Geotechnical Measurement
—Slope—

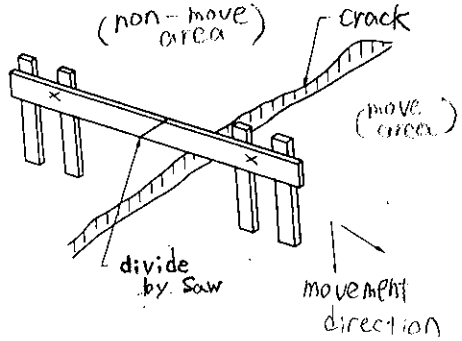
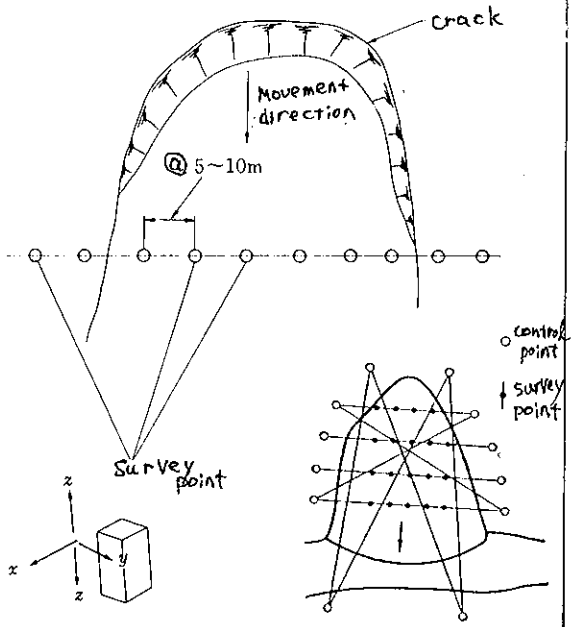
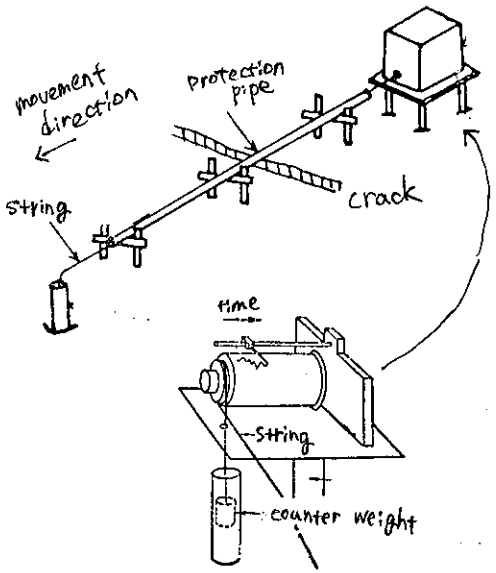
July, 2002

Lectured by;

M.Miyazaki

Geology Dept.
NIPPON KOEI CO.,LTD

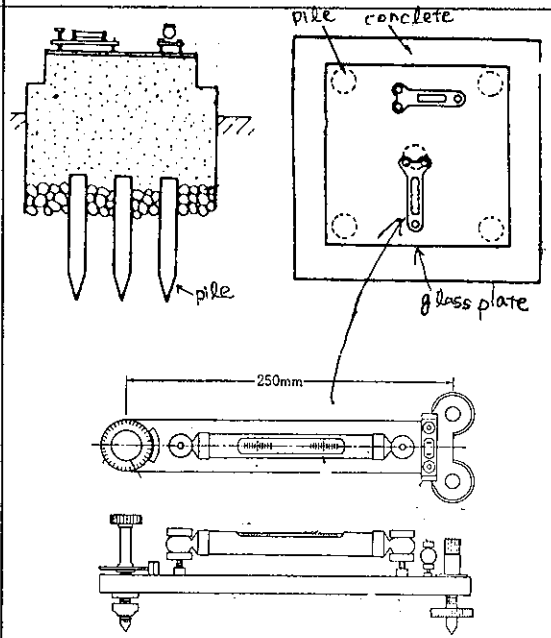
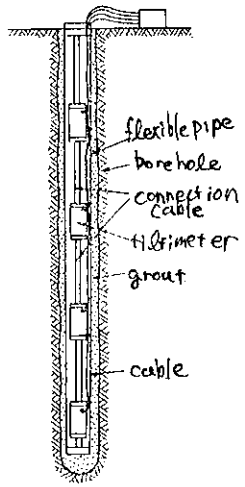
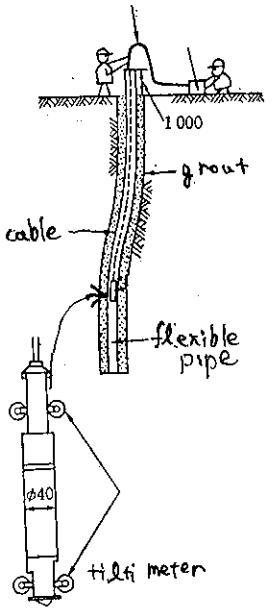
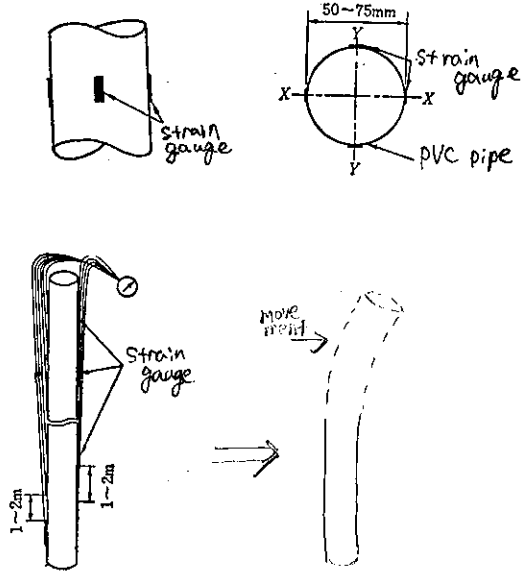
Table 1.1 Means or Equipments for Measurement (Slope)

Name		**Separate board(Japanese word "NUKI-ITA")**	**Survey point (by pile or pin) with topological survey equipment**	**Ground expansion meter**
Figure				
General Method		1.Put a board across a crack or gap 2.Divide the board by saw 3.Measure the separated distance between two boards	1.Put a pile or pin on immovable ground(control point) 2.Put a pile or pin in target area(survey point) 3.Measure	1.Put this equipment across a crack or gap 2.Expansion of string automatically protted
Target of Measurement		X and Z movement on ground surface	X,Y movement (with transit and steel measure tape *) or Z movement(with level *) on ground surface	One direction movement on ground surface
Range of Measurement		~1m	No Limit	~30cm
Accuracy		a few mm ~5mm	1mm	0.1~0.3mm
Merit		Very simple	Simple	Easy to get movement speed
Demerit		Not suitable for long-term measurement Not suitable for small movement ,under 1mm	Not suitable for small movement ,under 1mm	Can't measure for direction crossing string
Availability	on Investigation Stage	×	△	○
	on Construction Stage	△	○	◎
	on Maintenance Stage	×	○	○
	at Emergency Situation	○	○	◎
Possibility of Automatic Measure		×	×	○(Automatic only)
Note		Suitable for Big Movement	Suitable for Big Movement It's important to protect control and survey points ,especially for a control point. if total station, be careful for temperature	

*:inculde Total Station

SOURCE : Textbooks of JAPAN APPLIED GEOLOGY ASSOCIATION and JAPAN GEOTECHNICAL ENGINEER ASSOCIATION

Table 1.2 Means or Equipments for Measurement (Slope)

Name		**Ground tiltimeter**	**Underground tiltimater**		**Underground strain gauge with pipe**
			fixed type	**non-fixed type (insert type)**	
Figure					
General Method		1.Put a board across a crack or gap 2.Divide the board by saw 3.Measure the separated distance between two boards	1.Vertical borring 2.Put a flexible pipe into borehole and grout between hole and pipe. 3.Set equipment (fixed type).		1.Vertical borring 2.Put a PVC pipe with strain gauge into borehole
Target of Measurement		X and Y inclination movement on ground surface	X movement undergroud		One direction movement on ground surface
Range of Measurement		-	According to movable range of flexible pipe (~several 10 cm)		—
Accuracy		1 s	1mm		—
Merit		Detail	Detail,especiary fix type		Very sensitive
Demerit		A little difficult to set this equpment fixed	In case of fix type, the equipmet is buried. so expensive.		Not suitable a numerical measurement
Availability	on Investigation Stage	○	△	○	○
	on Construction Stage	○	△	○	△
	on Maintenance Stage	○	△	○	△
	at Emergency Situation	△	×	×	△
Possibility of Automatic Measure		△	○	×	△
Note			Straightness of borehole has big inflence on accuracy Flexible pipe must be move with groud. So grout milk must have same strength with ground		Use only for judgement the depth of landslide

SOURCE : Textbooks of JAPAN APPLIED GEOLOGY ASSOCIATION and JAPAN GEOTECHNICAL ENGINEER ASSOCIATION

Tablr.2 Standard criteria on Construcion and Maintenance Stage I(slope)

<Construction Stage>

		Be Careful or install additonal measurement	Discussion countermeasure	Caution and do urgent countermeasure	Refuge temporary
Ground expanssion metter	Movement speed on ground surface	>5mm/10days *1	5～50mm/5days	10～100mm/1day	>100mm/1day
Survey of point					
Underground tiltimater	Movement speed underground (near slip face)	>1mm/10days	5～50mm/5days	- *2	-
Underground strain gauge pipe	Accumulation	>100 μ	1000～5000 μ	-	-

<Maintenance Stage>

		Be Careful or install additonal measurement	Discussion countermeasure	Caution and do urgent countermeasure; Disucussion to close traffic	Refuge temporary; Close traffic
Ground expanssion metter	Movement speed on ground surface	>10mm/30days	5～50mm/5days	10～100mm/1day	>100mm/1day
Survey of point					
Underground tiltimater	Movement speed underground (near slip face)	>1mm/10days	5～50mm/5days	-	-
Ground tiltimeter	Accumulation	10～50s/10days	-	-	-

* 1: '5mm/10days' does not mean '0.5mm/1day' .

*2: '- ' means 'Out of measurement range'

SOURCE : Textbooks of JAPAN HIGHWAY CONSTRUCTION COMPANY

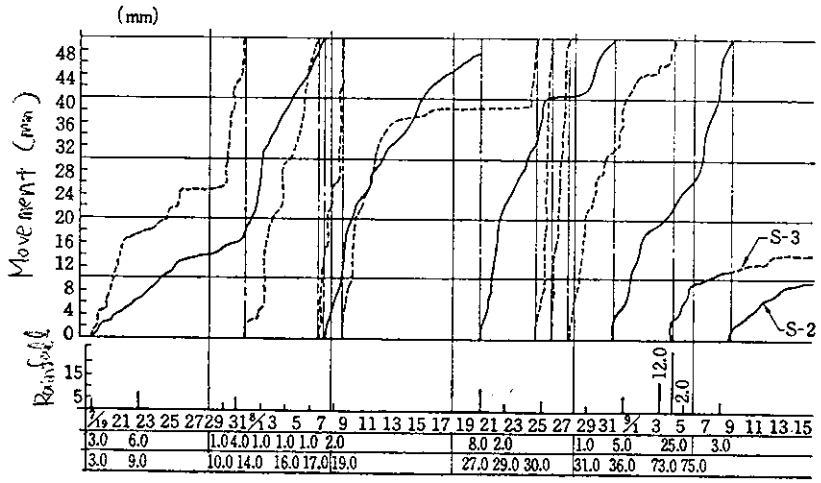


Figure.1 Sample Record of Ground Expansion Meter

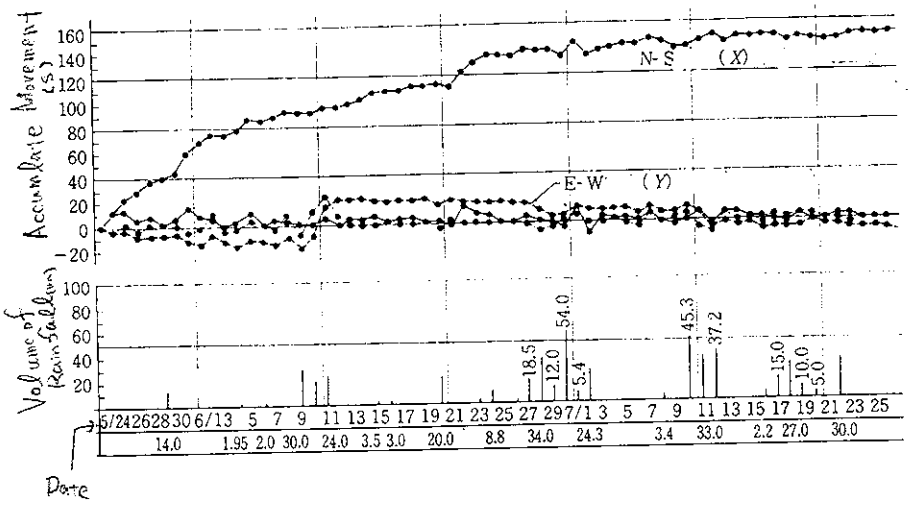
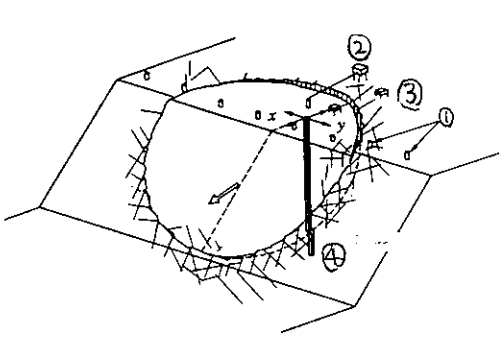
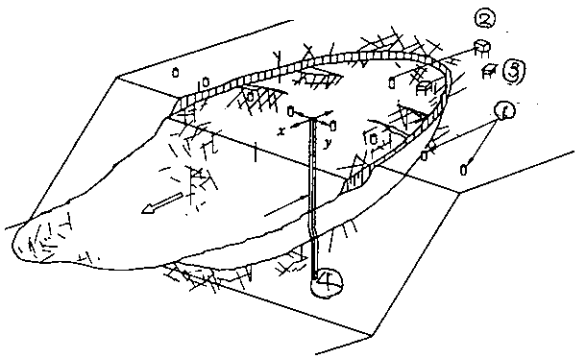


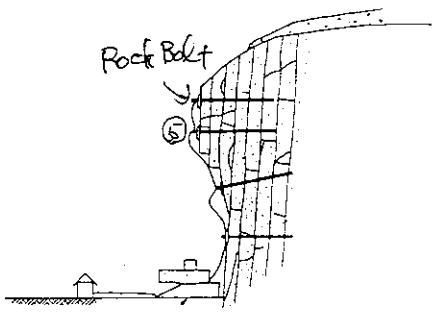
Figure.2 Sample Record of Ground Tiltimeter

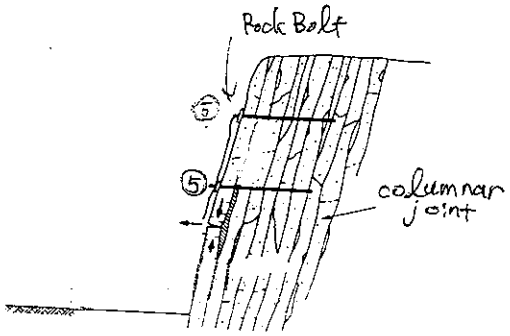
NOTE! At geotechnical measurement, it is very important to record not only movement itself but also the volume of rain fall and to connect this two data.





(ex.
Access Road to Powerhouse)





(ex.
Work Adit PI)

Figure.3 Models of Slope Disaster and Examples of Measurement Equipment

① Survey Point
② Ground expansion meter
③ Ground tiltimeter
④ Underground tiltimeter
⑤ Load strength meter on Rock Bolt

Geotehnical Measurement

—Tunnel—

July,2002

Lectured by;

M.Miyazaki

Geology Dept.
NIPPON KOEI CO.,LTD

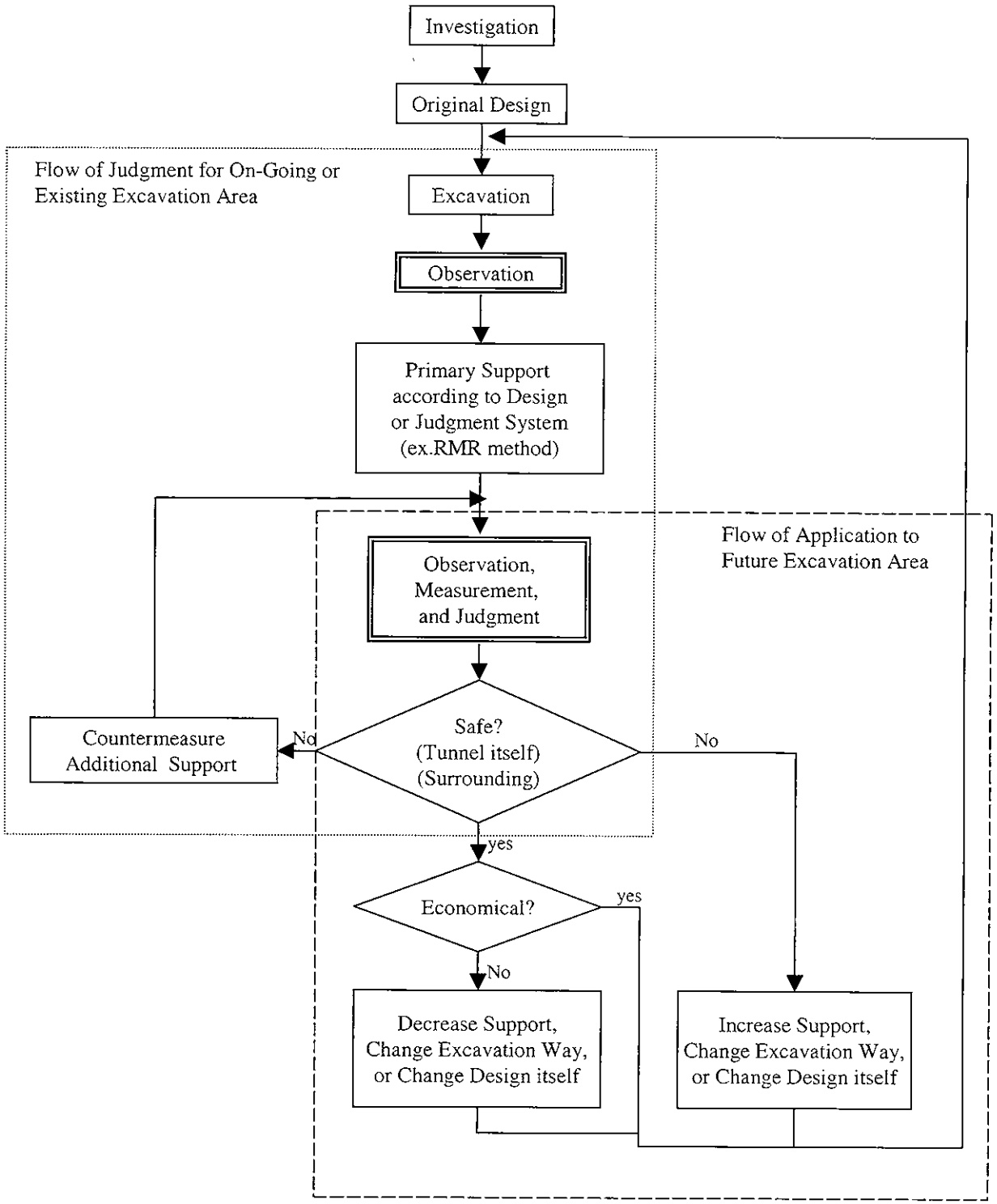
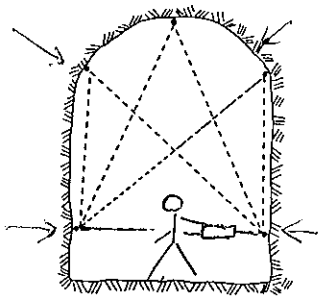
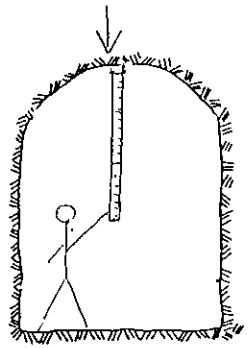
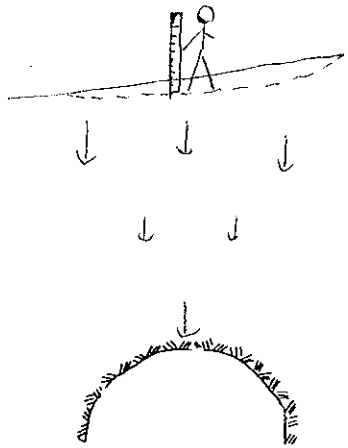
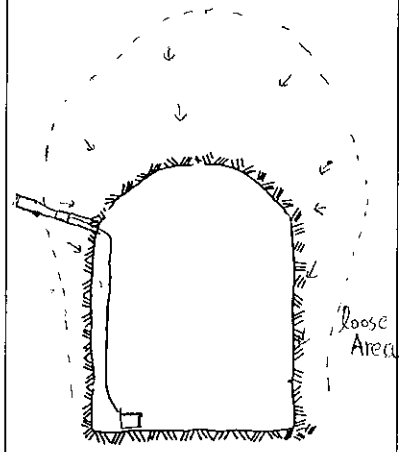
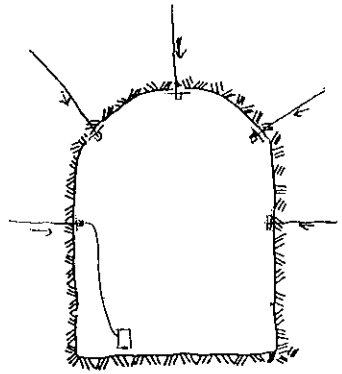


Figure 1. Flow Chart of Tunnel Excavation with Measurement

Table.1 Measurement Item (Tunnel)

Item		**Reduction of Distance between Tunnel Walls**	**Subsidence of Tunnel Crown**	**Subsidence of Ground Surface**	**Deformation inside Ground**	**Load on Rock Bolt**
Figure						
Equipment		Convergence measure Tape extensometer (see figure 3)	level	level	Incremental extensometer Rod extensometer Dial gauge etc.	Disk load cell Center hole load cell Rock bolt with strain gauge etc.
Use for		Stability of surrounding ground Effect of support Timing of lining concreting	Stability of surrounding ground	Stability of surrounding ground and other construction	Stain distribution around tunnel Loose range around tunnel Suitability of rock bolt length	Suitability of rock bolt length,number, position and fixing method
necessity	(1)	◎	◎	△	△	△
	(2)	◎	◎	△	△	△
	(3)	◎	◎	△	◎	◎
	(4)	◎	◎	◎	○	△
	(5)	◎	◎	◎	○	○
	(6)	◎	○	○	○	△
Note						especially useful for NATM method

(1) Hard rock ground (except fault zone) , (2) Soft rock ground (without plastic ground pressure), (3) Soft rock ground (with plastic ground pressure), (4) Soil ground
(5)Thin earth covering, (6)Around portal and danger area of slope disaster

◎:necessary, ○:desirable, △:as the need arises,

SOURCE : Textbooks of JAPAN TUNNEL ASSOCIATION and JAPAN CIVIL ENGINEER ASSOCIATION

Table.2 General Trend for Measurement (Accumlate Volume)

	Reduction of Distance between Tunnel Wa	Subsidence of Tunnel Crown	Subsidence of Ground Surface
Hard rock ground (except fault zone)	<10 mm 10 ~ 100 mm (earth covering <2D or with large crack on rock surface) Convergence at 1~2D backward from excavation surface		—
Soft rock ground (without large plastic groundpressure)	<20mm Convergence at 1~2D backward from excavation surface		<20mm (earth covering <2~3D)
Soft rock ground (with large plastic groundpressure)	10~100mm Convergence at >3D backward from excavation surface		
Soil ground	<20mm	<100mm	<100mm

	Deformation inside Ground	Load on Rock Bolt
Hard rock ground (except fault zone)	<10mm Loose range around tunnel:1~2m	<5ton
Soft rock ground (without large plastic groundpressure)		
Soft rock ground (with large plastic groundpressure)	10~100mm Loose range around tunnel:>3m	15~25ton possibilty for destruction of rock bolt
Soil ground	<10mm Loose range around tunnel:>3m, affect to subsidence of ground surface	<5ton

SOURCE : Asakura(1982)

This tunnel include "Soil" (Sandy Silt) and "Soft Rock(without large plastic groundpreasure)" (other).

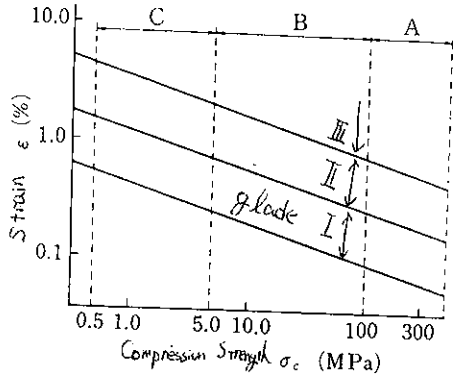
Table.3 Standard Criteria for Reduction of Distance between Tunnel Walls

Grade	Criteria		Countermeasure
	Speed of Reduction	Observation Factor	
1	>5mm/1day(on excavation surface)	Small crack on shotcreate surface Small water ingress	Report to responsible engineer
2	>10mm/1day(on excavation surface) >5mm/1day(backward of excavation surface)	Large crack on shotcreate surface Large water ingress	Report to responsible engineer Additonal rock bolt or shotcreate
3	Accelerate	More than Glade 2	Report to the responsible engineer Stop excavation Additonal long rock bolt or steel rib support Additional Investigation

SOURCE : Franklin(1976)

	Upper Criteria for Accumlate Volume of Reduction	
	Rock Mass Classfication I (very soft rock, near clay or sand) (need core leaving)	II～V (harder than I)
Single-Track Line (H5.1m × D4.7m)	25～75mm	<25mm
Double-Track Line (H6.4m×D8.5m)	50～150mm	<50mm
*In this Site	Sandy Tuff	other rock

SOURCE : Yoshikawa et al.(1983)



Upper Criteria for Accumlate Volume
(Tunnel Radius: 5.00m)

	A	B	C
I	0.3～0.5	0.5～1	1～3
II	1 ～1.5	1.5～4	4～9
III	3 ～4	4 ～11	11～27

(cm)

Figure. 2.1 Standard Criteria for Subsidence of Tunnel Crown

SOURCE :Textbook of JAPAN TUNNEL ASSOCIATION (Sakurai(1983))

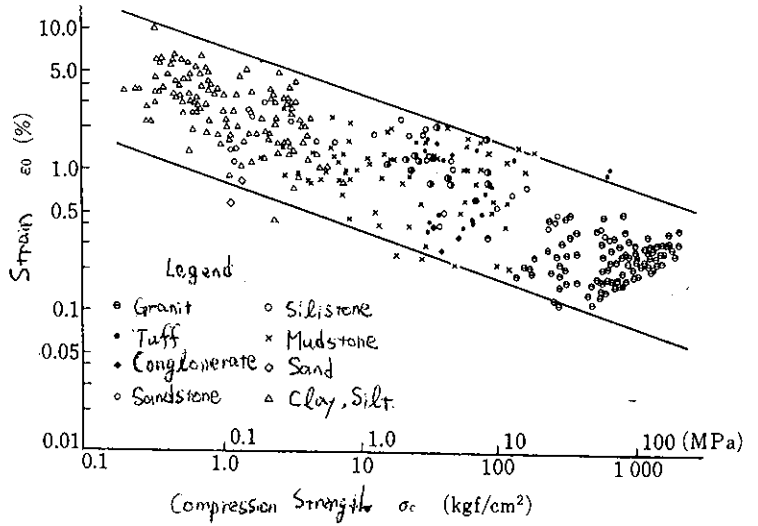


Figure 4.2 Relationship between Compression Strength and Strain

NOTE! : These criteia are general and temporary because each tunnel has different situation.
We must revise these criteria according to observation and measrurement.

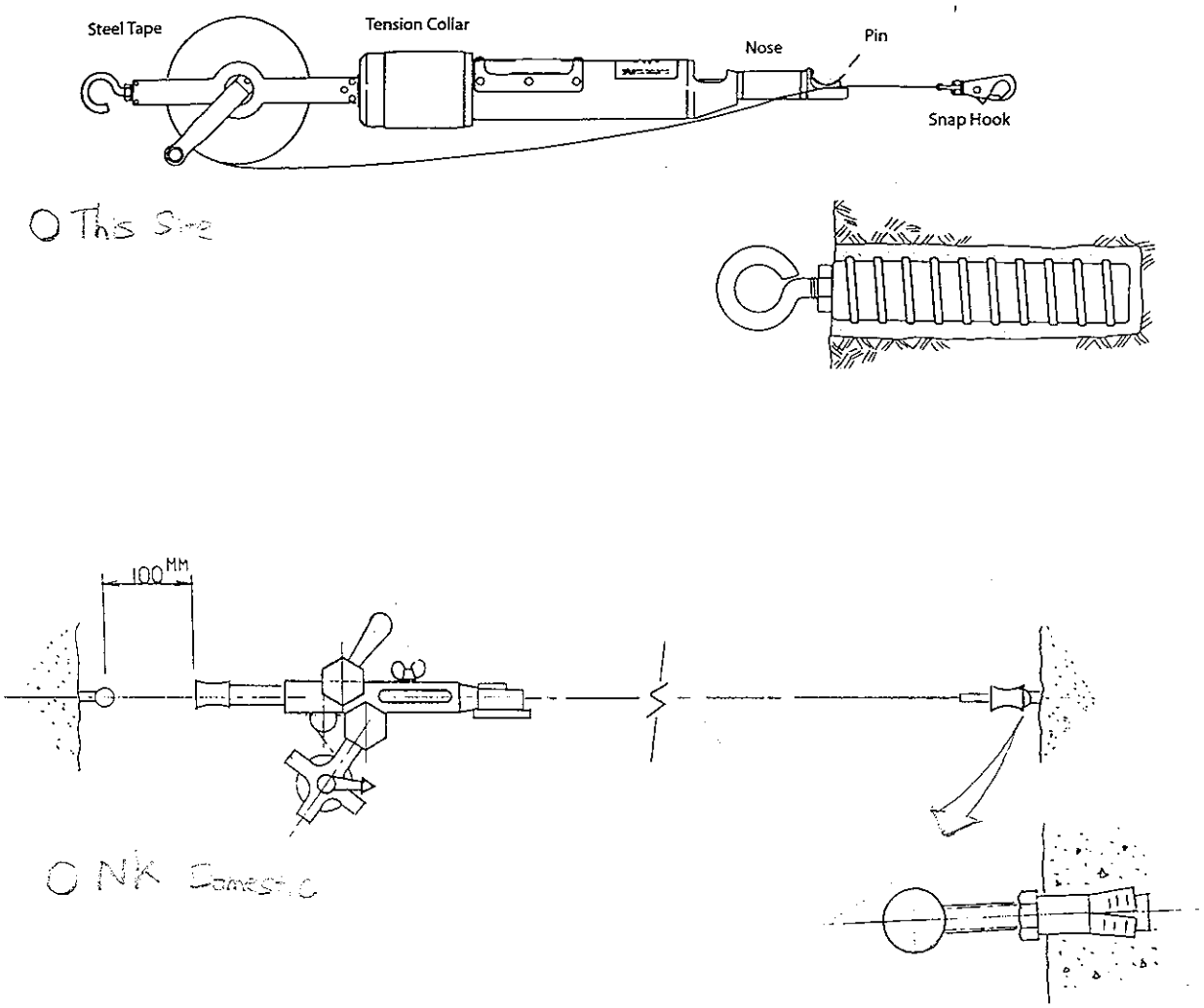


Figure.3 Measurement Equipment for Reduction Distance between Tunnel Walls

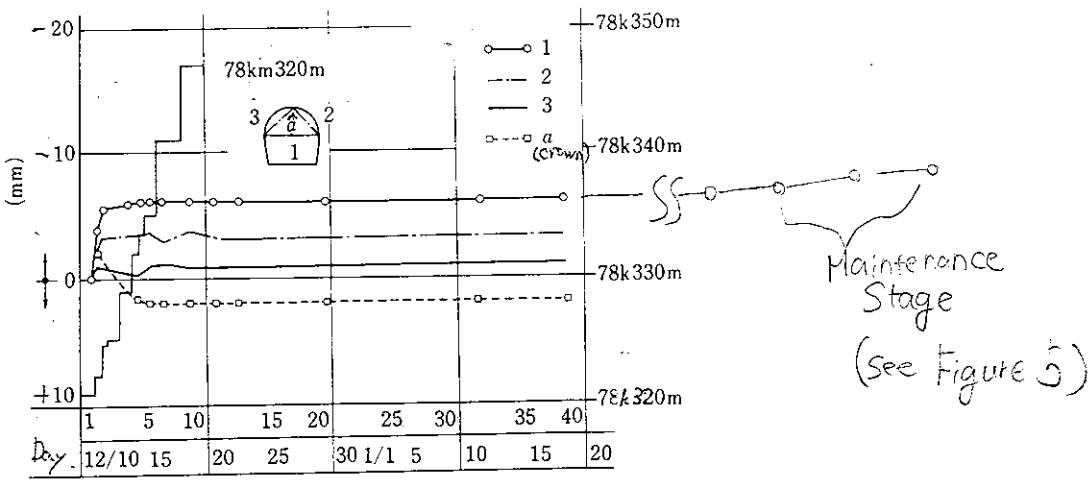
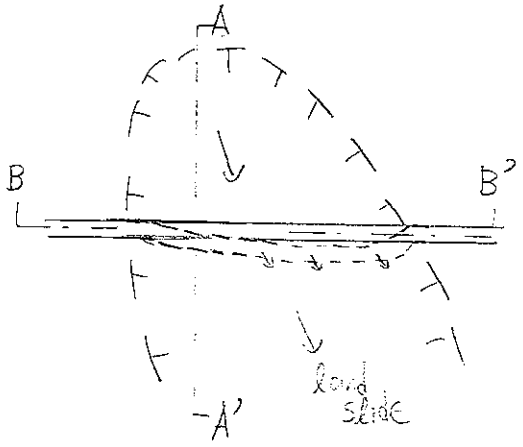


Figure.4 Sample Record

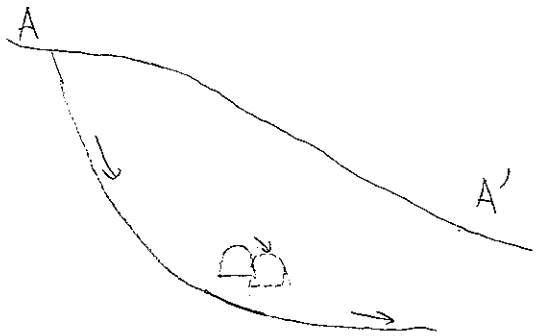
Appendix – Introduction of Tunnel Maintenance Case.

(1) α (alpha) HEPP Tunnel (Japan)

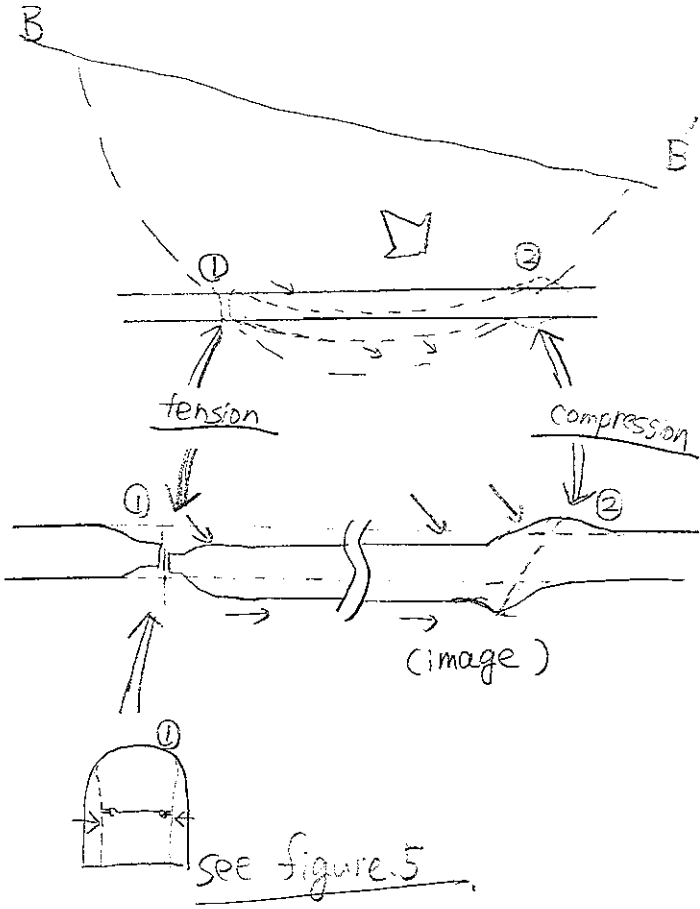
◦ Plan



◦ Cross Section (A-A')



◦ Longitudinal Profile (B-B')



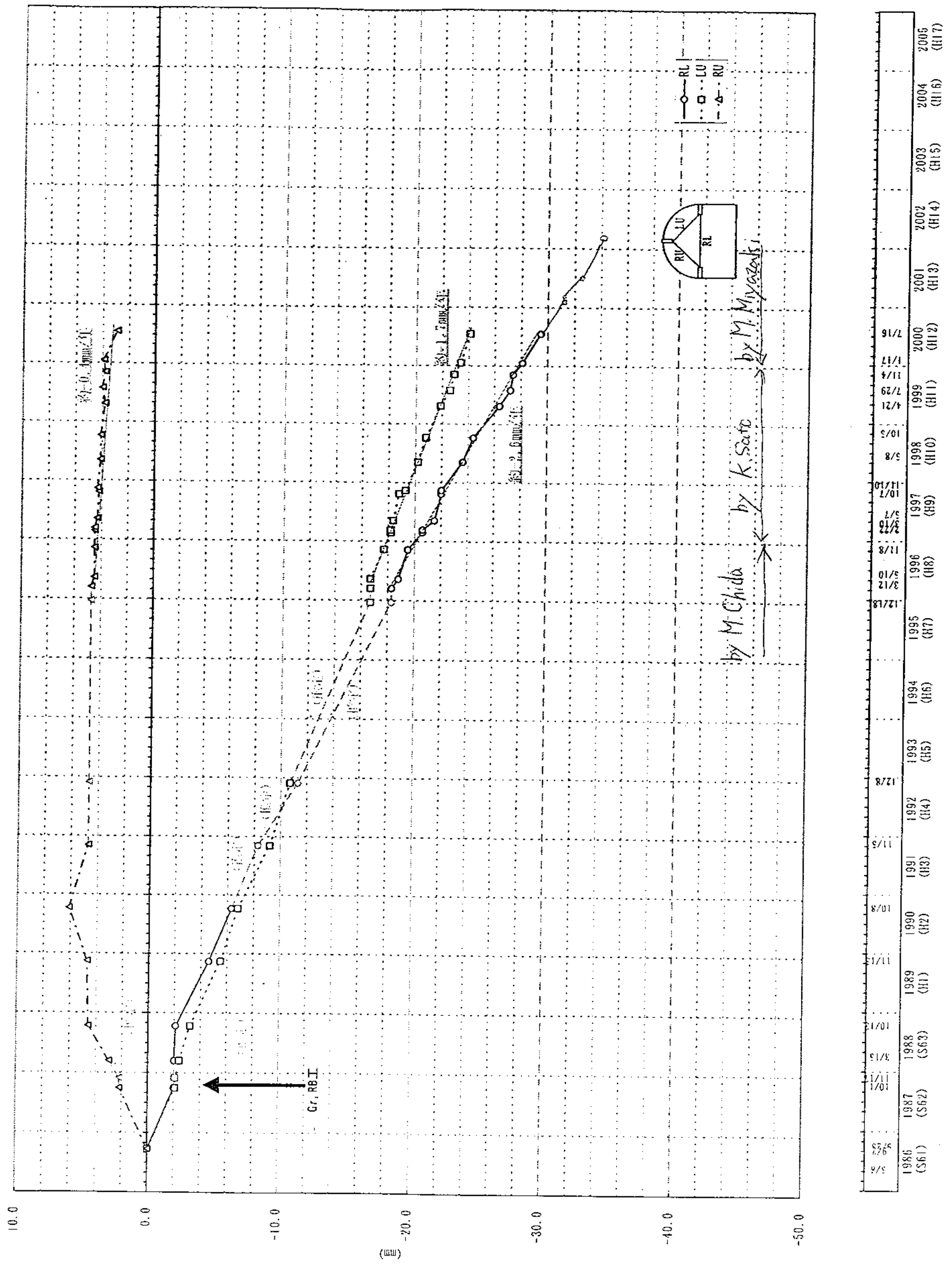
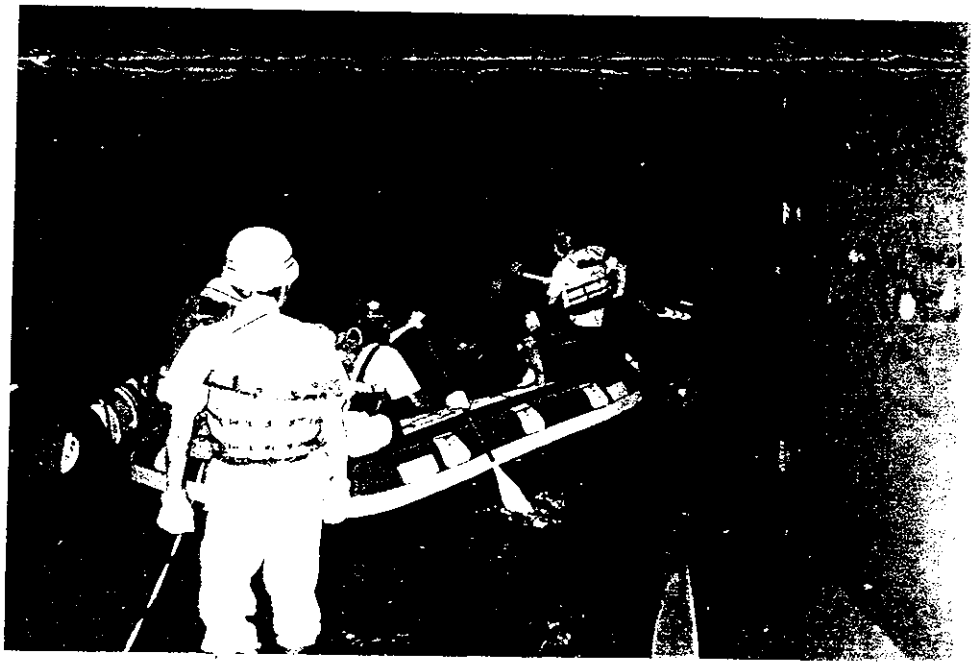


Figure. 5. Measurement on Maintenance

TST-1

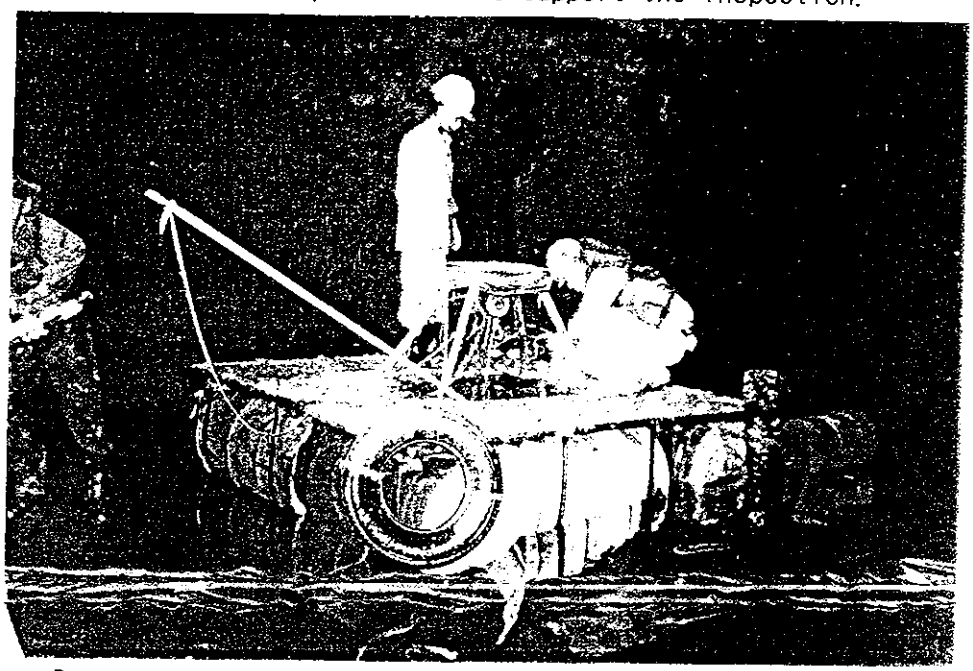
(2) Asahan Tunnel Inspection (1998)



Rubber boat and pro-rowers to support the inspection.

TST-2

(Siguragura Tailrace)

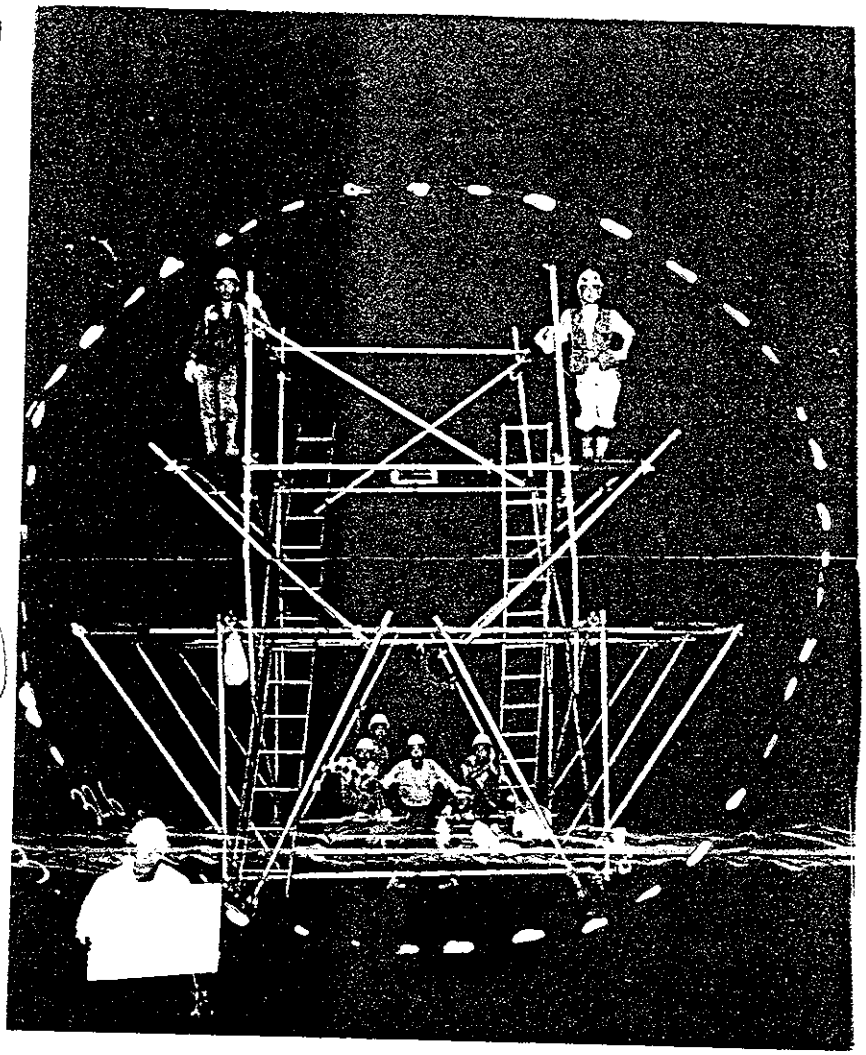


Drum can pontoon for tailrace inspection.

TST 3

Inspection staff and pro-rower of boat ~ Mr. Chida

S 1



(Tanga Tunnel)

(Scaffolding for Inspection)

S-2