Workshop Brief Notes on:

Construction of Pipe Roof and Support System

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Summary:

The notes herein illustrated the application of pipe roof/arch method of constructing circualr or rectangular/any shaped box culvert structures. These notes covered various considerations in the planning/design and construction of such works.

The pipe roof/arch method involves the use of microtunnelling /jacking / other trenchless machine to install a series of interlocking steel pipes which formed a temporary support system , below which the final section of the box culvert structures is then mined and constructed .Problems encountered and instrumentations issues were also mentioned .

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Title	**Pipe Roof/Arch –consideration in the construction**
Author /Speaker	**Mr Cheng Kim Hua**

- **Introduction.**
- **Consideration**
- **Planning and Design**
- **Construction**
- **Problems encountered**
- **Instrumentations and monitoring**
- **Conclusion**

Introduction.

1) Pipe roof as alternatives to open cut and other method.
Pipe roof method of construction can generally be suitable when a relatively short tunnel or culvert/underpass need to be installation in heavy traffic or where road /rail services cannot be interrupted and where settlement due to work are to be minimised .

2) Such method involve the construction of temporary works using interlocked steel pipes, installed by microtunnelling or pipe jacking ,to form the temporary ground support inside which the permanent structure is constructed.

3) The workshop will be conducted by Mr Cheng Kim Hua, PE, BE(Hons) Monash, Dip Hydraulic Eng(IHE, The Nederland's) who have been in the trenchless line since 1989 , and have been involved in many microtunnelling projects in S E Asia, India and the Middle East.

Considerations

4) The cases for the need to consider pipe roof will include:
a) Installing sections across roads, railway for underpass or drainage/sewer /other culvert
b) Relatively large sections, sometimes as long as 19 m x 4.5m x 293 m (Ref 1:-Coller P 1994)

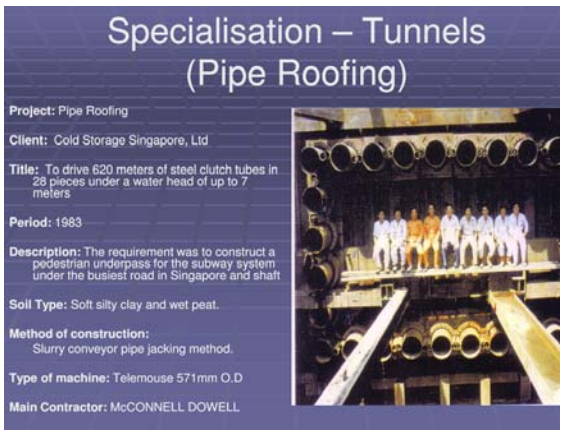
c) Martha Railway, Atlanta

Fig 1-pipe roof in Martha Railway, Atlanta (Ref 2)

Figure 1. Twin Tunnel Construction using microtunnelling assisted pipe-roofing under I-285 in Atlanta, Georgia as shown in Wallis [3]

d) Singapore underpass 1993 –

Fig 2 –Singapore Orchard Underpass(Ref 3)



e) Sensitive settlement issues, where cost of interruptions/repair are probative, or as mandated by Authorities such as near MRT or other services (Singapore's LTA project 6 m x 4 x 53 m - undercrossing Major road, and above MRT Lines)

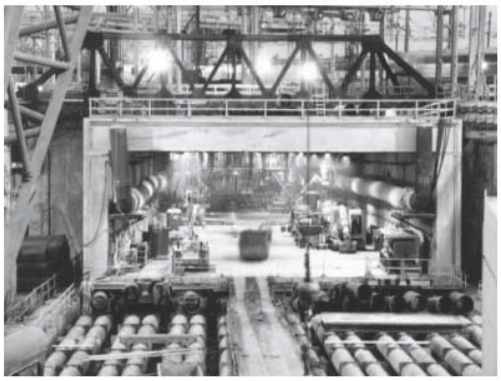
5) The other methods that may be considered include:

a) Pipe ramming (where the pipes are rammed to form the support) or by auger microtunnelling
Fig 3- pipe roof by Auger microtunnelling (Ref 4)

A line of pipes installed using pilot auger microtunnelling technology as the roof section of a pipe arch for an under-rail tunnel installation.
Picture courtesy of Bohrtec GmbH

b) Direct box culvert jacking/pushing (such 10 m x 4 m box section of services tunnel – Singapore Power Grid, Jacking under Boston Railway, USA)

Fig 4 - Jacked tunnel under Boston (Ref 5)



A summary of method used in pipe roof/arch construction is given in ISTT (Guideline) (Ref 4).

6) The general soil parameters used in the design of the shaft and tunnel(pipe jacking) and portal frame will include soil investigation, study of the project areas , and discussions with the client and authority

7) Generally the pipe roof is undertaken on a design and build basis, where by the appointed main contractor will appoint either specialise sub contractor for such task or have its own specialist design team, and assemble specialist trade such as pipe jacking to carry out the works,

8) Additional teams of specialist will include soil improvements, geotechnical measurement and monitoring teams

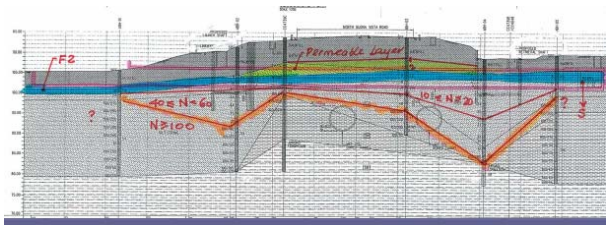
9) The client will appoint its own supervising team, and sometimes independent check.

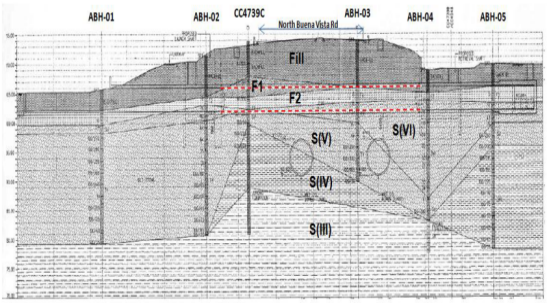
10) The performance criteria will follow pipe jacking tolerances for jacking works, and structural tolerances for others sections .The monitoring /suspension. Alert levels for instrumentation works will be decided by site and design considerations, and agreed upon prior to work commencement.

Planning and Design

11) The soil parameters are mainly used to design the shafts for which to launch the pipe roof –pipe jacking machine .typically:

Fig 5 Soil profile (typical) -General soil profile of the pipe jacking / mined tunnel zone





12) The design parameters is sampled as shown

Fig 6 Design soil parameters

Formation		Fill	
Grouping or Soil Type		MLs	Gravel-sar
SPT	blows/30cm		16
Unit wt (bulk)	[kN/m³]	20.0	20.0
Shear Stre C_U/N Undrained, c_U	[kN/m²]	25	
Drained, c'	[kN/m²]	5	5
Friction angle f	[deg]	27	30
Soil Modul E_U/C_U E'/N		400	1.0
E_U	[MPa]	10.0	
E' or DE'	[MPa]	8.67	16.0
Coef. Of Permeability	[m/s]	1.0E-07	1.0E-04
Coef of At-rest Pressure K'o		0.5	0.6

13) The key considerations.

The key design considerations can include factors such as:

i. Geotechnical aspects, including soil-structure interaction between pipe-roof and surrounding ground, stability of the excavated face and base stability during excavation;

ii. Structural aspects such as the design of the pipe-roof and the structural steel frames supporting the piped-roof;

iii. Soil improvements and types and extent of protection to existing services;

iv. Other pertinent points related to method and operation included: the adoption of single or multiple sided(3, 4) pipe roof , type and capabilities of jacking machine used, their maintenance of face pressure, excavation speed especially when encountered with obstructions such as sheet piles, timber pieces, skill of operators, details of pipe clutching and damages expected to be caused by excessive settlement , mitigation measures and others.

v. Risk assessment and hazard analysis including alert and suspension levels for instrumentations such as inclinometers and settlement markers, tilt meter etc during construction stage

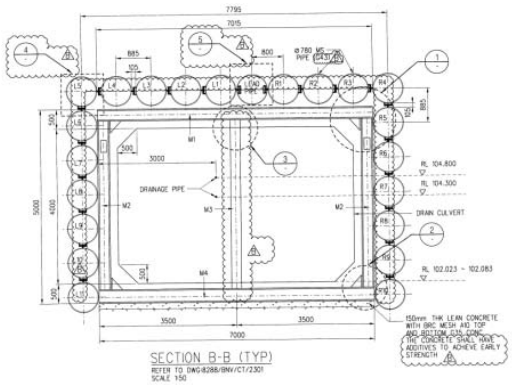
Other calculations:

a) Thrust wall design

b) Jacking force calculations;

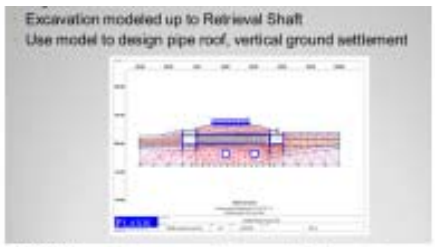
c) Final drawing of culvert

Fig 7-sample design drawings of culvert section



14) Design modelling: Use 2 D Plaxis -2D Plan strain model

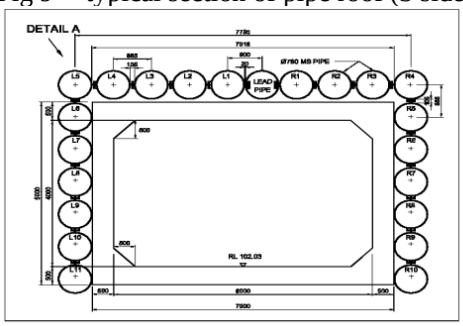
Fig 8- 2 D Plaxis Modelling



Ref 1003- PB presentation (to remove for final version)

15) Typical section of the pipe roof is as shown

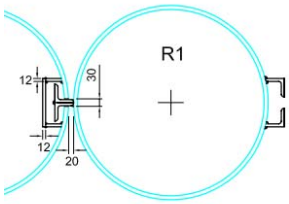
Fig 9 - -typical section of pipe roof (3 sided)



Construction

16) Methodology

The interlocking sections are sampled below:
Fig 10- -interlocking steel pipe – sample

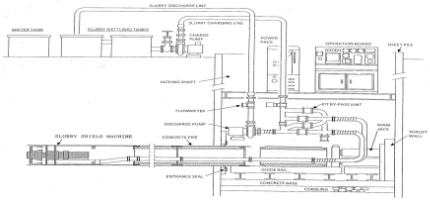


17) Pipe jacking of individual pipe .typical work

18) The following pictures show the pipe jacking and pipe roof construction

i. Slurry shield jacking layout

Fig 10- typical layout for pipe jacking



ii. Constrction of jacking and receiving shaft

Fig 11- shaft construction

iii. View of jacking machine

Fig 12- jacking machine

iv. Preparing guard Rail for jacking

v. Setting TBM

Fig 13-preapring and setting up Jacking Machine

vi. Welding steel sections

Fig 14- welding joint

Vii. ready for jacking

Fig 15 –ready for jacking

viii. Break through at receiving shaft

Fig 16- Break through

ix. Completed row

Fig 17- completed row

Problems encountered

19) The problems encountered in any pipe roof works will likely to include:

Problems	Solution?
Soil profile different from provided in tender or soil investigation report	Choose more versatile machine, use conservative paramours
Excessive settlement/problem in jacking due to obstruction	Site solution , innovative , rescue operations well coordinated , use of man entry(as far as possible –bigger than 760 mm OD) Alternative design to ensure conditions met(cover, alignment)
Encounter of services not envisaged /in tender drawings	Coordinated response , insurance cover , night or overtime work , mapping and service detection especially for shaft areas
Others	Etc

Instrumentations and monitoring

20) The requirements of the authorities/client will determine primarily the extent of monitoring needed .Considerations will include the frequency and extent of measurements-

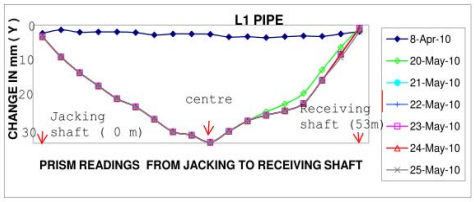
21) Measurement areas will cover the crossing (road /rail settlement), water table, adjacent structures (movement, tilt)

22) Instruments will include inclinometers, settlement markers piezometer, tiltmeter, vibration meter

23) Reports to include alert/suspension levels, frequency and measurement/readings/interpretations /recommendations for additional instrumentation

24) Usually separate/independent specialist to carry out, sometimes done directly under the client's purview.

Fig 18 shows typical mentoring plot



Conclusion

Pipe roof/arch method of construction by pipe jacking generally are useful and effective solution to situations where the constraints of settlement , crossings and client's requirements cannot be met by other cheaper method such as open cut or other trenchless method.

There are numerous issue to consider and as the work are normally contracted out on a design and build basis , the contractor will need to weight the risk and allow for specialist inputs to be always on the site, and during planning/design stage.

With well coordinated efforts from all stakeholders, the pipe roof method can perform as planned, and has been successfully adopted since the 90's.

References

1- Coller, p, Abbot,D , 1994 Microtunnelling used for record braking pipe roofing project(Japan) North America Tunnelling 94

2- Attalla, A.L. and D.T. Islay, 1991. "*Pipe Arch Horizontal Drift Method for MARTA's Transit Extension Under I-285,*" Proceedings of Rapid Excavation and Tunneling Conference, SME, Chapter 24, June, pp. 435-453.

3- Darling, P., 1993. "*Jacking Under Singapore's Busiest Street,"* Pacific Rim Supplement to Tunnels & Tunnelling, summer, pp. 19-23. Jacking under Singapore's Busiest Street.

4- ISTT Guideline , *TRC ,SECTION 9- Associated Techniques*

5- S. Taylor, D Penrice , *Jacking Large Tunnel underneath active Rail Tracks*