CHECK AND REVIEW MANUAL ON SUPERVISION WORKS FOR TUNNEL CONSTRUCTION

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Preface

Renun Hydroelectric Power Project involves many tunnel construction works which consisting of ;

1) Upstream headrace tunnel (4.0 m in diameter excavated and 8.8 km length)
2) Downstream headrace tunnel (3.9 m in diameter excavated and 11.2 km length)
3) Branch tunnel (3.2 m in diameter excavated and 3.4 km length)
4) Penstock tunnel (4.5 m wide x 5.0 m high to 2.5 m wide x 3.0 m high excavated and 863 m length)

The tunnel excavation has been carried out by two (2) methods, i.e., TBM (Tunnel Boring Machine) and DBM (Drilling and blasting method).

The work performance of tunnel construction not only for excavation, but also for concreting is very essential to control the target progress rate keeping necessary quality stipulated in the Technical Specification.

Tunnel engineering, and especially construction, requires a great deal of know-how acquired by many years of experience and work in this filed.

To ensure the supervision works for tunnel construction to check & review the quality of construction works we are forwarding herewith CHECK AND REVIEW MANUAL ON SUPERVISION WORKS FOR TUNNEL CONSTRUCTION which has been prepared by Mr. K. Sato, Superintend Construction Engineer of Nippon Koei Co., Ltd.

This manual will be very useful for PLN Site Engineers and the Consultant's Engineers & inspectors to recognize the methodology of tunnel construction works and to ensure the concerned supervision works.

The tunnel covers Drilling, Blasting, Rock Bolting, Lining Concrete, Backfill Grouting, Consolidation Grouting and Repair of Defective Concrete Lining.

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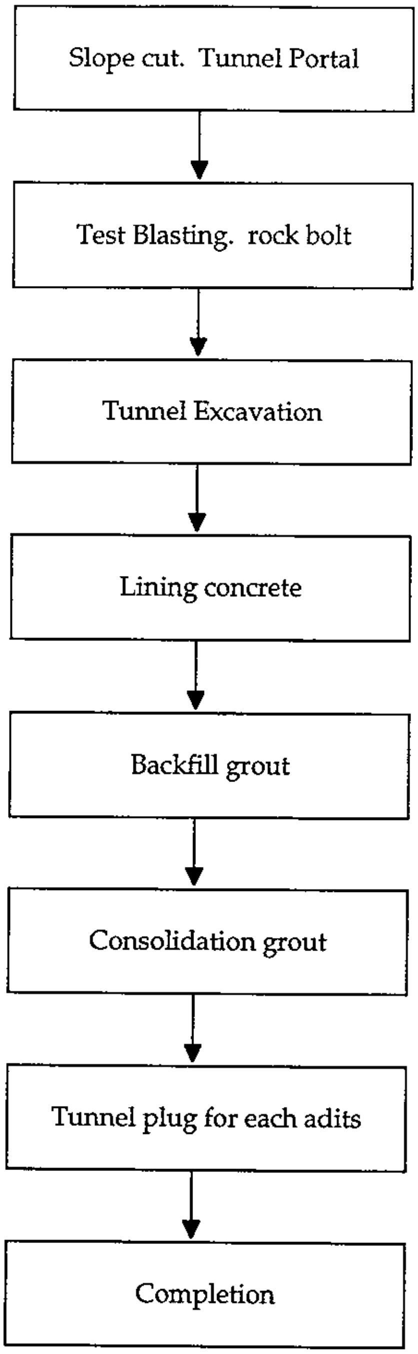
PART - A

EXCAVATION and CONCRETE WORKS

Tunnelling Work Flow



1. Item of the Tunnel

1.1 Road Tunnel

1.2 Rail way, subway

1.3 Storage cavern (oil, water, flood water storage)

1.4 Water way (pressure, free flow)

2. Excavation Method

2.1 Tunnel boring machine (movable type, stationary type)

2.2 Shield machine

2.3 Blasting

2.4 Excavater, Giant Breaker

2.5 Manpower

3. Blasting Method

3.1.1 Drill method

- Jumbo drill machine
- Crawler drill
- Leg drill

3.1.2 Drill pattern

3.2 Electric Detonator and Dynamite

3.2.1 Time difference

DS

Step	0	2	3	4	5	6	7	8	9	10
Sec	0	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.3

MS

Step	0	2	3	4	5	6	7	8	9	10
Sec	0	0.025	0.05	0.075	0.100	1.130	1.160	0.200	0.250	0.300

3.3 Blasting procedure

3.3.1 Time difference detonator will be carried out by the following sequences as follows :

1. Marking drill pattern on the tunnel face by paint
2. Drill
3. Check a stray current static electricity and short circuit of electricity
Check weather condition (thunder and atmospheric depression)] To prevents from induced an explosion
4. Charging powder with detonator
5. Tamping the hole by the timber stick or bamboo stick tightly (check detonator by optical battery tester 0.2 ~ 0.8 mA)
6. Connect the electric main wires
7. Check, turn on electricity by an ohm meter controlling (nominated skilled person shall check and instruct workers to take shelter at the safety area), less than 0.01 A
8. Check, whether all members got under shelter (safety check)
9. Explosion

10. Operate ventilation, check density of oxygen and harmful gas
11. Safety check (precaution of detonators not exploded yet. excavated face)
12. Scaling
13. Protection (shotcrete, rockbolt, H.beam rib if required)

3.3.2 Connection of electric wires in Series Circuits

E = I (R1 + R2 + R3)

E = Voltage

I = Current amperes 2A (am.pere)

R1 = Resistance of main line (approx. 0.02 Ω/m)

R2 = Resistance of detonator (approx. 1.0 Ω)

R3 = Resistance of Blasting ignition

n = Number of detonators

3.3.3 Dynamite

Dynamite is composed of more than 6% of Nitrogel and explosion Velocity is 3000 ~ 8000 m/sec (shock wave velocity)

W = Minimum resistance length

r = Radius of crater

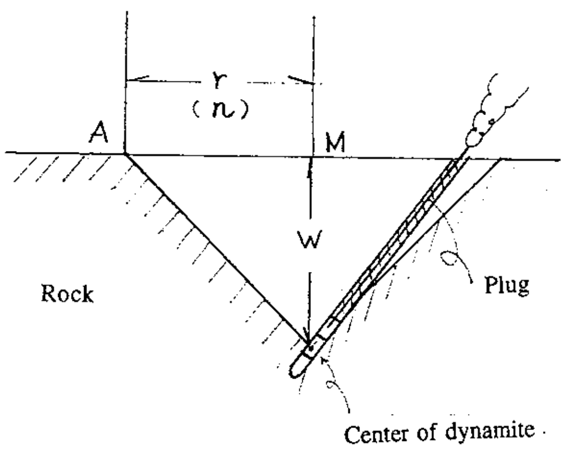
n = r/W

$L = CW^3$

L = Dynamite quantity

C = Blasting coefficient

$C = L/W^3$



$$V = \frac{1}{3}\pi r^2 W$$

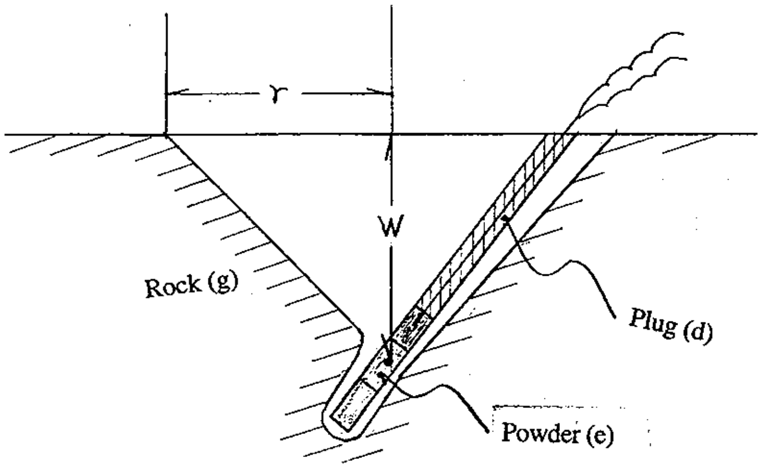
$$r = W$$

$$V = \frac{1}{3}\pi W^3$$

$$\pi \neq 3$$

$$V = W^3$$

to control n = 1 = W



$$L = cw^3 = g \cdot e \cdot d \cdot W^3$$

$C = g \cdot e \cdot d$
- g = coefficient of rock friction (1.0 ~ 3.3)
- e = coefficient of powder power (0.6 ~ 1.5)
- d = coefficient of hole plug (1.0 ~ 9)

3.4 Core cut. blasting

V cut
Double cut
Burn cut

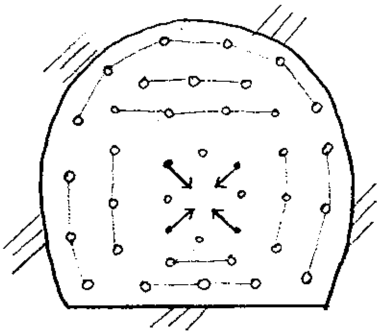
Pyramid cut

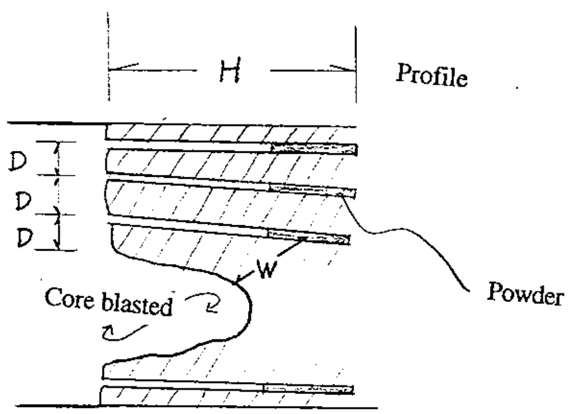
- ℓ = hole length of core blasting
- $\ell = a\sqrt{A}$
  - A = Excavation area
  - a = 0.6 ~ 0.7
- $L = CW^3$

Other Section

- L = C•D•W•H
- D = Interval of hole
- W = distance between center of Dynamite and minimum length of free space
- H = hole length

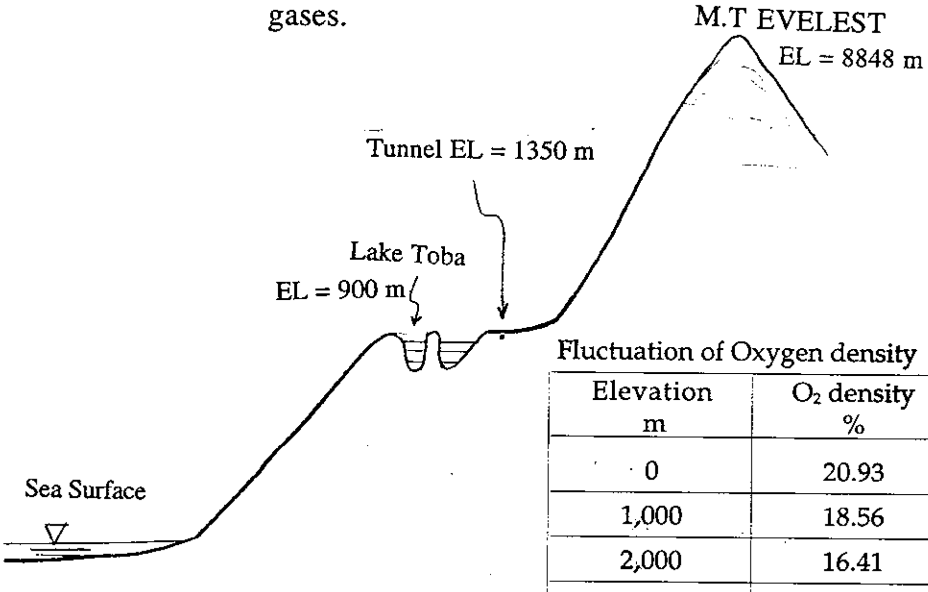
Drill hole nos.





3.5 Measures for Oxygen

3.5.1 The air is composed of 21% of oxygen. 78% of nitrogen and other 1% of gases.



Fluctuation of Oxygen density

Elevation m	O_2 density %
0	20.93
1,000	18.56
2,000	16.41
3,000	14.46
4,000	12.72
5,000	11.15
6,000	9.72
7,000	8.46
8,000	7.35
9,000	6.33
10,000	5.45

O_2

O_2	Lack of O_2 Symptoms
18%	Normal
16 ~ 12 %	Increase Pulsation Headache
14 ~9 %	Tired Headache feel nausea
10 ~ 6 %	Convulsion no active
Less than 6 %	fainted

stipulated that not less than 17% of oxygen
clause 2.5.3(4) of Technical Specifications

3.5.2 Other gases in the Tunnel

1) Hydrogen Sulfide (H_2S)
2) Carbon Dioxide (CO_2)
3) Methan (C_2H_4)

H_2S

PPm

density of H_2S	Symptoms
0.025 ~ 5	Smell of arotten egg
10	Allowable limit for eye
20 ~ 30	Allowable limit of lungs
30 ~ 300	Eyes disease Edema of the lung
300 ~ 400	Life is in danger 1 hour
600	After 30 min. life is danger

3.5.3 Ventilation

For each person working in the underground construction sites a minimum amount of 3 m^3/min. of fresh air shall be provided. (Clause 2.5.3(4)).

4 Tunnel Excavation

4.1 Portal excavation procedure

(1) Fore piling method will be applied before tunnel excavation

(2) Excavation Section shall be divided in to 3 ~ 5 parts (depending on rock condition) see fig.-1

(3) Excavation by manpower from crown and as Figure 1

(4) Shotcrete first layer for just excavated face

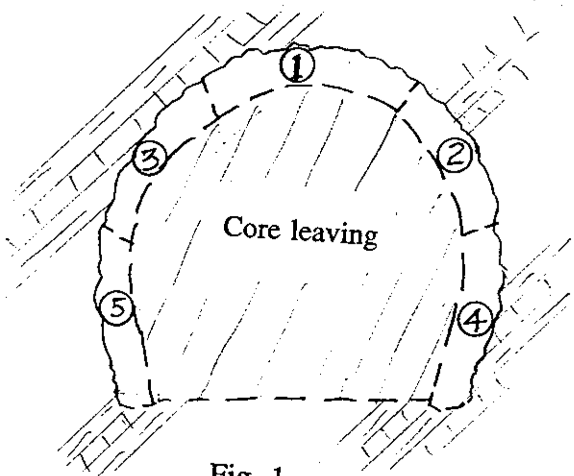
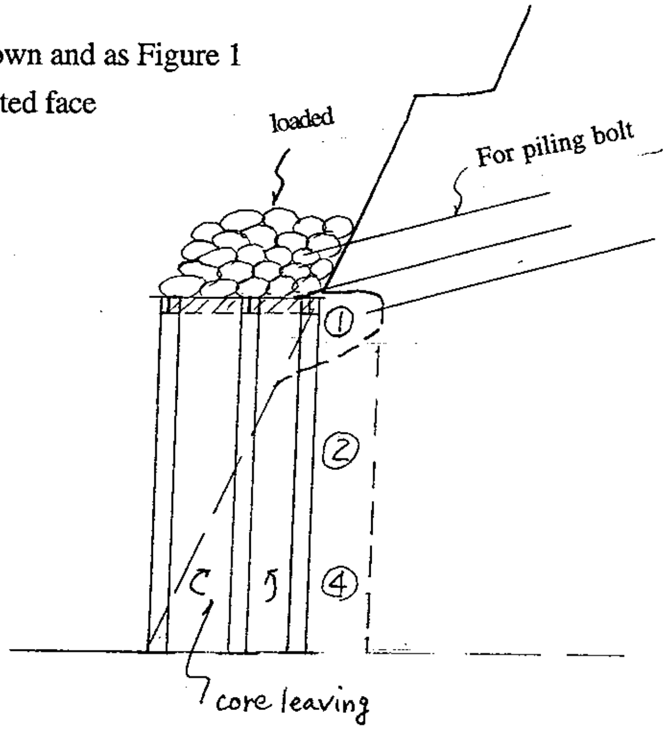


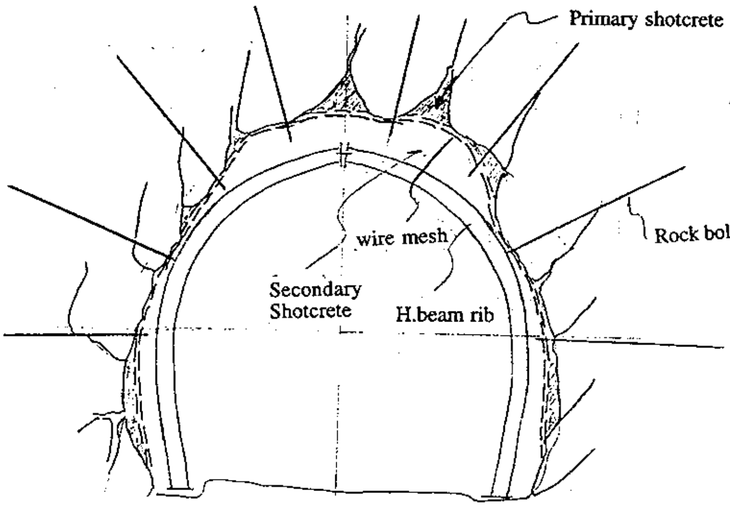
Fig. 1



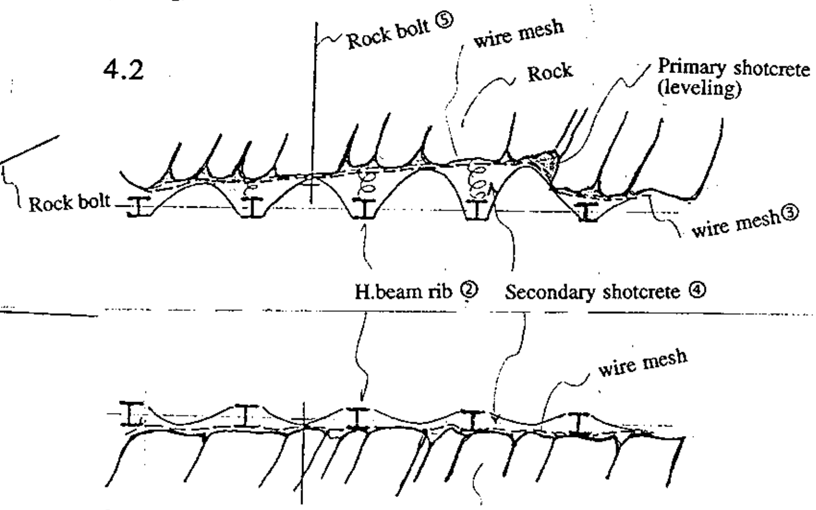
(5) Move excavation face to next section. shotcrete will follow the excavation work

(6) Installation of H.Beam Support for specified height and width

(7) Blocking and supporting shall be installed for firm contact between H.Beam and first layer of shotcrete face (wire net if specified)



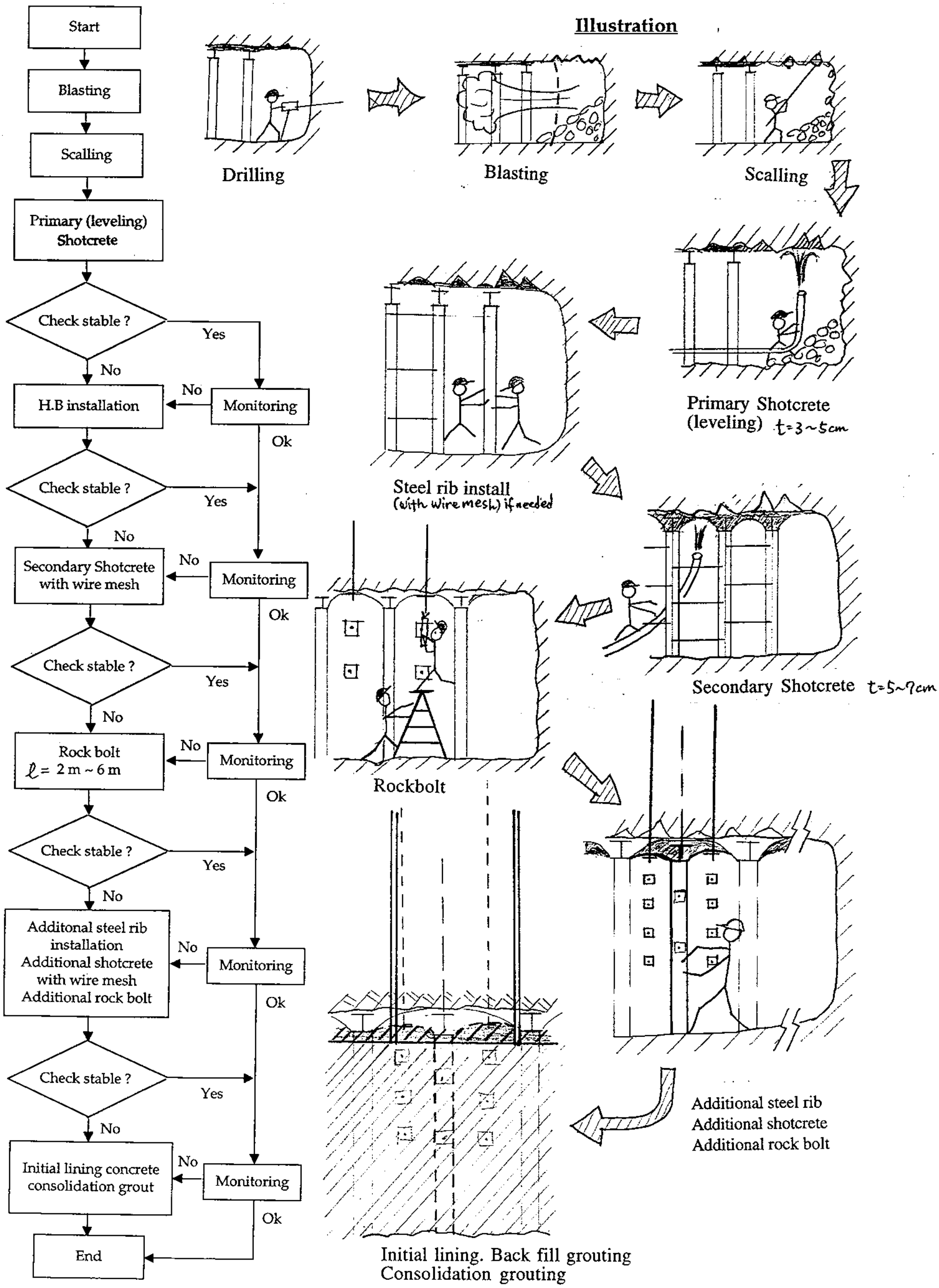
4.2



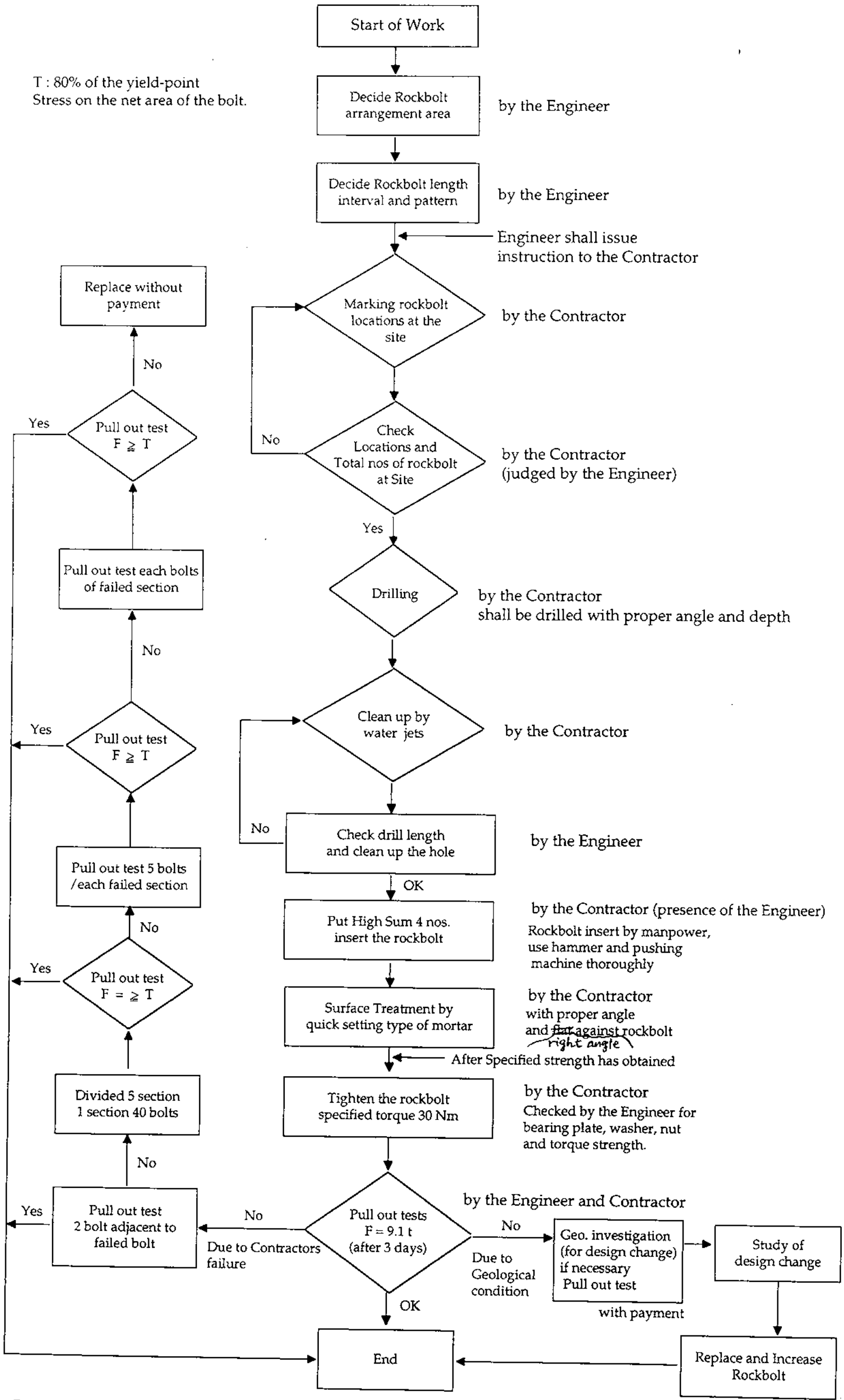
* (7) Blocking shall be provided for firm contact between rock and steel rib and be completely tightened by approved material.

Consequently, this temporary tunnel supporting could be maintained at a certain stable condition to withstand the rock road without any further loosing of the surrounding rock.

Supporting Work Procedure for Blasting Method



Work flow for Rock Bolting



Putting pull out load test is carried out basically 1 bolt/200 bolts

LINING CONCRETE

Work Flow for Lining Concrete

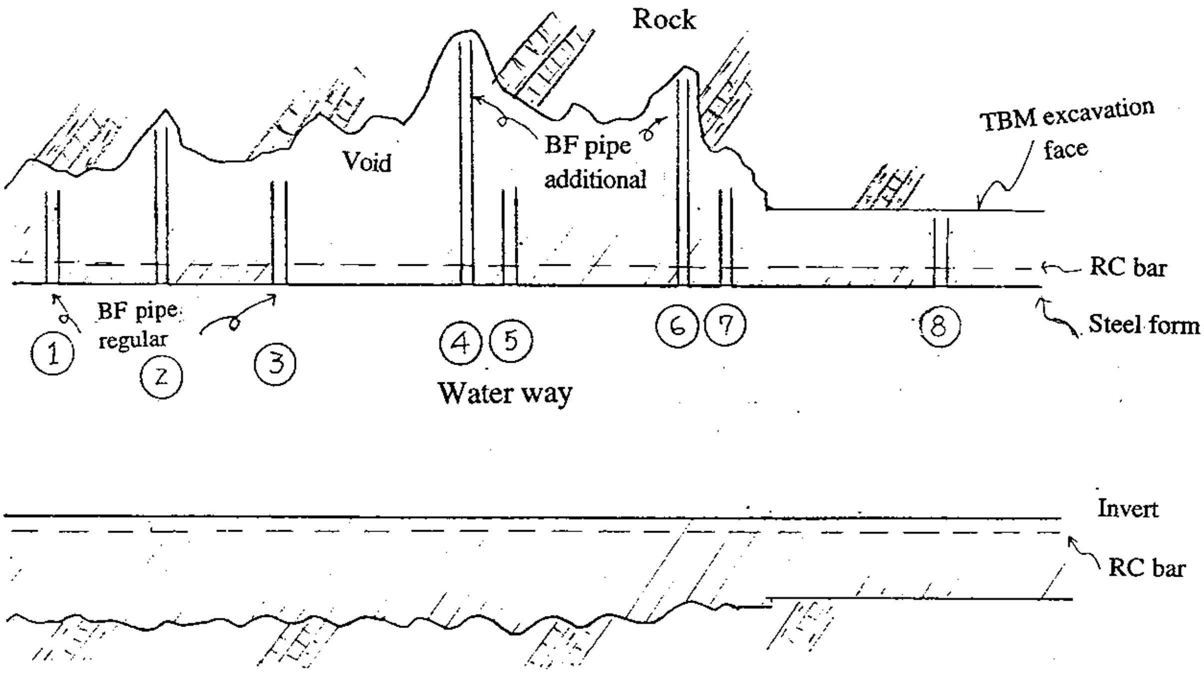
Work start	
Clean up for rock surface	by water jets
Inflow water treatment	Drainage system
R.C bar install	• Survey (line level) Dewatering from concrete placement section • Check Rebar (jointing location shall be arrange alternately)
Steel form setting	• Check position (line level) dimensions. clean up (mortar adhered) on steel form behind RC bar. oil coated. Backfill grout pipe locations, dewatering of invert. bulk head form. equipment. manpower. lighting
Concrete placing	• Check workability of concrete. slump. placing time after concrete mixed at batcher plant. vibrating. concrete level. (shall be placed with same level) steel form (deform or not). leakage. calking. Full filling of the crown.
Curing	• Arch steel form shall be removed as early as possible after hardening of placed concrete • Don't expose initial hardened concrete in the wind
Back fill grouting Check by Acoustic Sound Analyzer	
Consolidation Grouting	
Repair Conctee Lining Water Tightened	
End	

Payment for additional B.F grouting pipe instructed to the Contractor shall be made as follows :

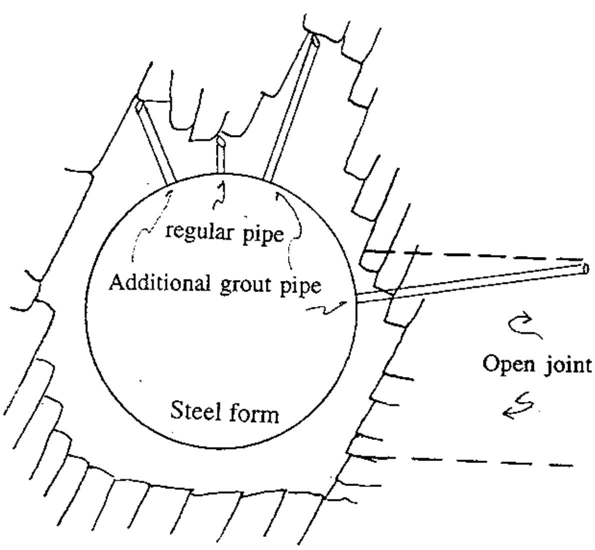
- Location of over excavated area (separate payment for the pipe weight will be made)
- Open joint (separate payment will be made for the pipe weight and B.F grout)
- Temporary divert drain at invert (if any)(no payment)
- Consolidation grouting pipe for double R.C bar location (no payment)

5 Backfill grouting pipe arrangement

5.1 Pipe for back fill grout shall be arranged at the specified locations as instructed by the Engineer prior to setting of steel form (to record location. pipe length)



5.2 Cross Section



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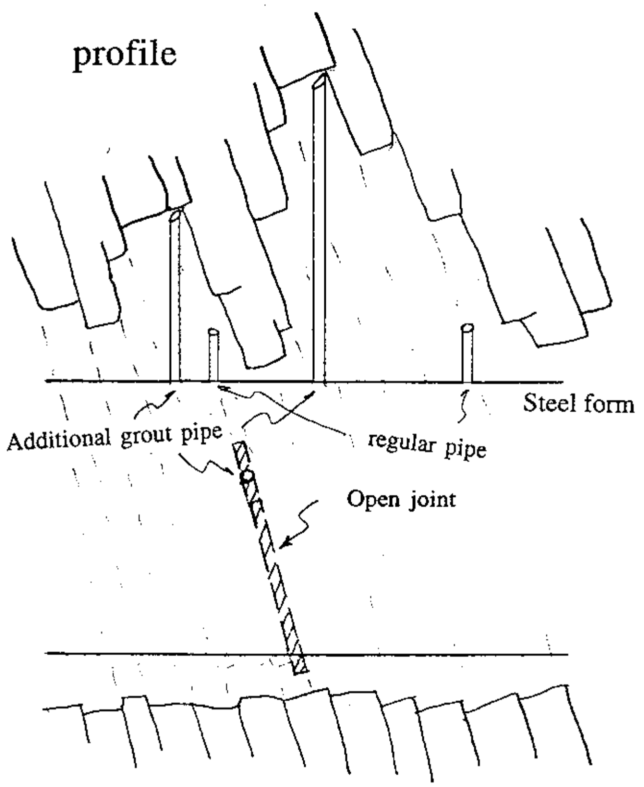
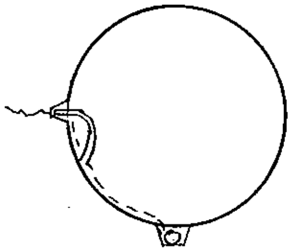
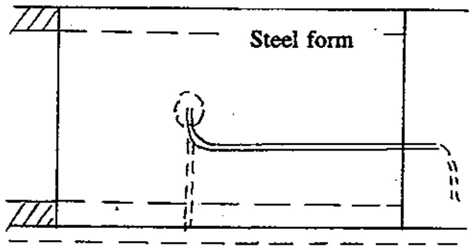


5.3 Spring water treatment

1) Spring water shall be drained to outside of the steel form using proper vinyl pipe. as instructed by the Engineer.





5.4 Steel bar inspection

1) Position. Dia. Interval. covering. tightening lapspace. R.C bar nos., binding and clean up.
2) Additional B.F grout pipe location shall be instructed (if any) especially for blasting excavated Section.

- Check open joints and record (height. width and extends)

5.5 Steel form set up and inspection

1) Concrete casting pipe shall be fixed just center of crown
2) Open all the inspection windows before inspection
3) Check and record BF grout pipe locations. and length
4) Survey steel form at two sections selected
5) Check spring water treatment. RC bars. clean up of the steel form and rock surface
6) Deformation of steel form

5.6 Concrete placement

1) Vibrating condition
2) Quality of concrete
3) Any damage of delivery concrete pipe
4) Don't stop concrete placement works except concrete work is suspended more than 1.5 hours.
(Joint treatment will be required).

5.7 Curing of Lining Concrete

In general, the concrete at the tunnel roof behind the steel form is sustainable even in earlier time than a specified curing of 10 hours, by the arch action due to self-weight of arch concrete. And the occurrence of cracks in concrete at the tunnel roof will be restricted by the creep strain along the circumferential direction in the lining concrete. Therefore, the steel form for arch section could be slided as early as possible after initial hardening of concrete within 5 hours.

5.8 Repairing for lining concrete

1) Repairing location. area and depth shall be given
2) Skilled person is qualified
3) Check repairing tools and materials
4) Chipping for repairing area
5) Water treatment

LINING CONCRETE CRACKS

6. Reason of crack occurrence

The following conditions cause cracks in lining concrete.

6.1.1 Thermal shrinkage

The temperature in concrete is increased due to heat hydration of cement after placement. The shrinkage in concrete will occur when the temperature in concrete is dropped.

The magnitude of shrinkage is estimated as follows :

$$\underline{12{,}000} \times \underline{10 \times 10^{-6}} \times \underline{36^{\circ}C} = \underline{4.3}$$

- 4.3 — Shrinkage value (mm)
- 36°C — 60° - 24° (estimated maximum temperature after placing minus lowest of annual temperature in tunnel)
- 10×10^{-6} — Thermal expansion coefficient of concrete
- 12,000 — Concrete lining length (mm)

The shrinkage is estimated to be about 4 mm in a block length (12 m).

6.1.2 Drying shrinkage

The dry shrinkage is caused by the hydration operation of the cement gel.

In general the possible factor induced concrete dry shrinkage is excess water content and air quantity in concrete. On the other hand, despite mix proportion in Da Mi Hydropower Project in Vietnam was designed within standard range, shrinkage crack in concrete not occurred.

In case of Da Mi Hydropower project, it is expected that the shrinkage crack might have not occurred due to high humidity in the headrace tunnel after concrete pouring.

6.1.3 Restraint of rock

When the temperature is dropped by cooling after heat hydration of cement is terminated, the concrete also shrunk. At this time, the shrinkage is restrained by the surrounding rock behind the lining concrete and the occurrence of the shrinkage cracks in concrete is possible.

6.1.4 Crack in concrete due to Displacement of surrounding rock

This is concerned that when the lining concrete is placed on the loosened rock, the surrounding rock will be deformed with the excavation progress. The Engineer should carefully observe whether such phenomenon is developed on the shotcrete surface and lining concrete surface. However, any horizontal cracks is not observed at lining concrete of upstream headrace tunnel. Therefore, the displacement of surrounding rock may not be developed in UHT.

6.1.5 Ground water pressure

Prior to sufficient strength of concrete is gained, the crack that is caused by the underground water pressure will occur. However, with increasing the strength of concrete after enough curing period, such risk will be disappeared.

6.2 Characteristic of underground concrete structure

In case of the underground concrete structure, the shrinkage action of concrete is restrained by the surrounding rock. Therefore, occurrence of cracks in concrete is possible.

6.3 Method of repair

- Pouring and injection method.

The cracks (exceed 0.30 mm width) will be poured or injected by the material, using manual pump (refer to fig. 1-1).

- Filling method

The leaking cracks which could not stop by grouting, using hard mix mortar (water tightening type of Sika 102 and strong adhesive type of Sika monotop 615 HB) fills into the U shape of grooves by hand firmly (refer fig. 1-2)

6.4 Materials

- Resin system

It is an excellent glue in ability and durability, but very costly.

- Cement system

Volume change is small and it very excellent at the workability and durability.

The material to be used : - Sika 731 (corting concrete surface for strong bonding)
- Sika 102
- Sika monotop 615 HB

See details page 28 ~ 35