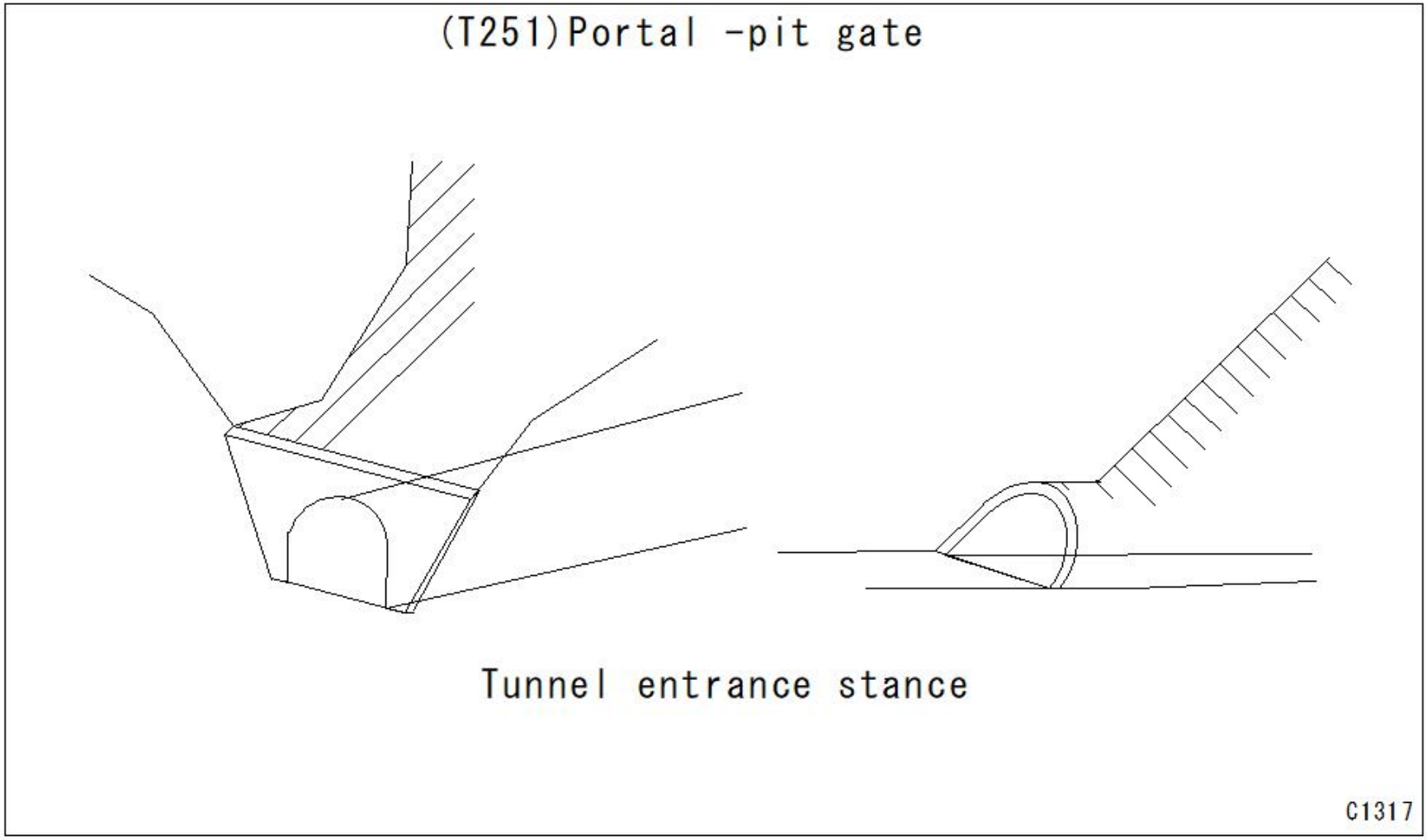
(T249)tunnel(pit)



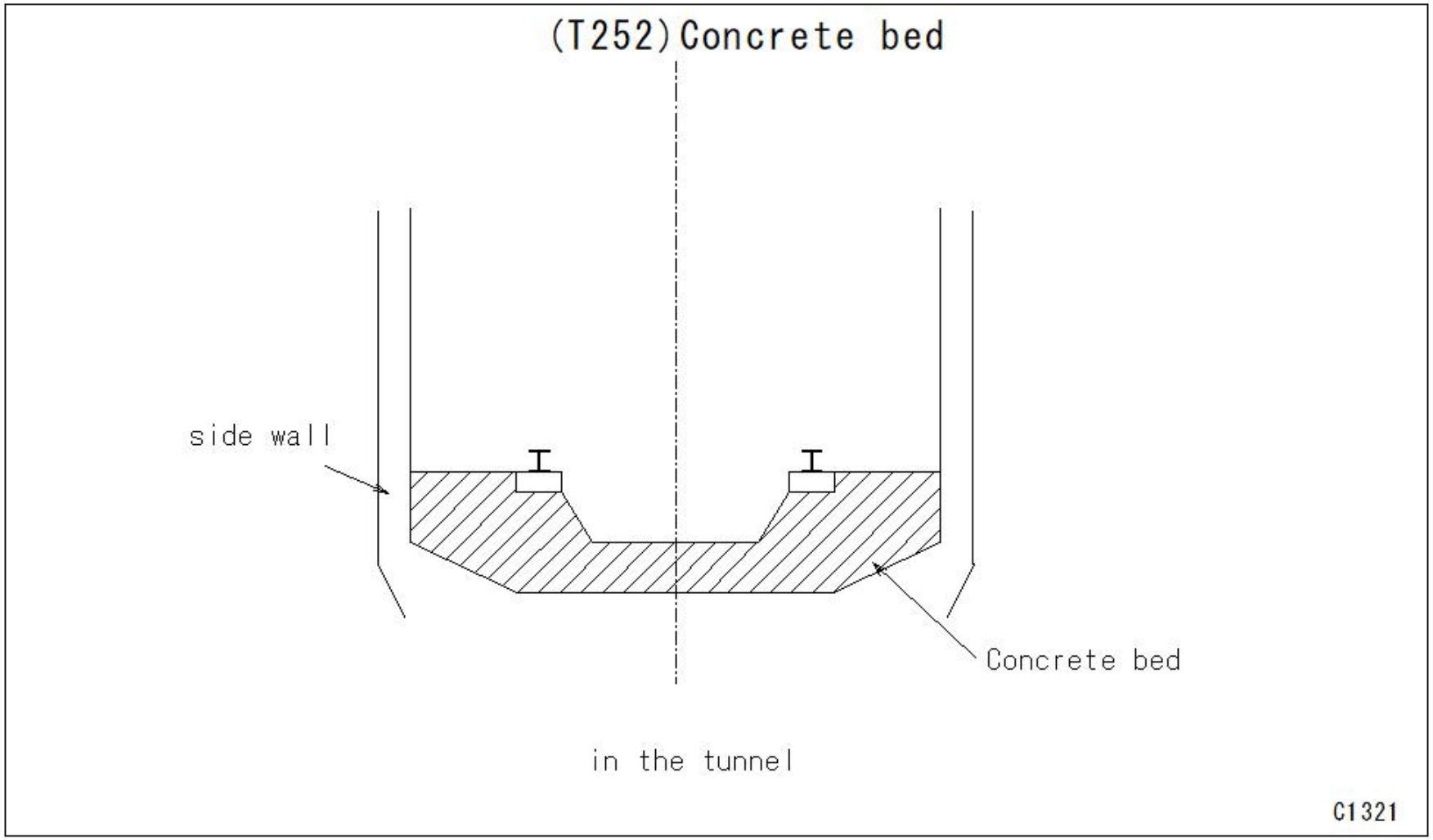
(T250)tunnel(undermining blast method)



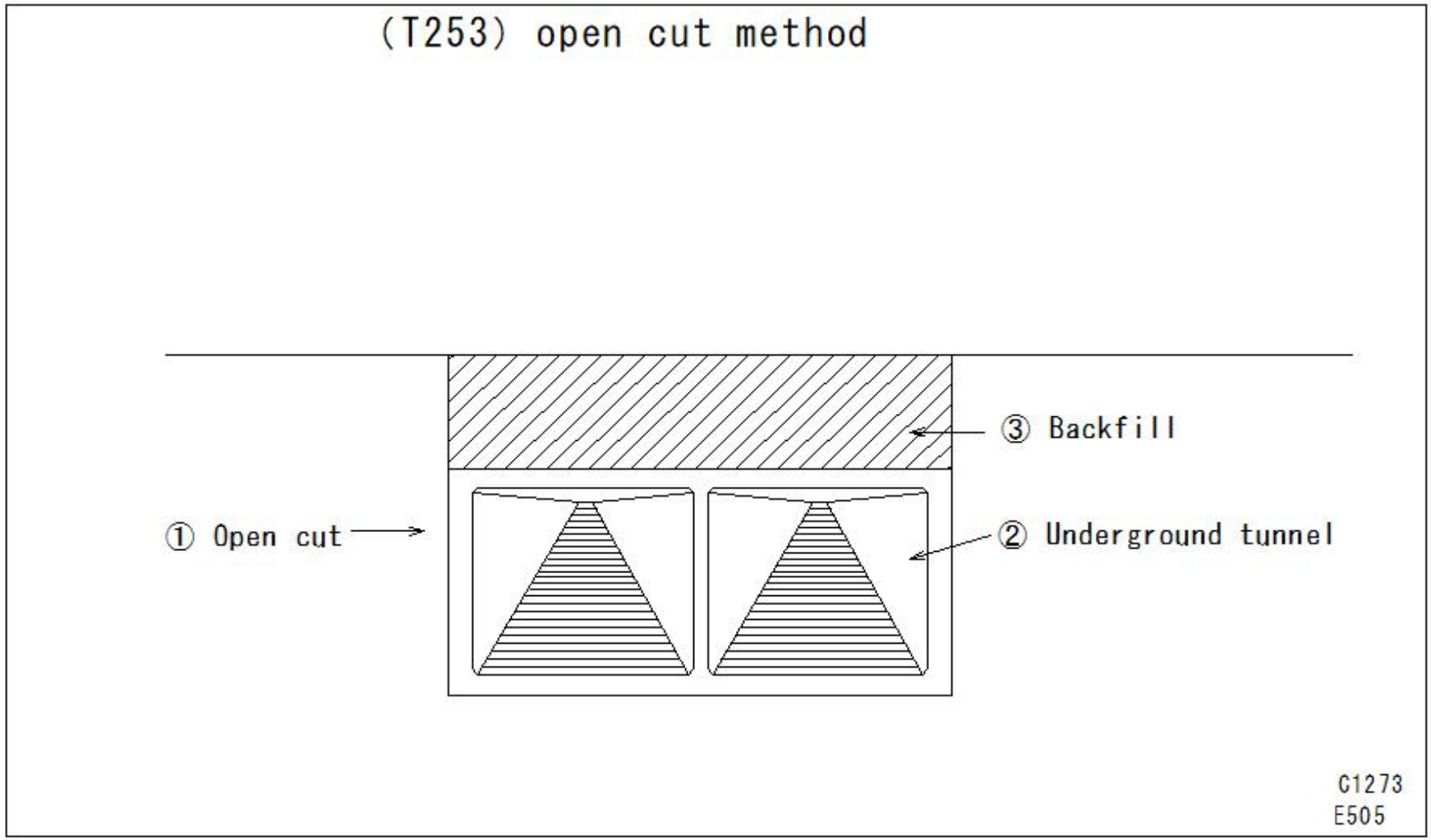
(T251)Portal -pit gate



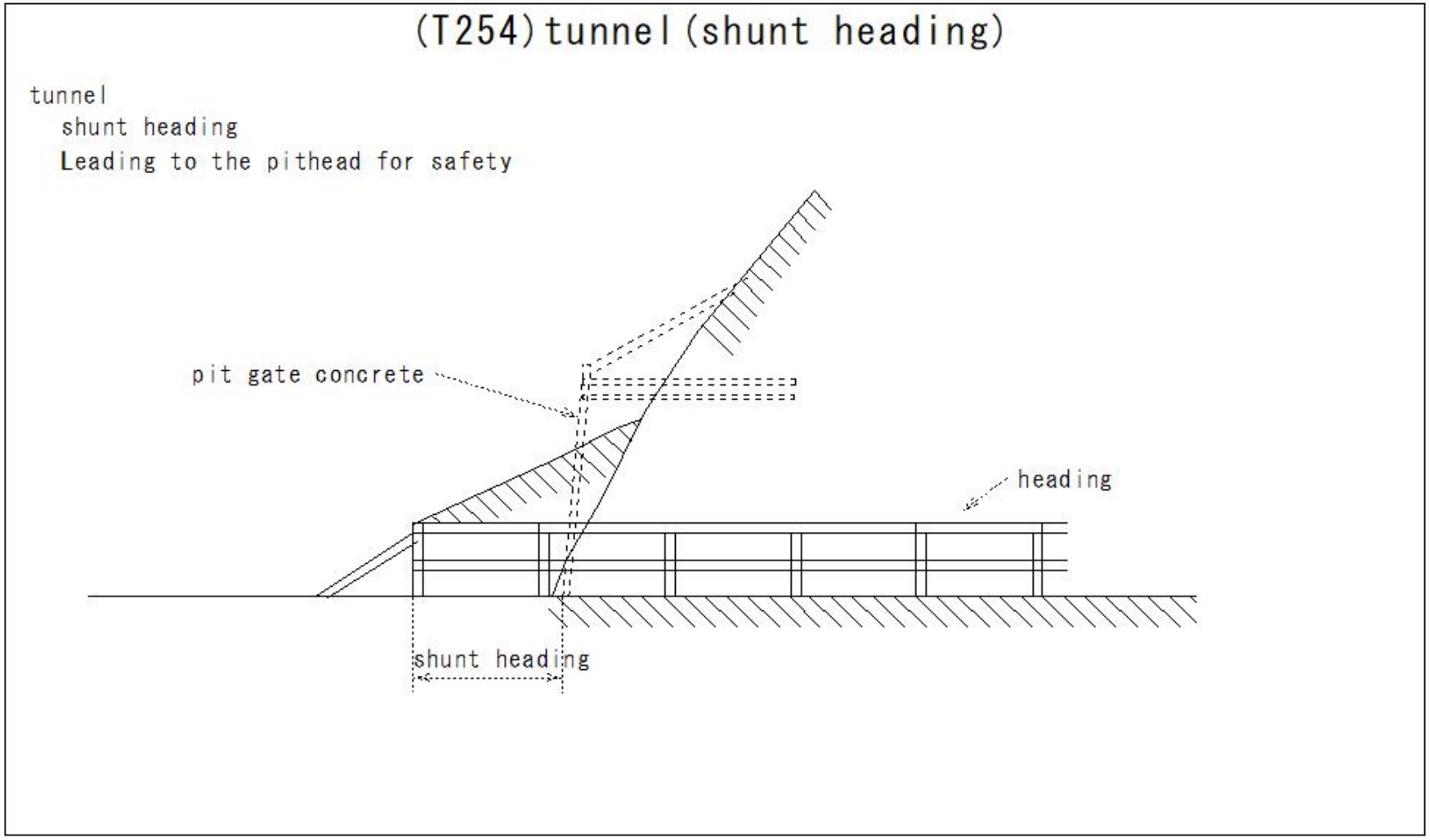
(T252)Concrete bed



（T253）open cut method



(T254)tunnel(shunt heading)



(T255)tunnel(mucking)

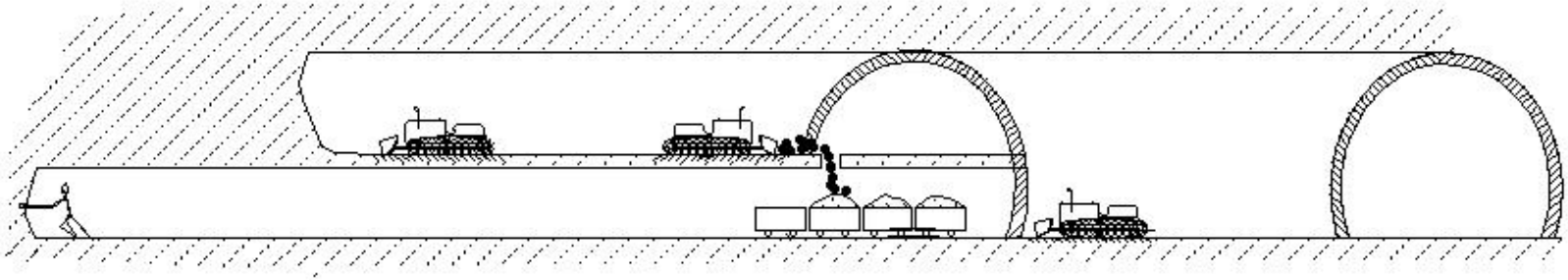
(T255)tunnel(mucking)

tunnel

mucking

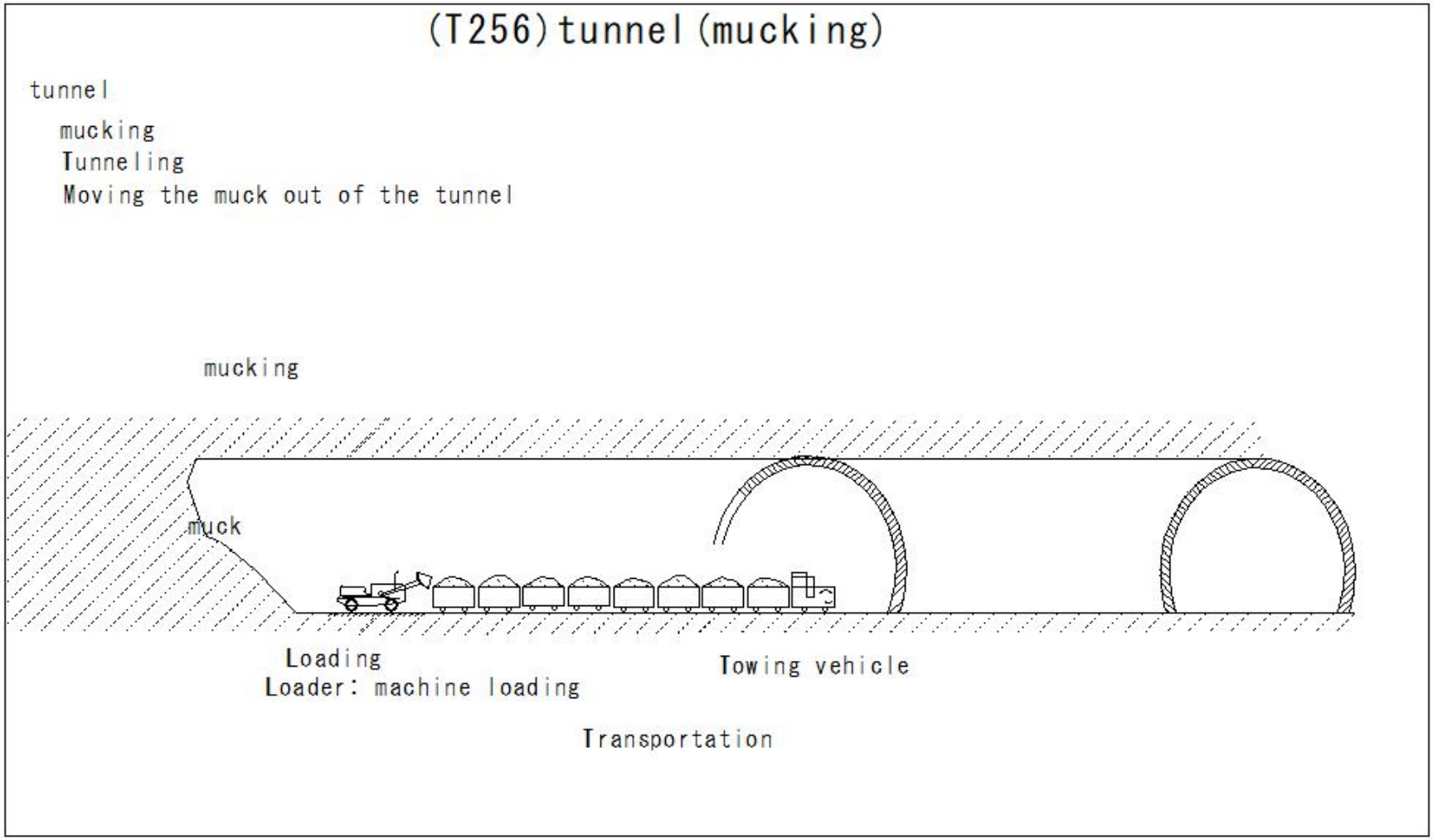
Tunnel excavation soil

Excavated soil for fracturing drilling

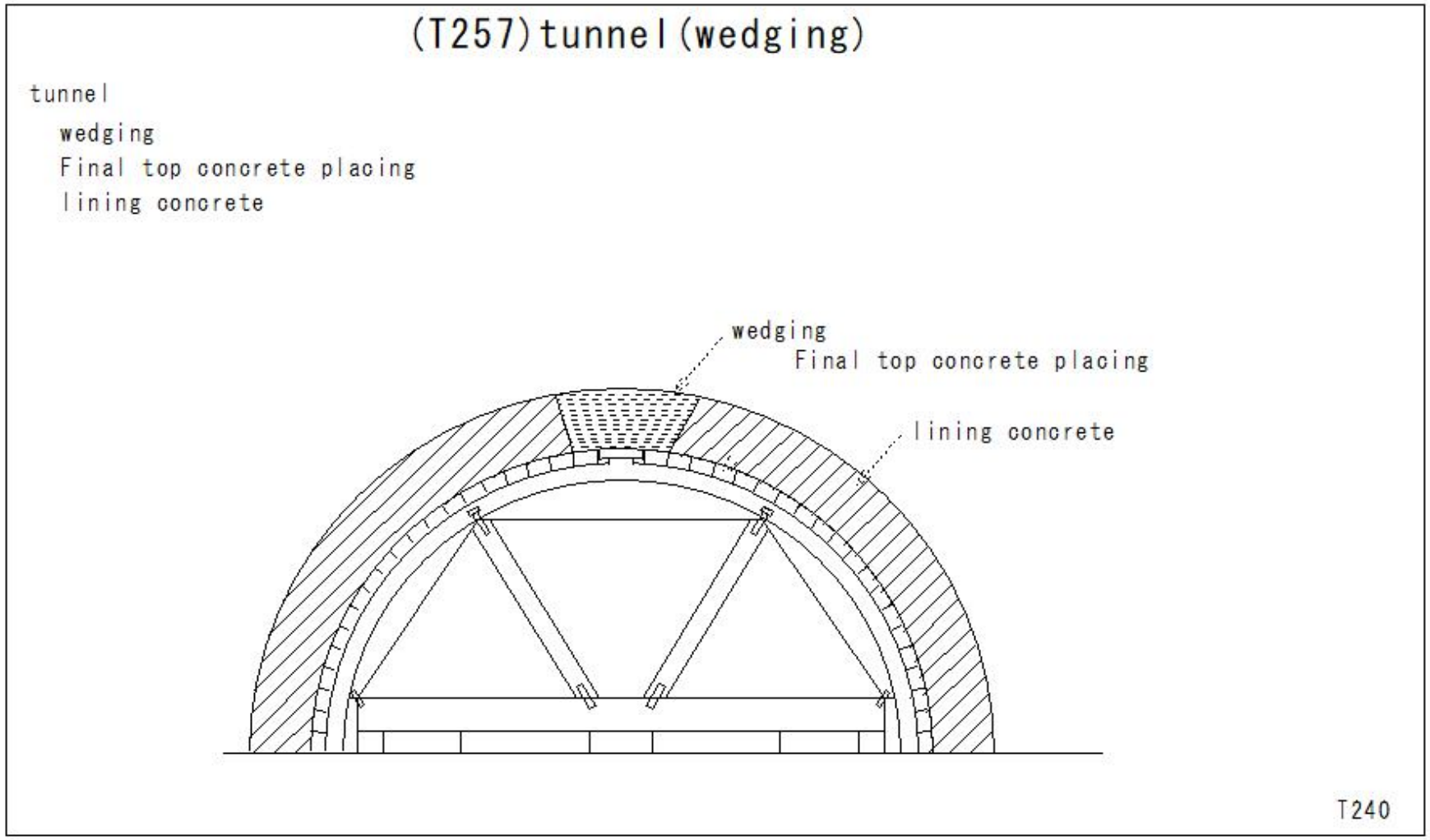


T45

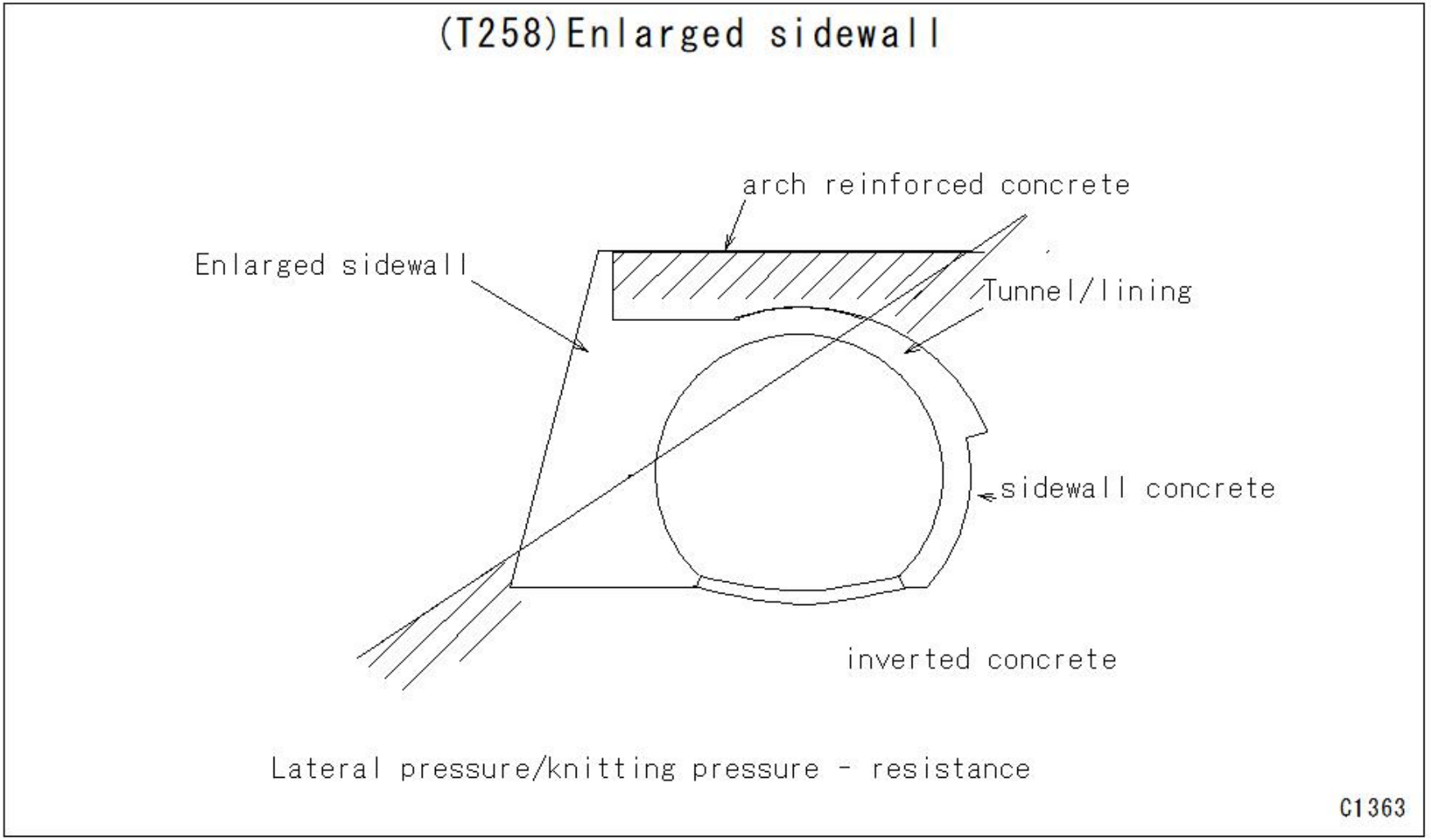
(T256)tunnel(mucking)



(T257)tunnel(wedging)



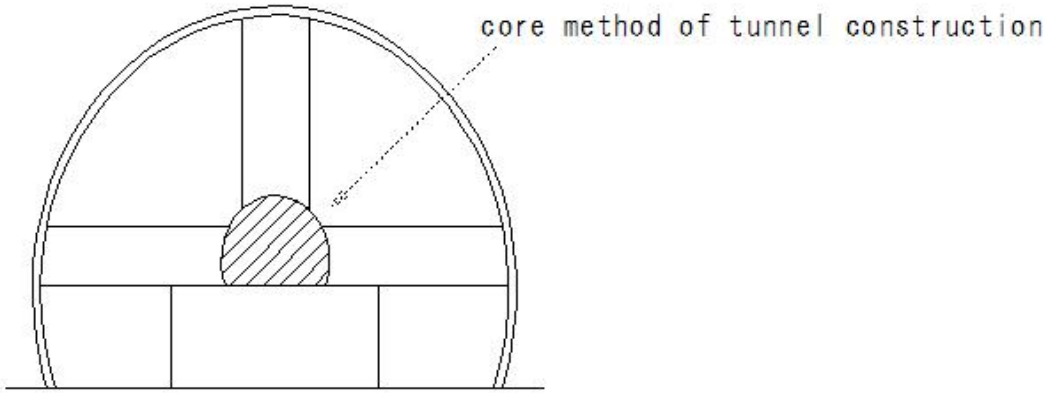
(T258)Enlarged sidewall



(T259)tunnel(core method of tunnel construction)

(T259)tunnel(core method of tunnel construction)

tunnel



(T260)tunnel(upraise)

(T260)tunnel(upraise)

tunnel

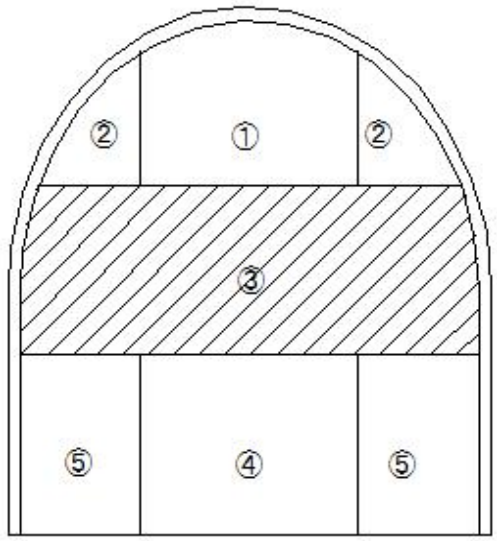
Tunneling surface

①top heading of tunnel construction

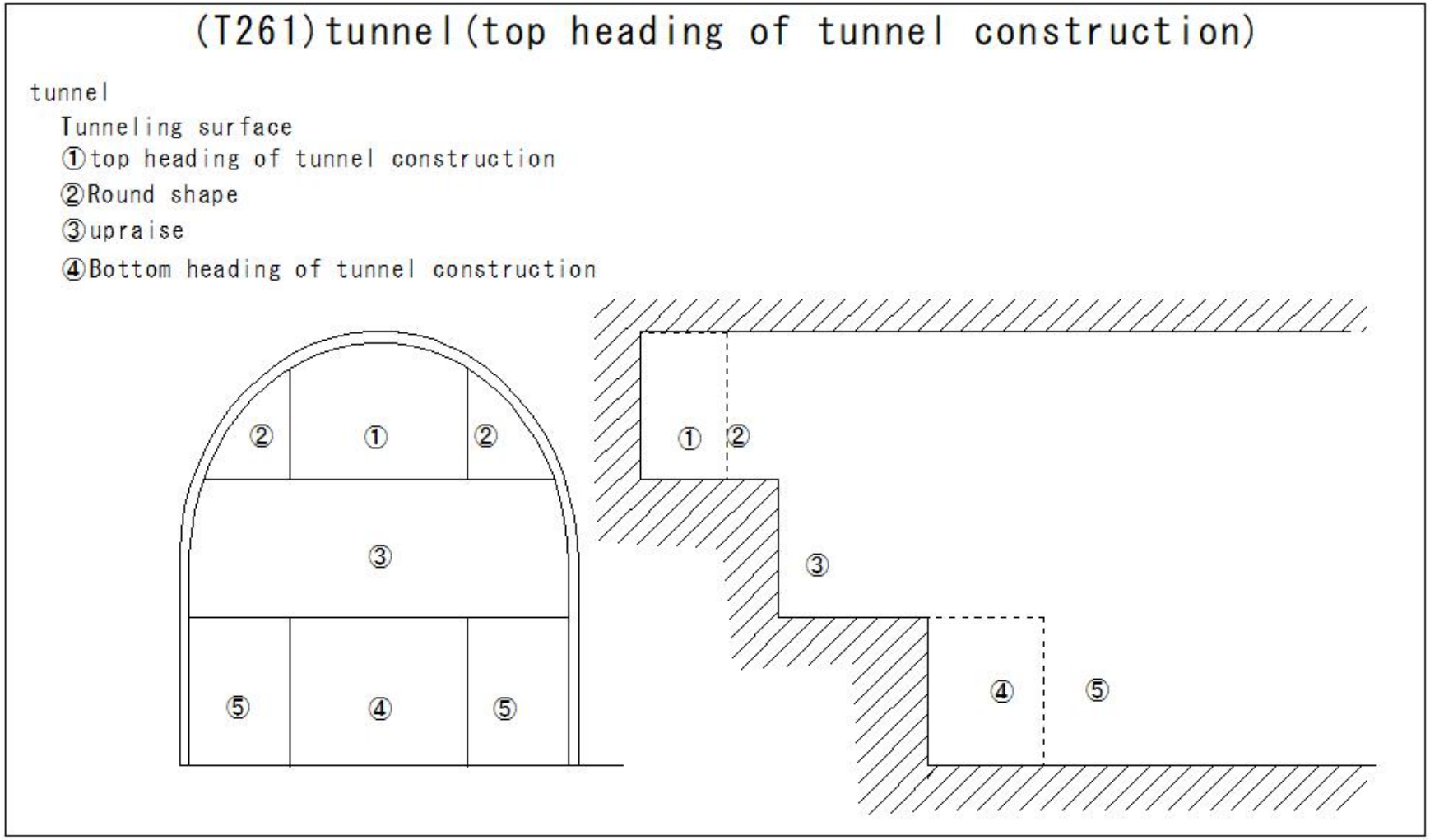
②Round shape

③upraise

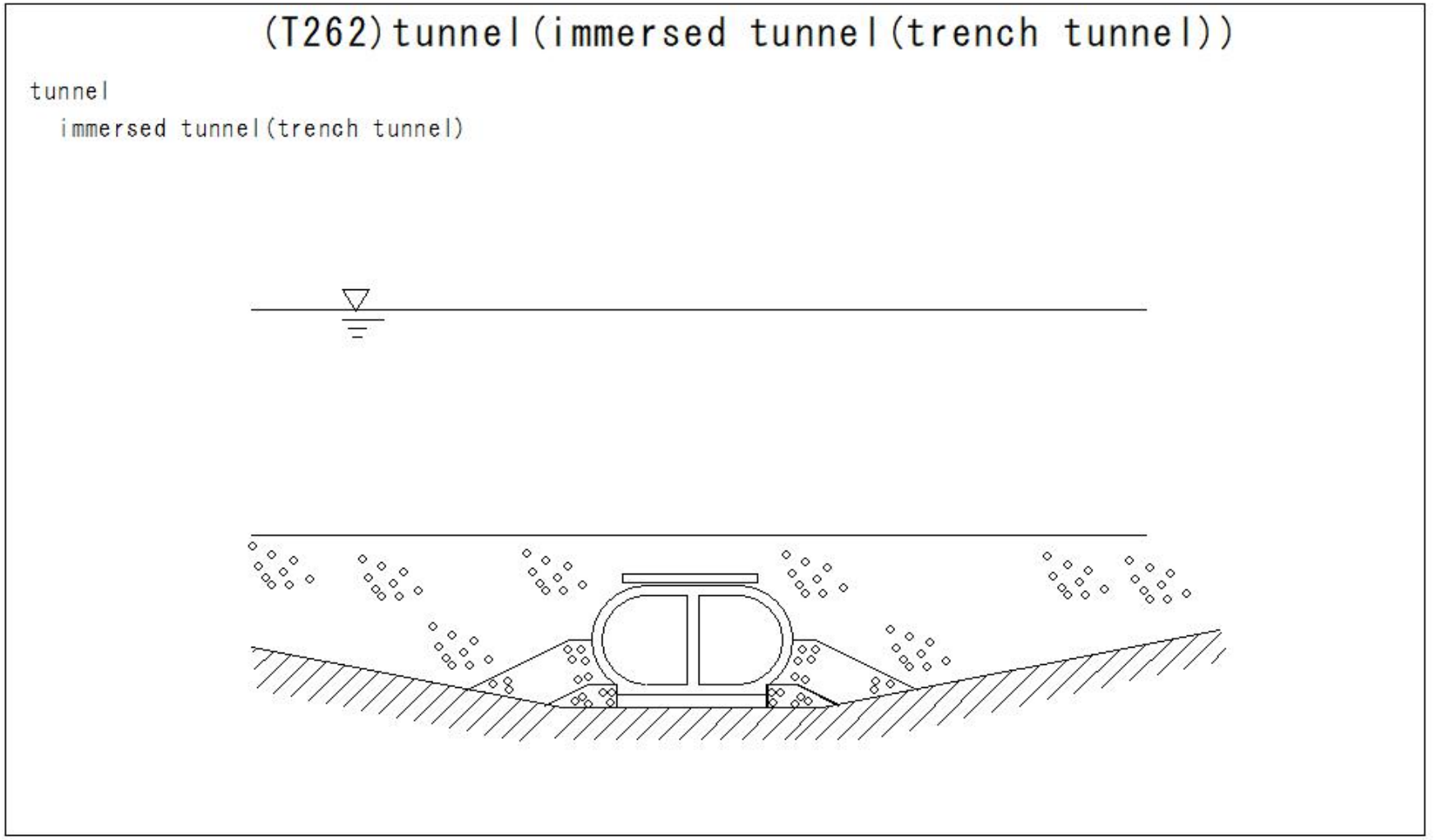
④Bottom heading of tunnel construction



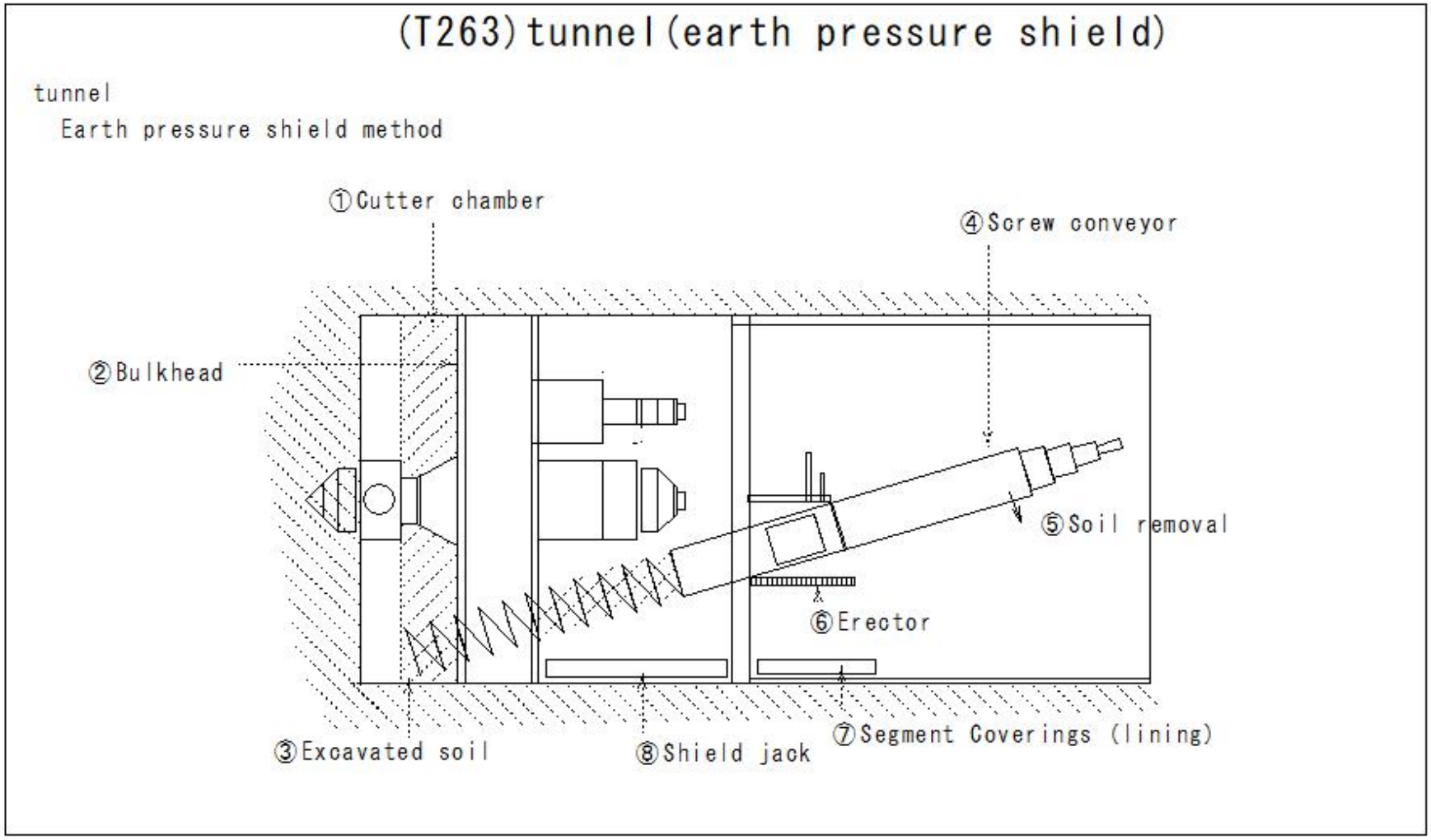
(T261)tunnel(top heading of tunnel construction)



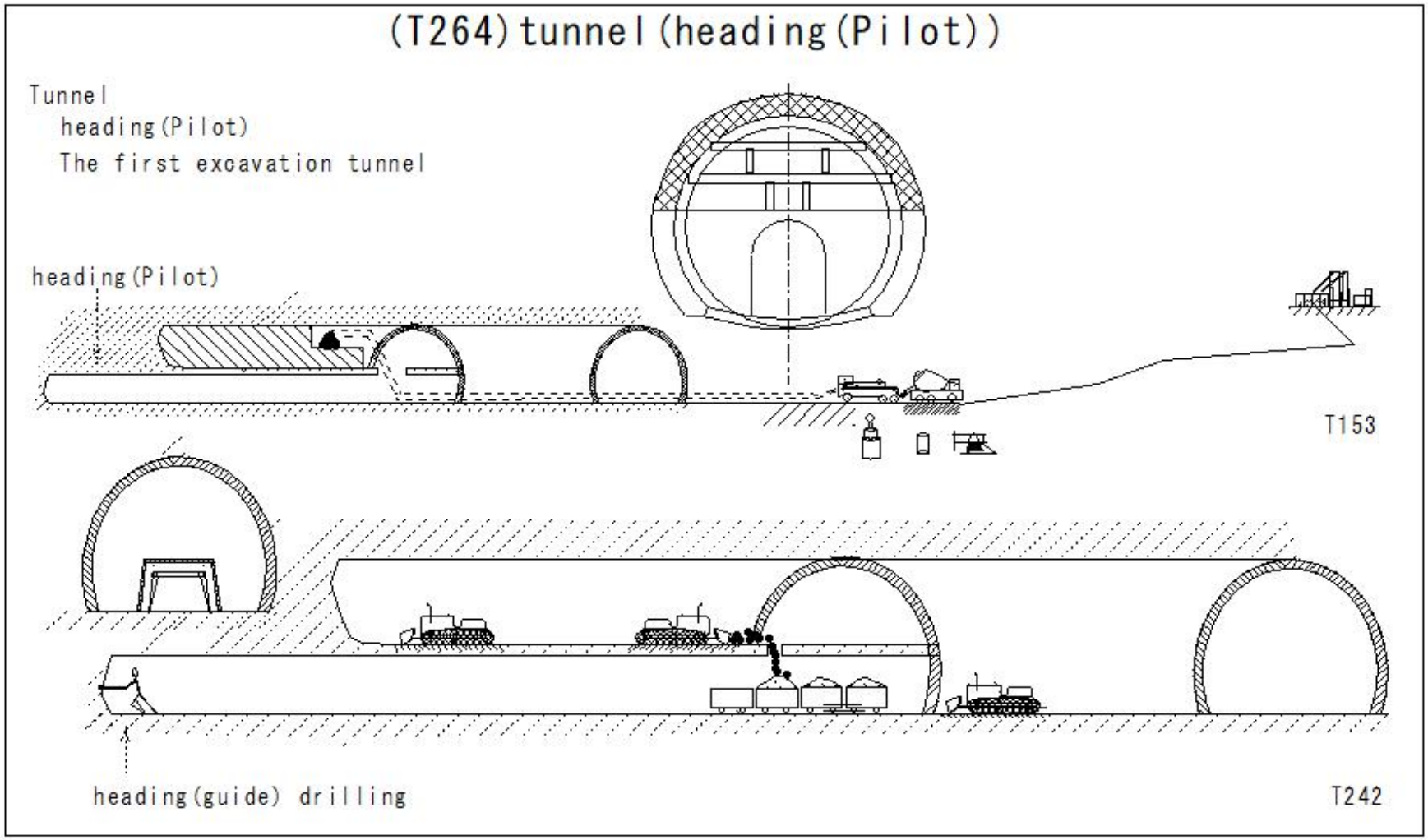
(T262)tunnel(immersed tunnel(trench tunnel))



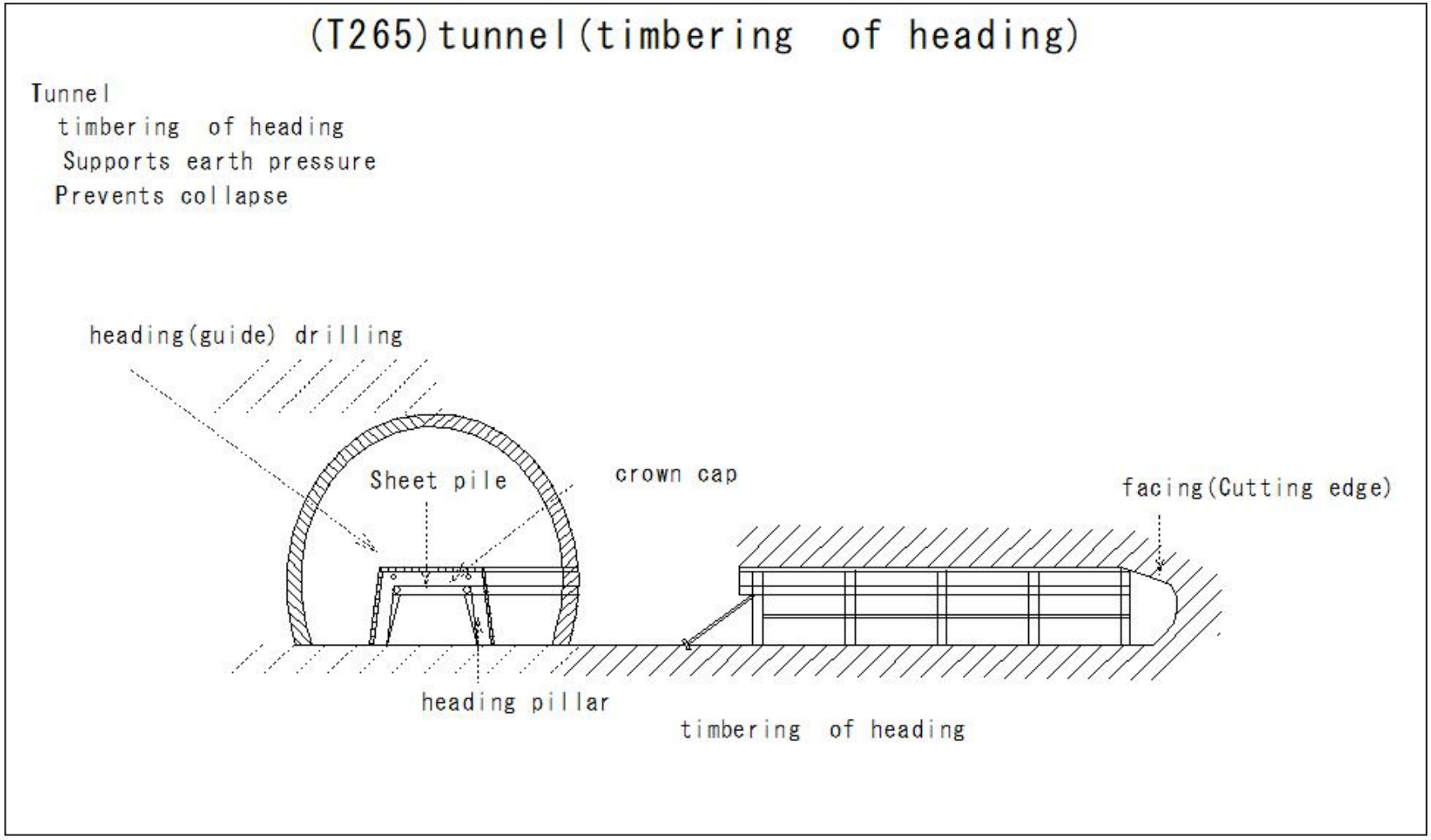
(T263)tunnel(earth pressure shield)



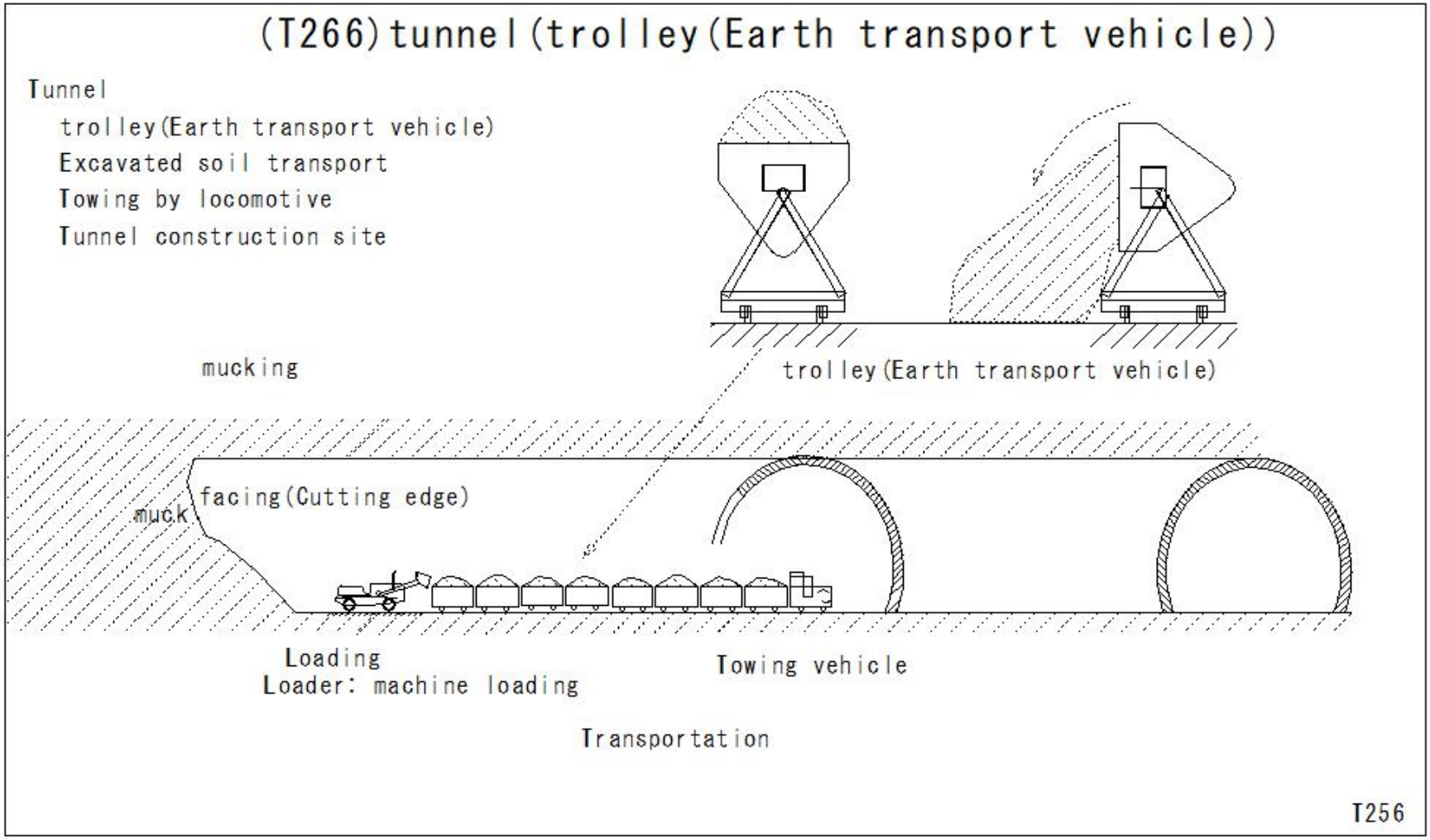
(T264)tunnel(heading(Pilot))



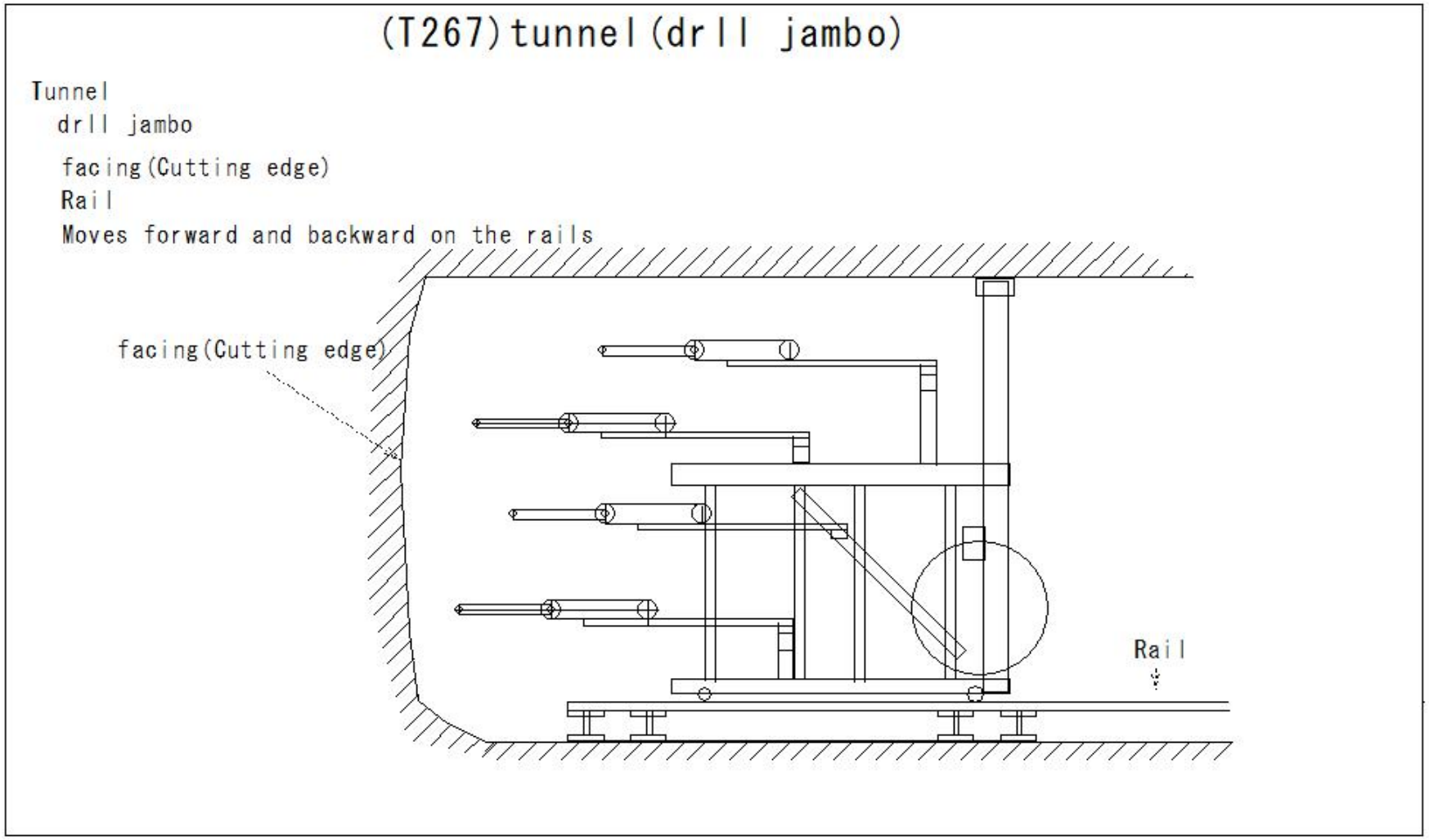
(T265)tunnel(timbering of heading)



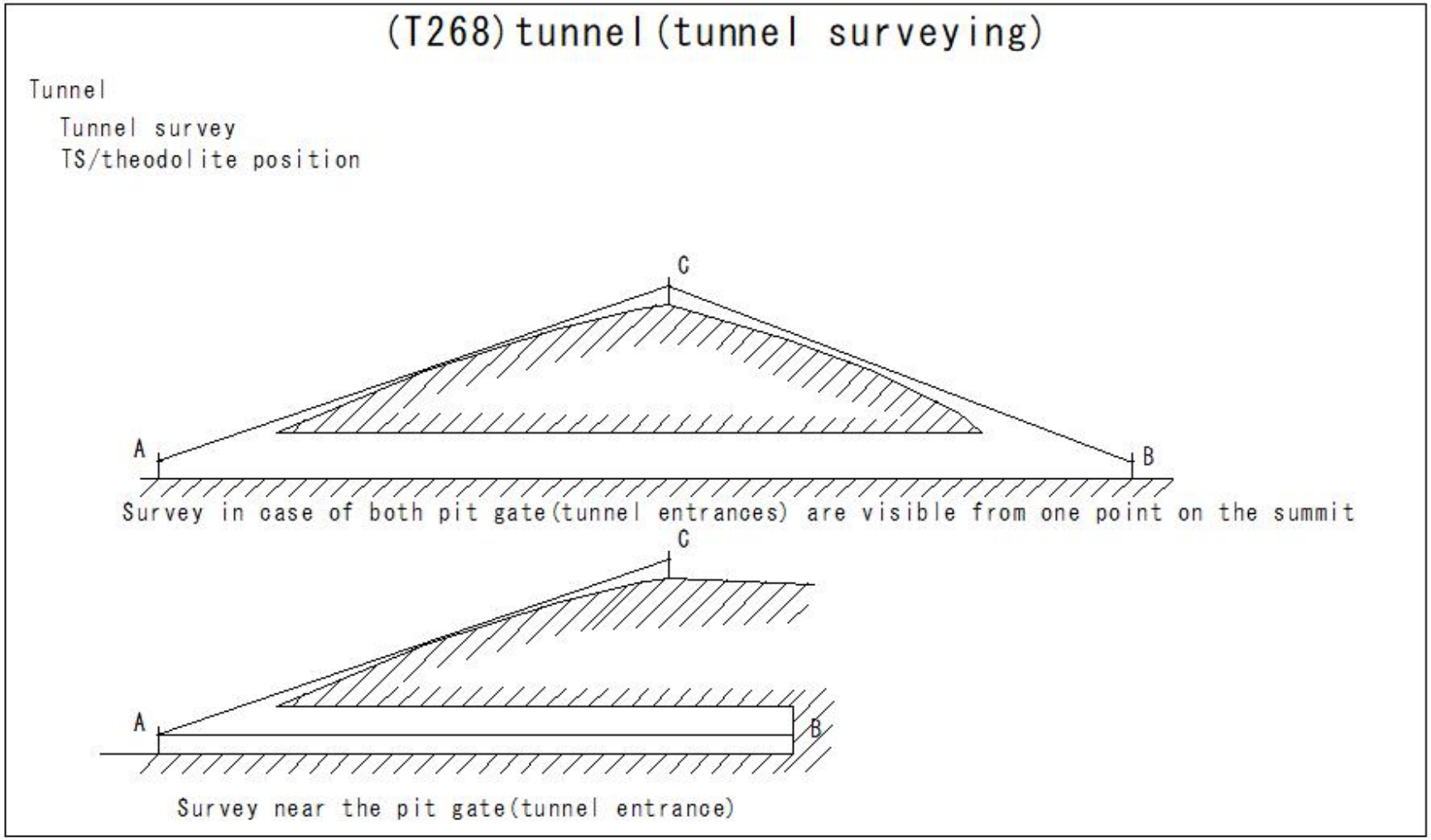
(T266)tunnel(trolley(Earth transport vehicle))



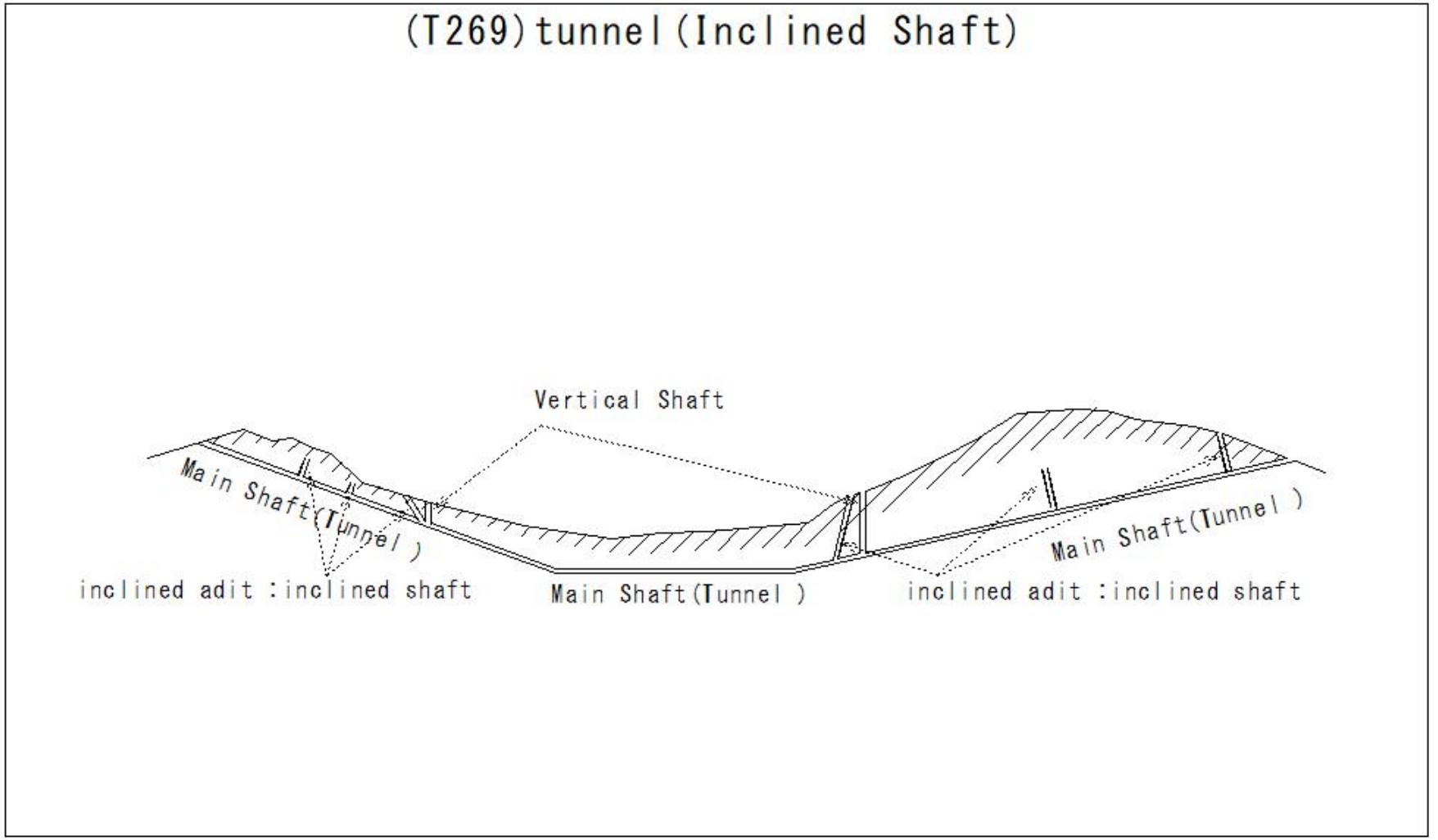
(T267)tunnel(drll jambo)



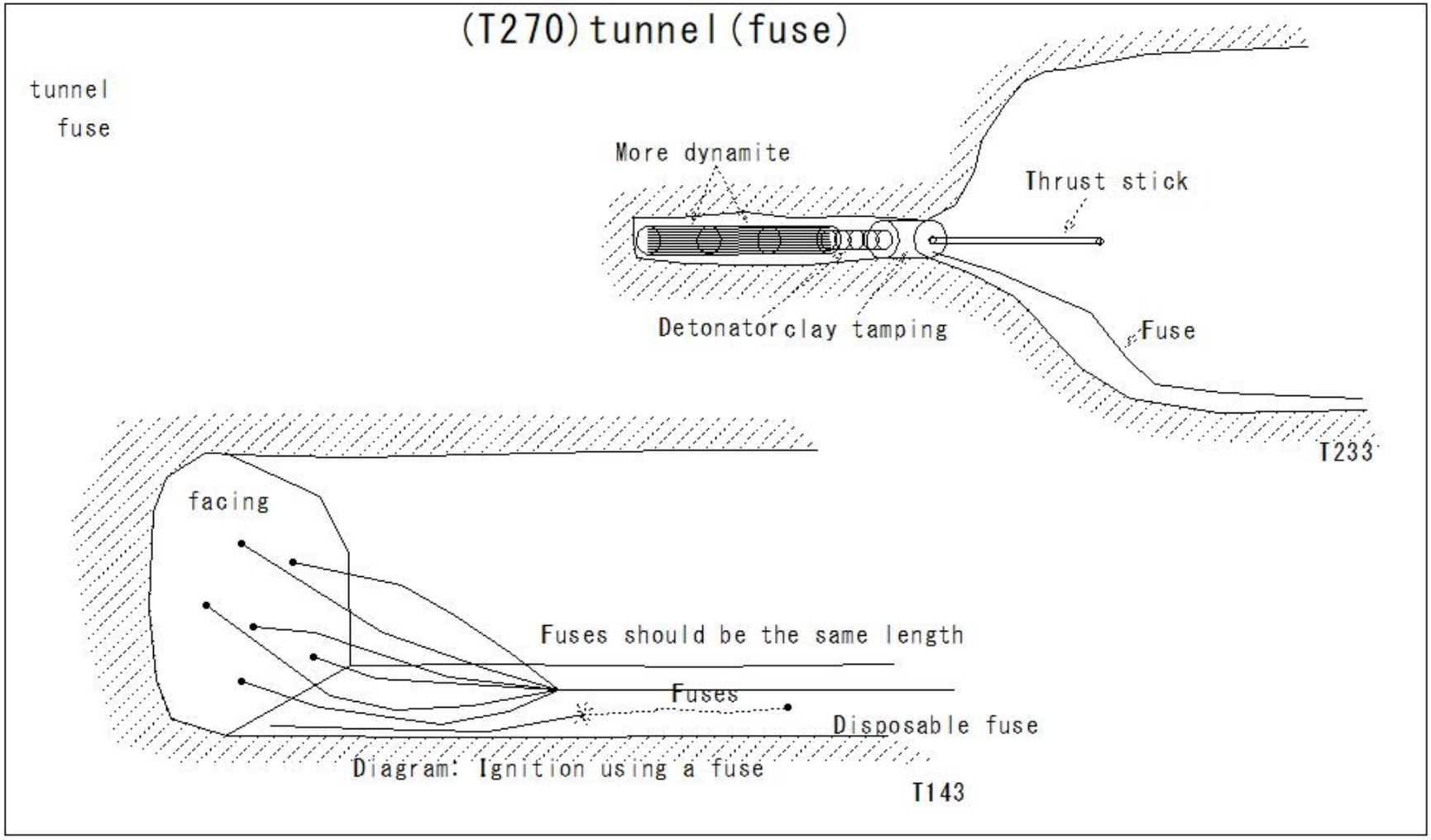
(T268)tunnel(tunnel surveying)



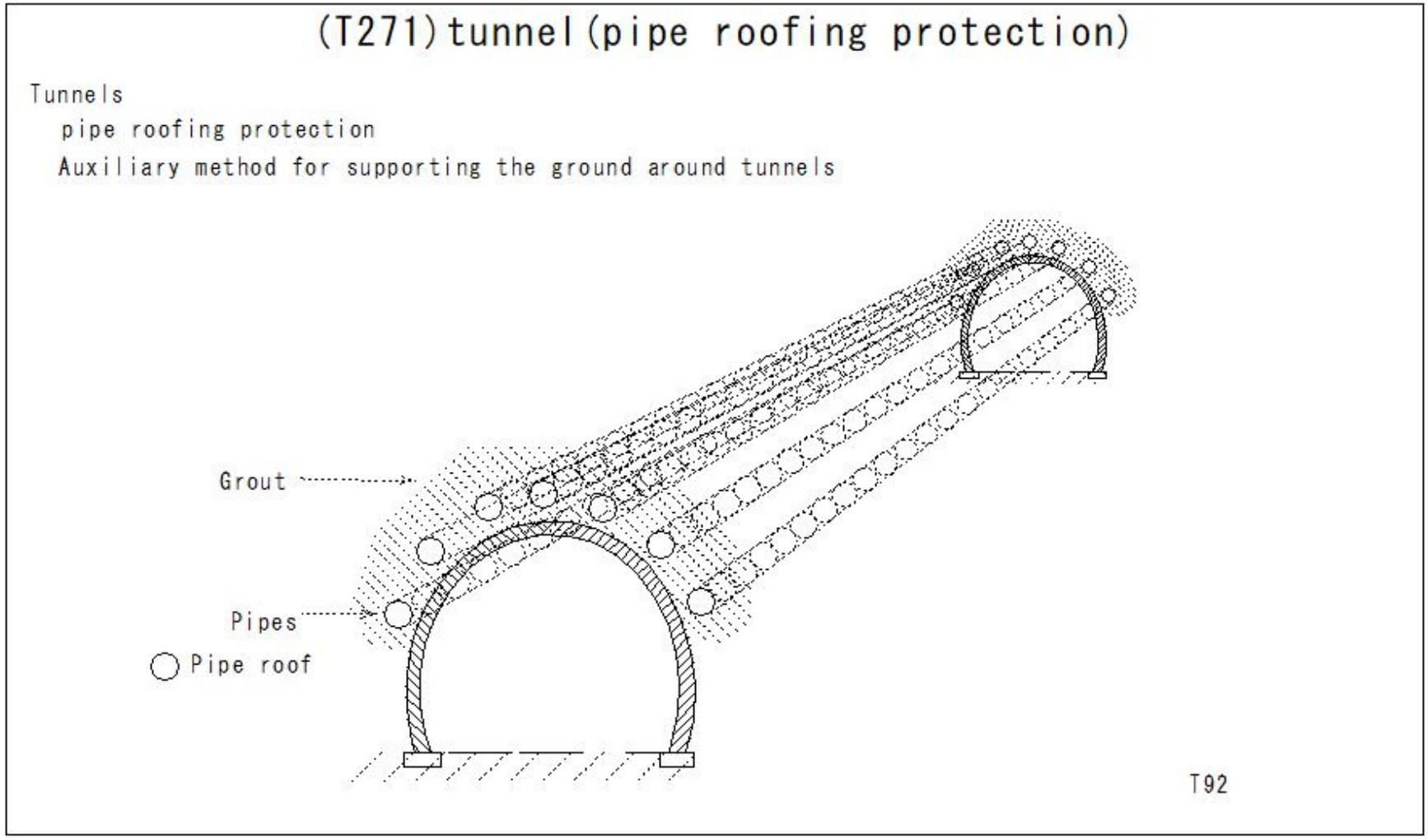
(T269)tunnel(Inclined Shaft)



(T270)tunnel(fuse)



(T271)tunnel(pipe roofing protection)



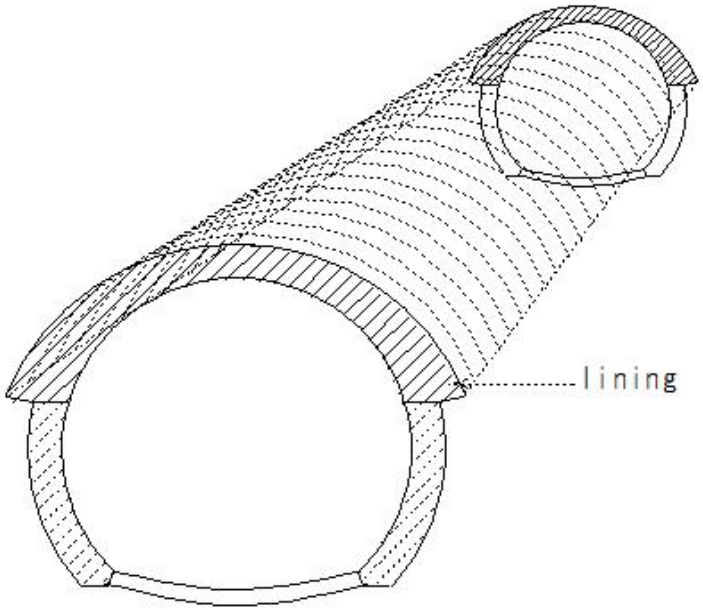
(T272)tunnel(lining)

(T272)tunnel(lining)

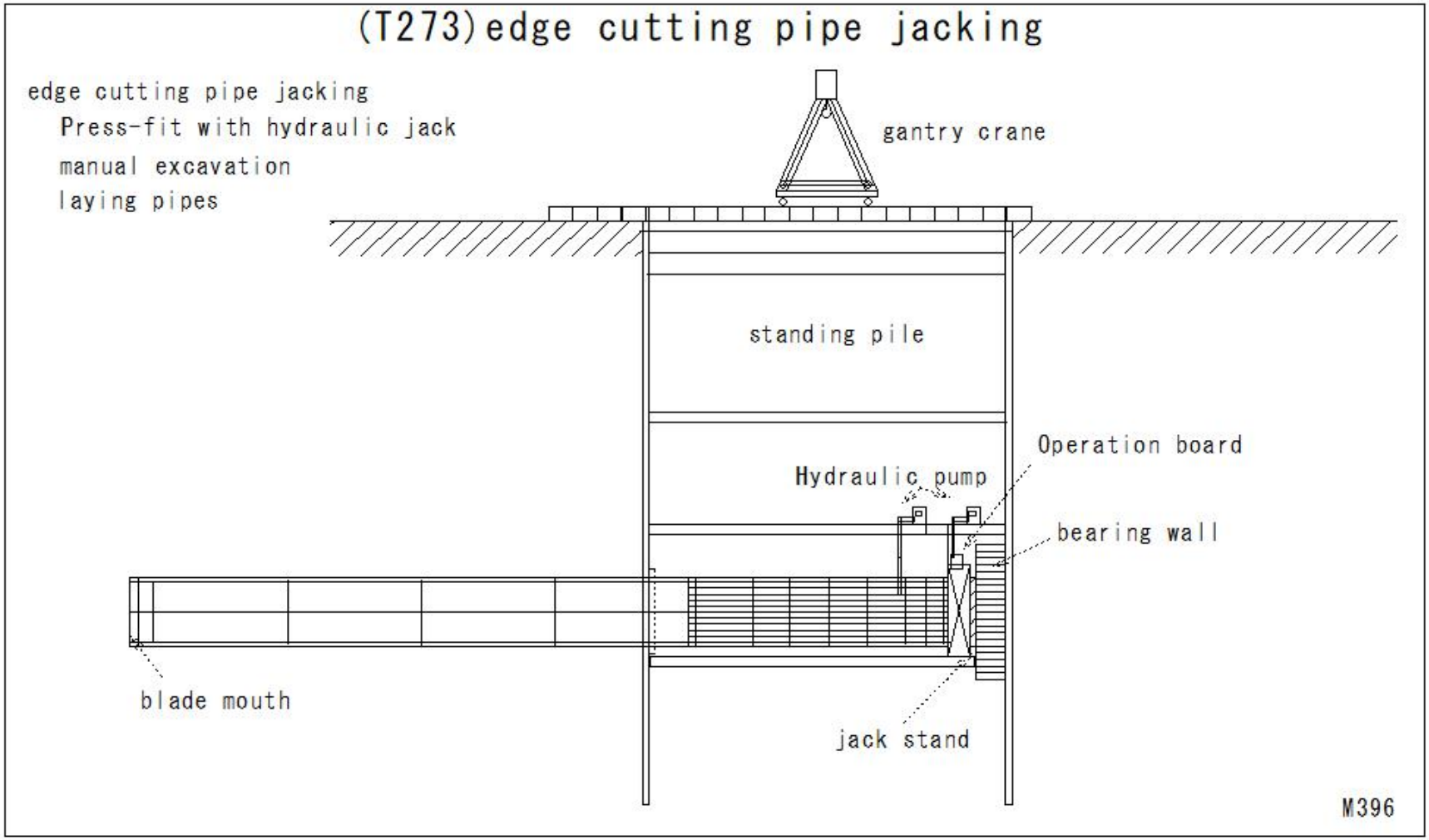
tunnel

lining

- Prevention of ground collapse
- Prevention of water leakage
- lining(Covering) the ground



(T273)edge cutting pipe jacking



(T274)Tunnel(half section excavation)

(T274)Tunnel(half section excavation)

Tunnel

Half-section excavation

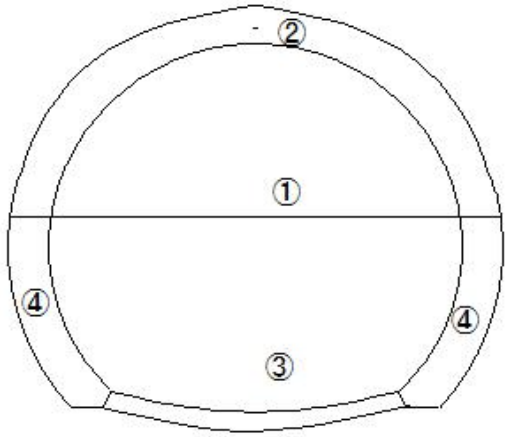
Construction order

①Excavate the upper half of the arch

②Coverings (lining) concrete

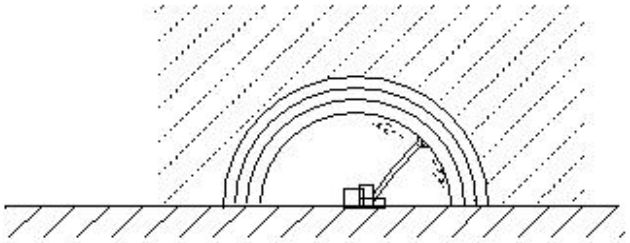
③Excavate the lower half

④lower Coverings (lining) concrete



(T275)Tunnel(shot crete)

(T275)Tunnel(shot crete)



tunnel

slope surface-stable

spraying

slope protection work

excavation surface

cement + sand+water

①Wet type

spraying - Perpendicular to face

②Dry type

cover for long distance transport

a lot of bounce

C1384

M400

(T276)Tunnel(bench cut method)

(T276)Tunnel(bench cut method)

Tunnels

bench cut method

Tunnel excavation method

Step excavation

Advantageous in case of the tunnel cross section is wide