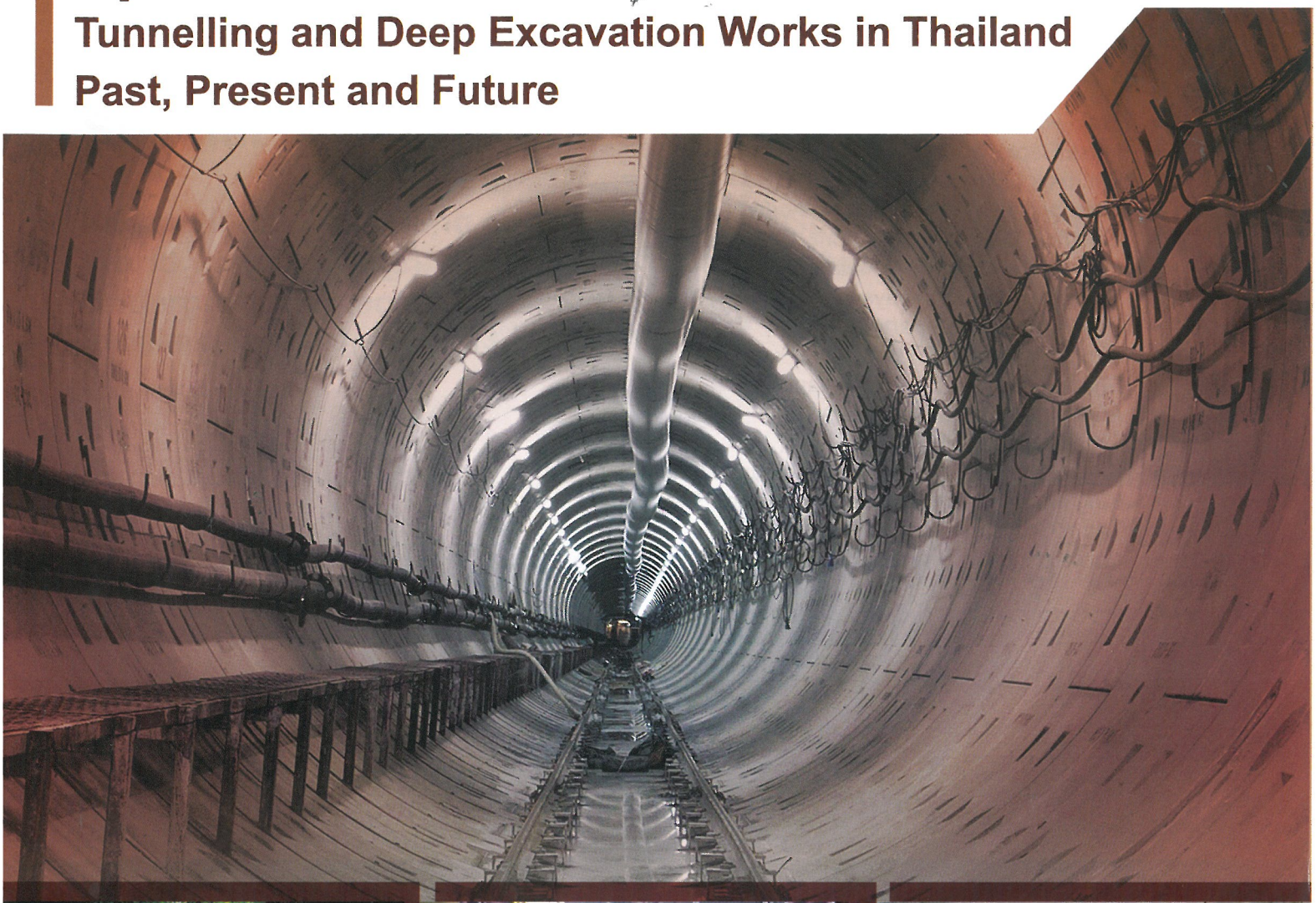
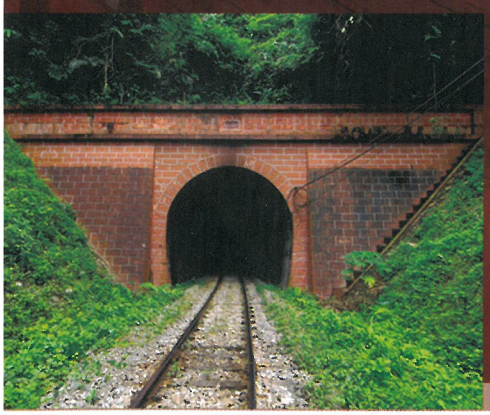
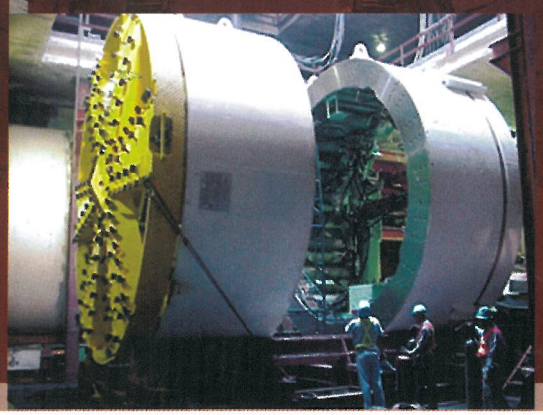
ITA-AITES World Tunnel Congress 2012 and 38th General Assembly
18-23 May 2012, Bangkok, Thailand

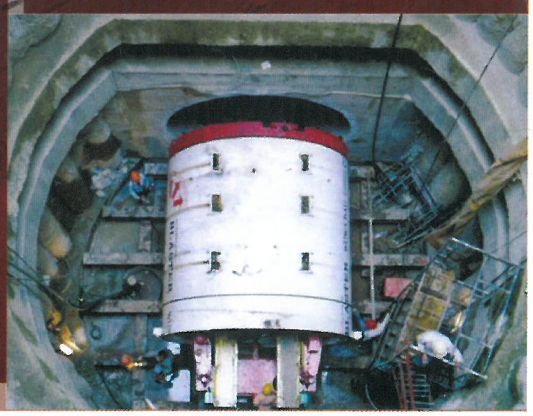
Special Publication

Tunnelling and Deep Excavation Works in Thailand
Past, Present and Future









Thailand Underground and Tunnelling Group (TUTG)
The Engineering Institute of Thailand under H.M the King's Patronage

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- Airport Authority of Thailand
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Special Publication

International Tunnelling and Underground Space Association
World Tunnel Congress 2012 & 38th General Assembly
Underground Space for a Global Society
Bangkok, Thailand, 18th to 23rd May 2012

Tunnelling and Deep Excavation Works in Thailand - Past, Present and Future

Prepared by
Thailand Underground and Tunnelling Group (TUTG)

Editors

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Aphichart Sramoon
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Auttakit Asanprakit

Special Publication

Tunnelling and Deep Excavation Works in Thailand Past, Present and Future

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Preface

This special publication is issued on the occasion of The World Tunnel Congress 2012 and 38th General Assembly (WTC2012) which will be held in Bangkok, Thailand from 18th to 23rd May 2012. Organized by Thailand Underground and Tunnelling Group (TUTG) of the Engineering Institute of Thailand under His Majesty the King's Patronage and Tunnelling and Underground Space Association (ITA-AITES) ; this is the first time Thailand will host the International World Tunnel Congress.

The Asia region has witnessed the tremendous development of infrastructure projects including construction of mega underground structures. Recent developments have been spurred by the increasing demand for underground space particularly in the congestive urban environment. Under the theme "Tunnelling and Underground Space for a Global Society", WTC2012 Bangkok will call together the tunneling and underground space community in Southeast Asia region to set up a forum with the World Tunnelling and Underground Space Society.

This special publication presents the past, present and future of tunnelling and deep excavation works in Thailand. Compiled and edited from available published and unpublished literatures, it is intended to give a glimpse of major usage and key features of tunnelling and deep excavation works in Thailand.

The WTC2012 organizing committee expresses its appreciation to ITA-AITES for co-organising this event. The successful organizing of this congress is owed to the time and effort of the members of the Thailand Underground and Tunnelling Group of the Engineering Institute of Thailand under H.M. the King's Patronage (EIT). The organizing committee extends its appreciation to all sponsors, supporters and participants who have made this congress successful.

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Tunnelling and Deep Excavation Works in Thailand - Past, Present and Future

1. Introduction

Located in Southeast Asia, between latitudes 5°37' N and 20°27' N and longitudes 97° 22' E and 105°37' E, Thailand covers an area of 518,000 km^2. The country can be divided into four main physiographic regions; the mountainous highland in the north and northwest, the Khorat plateau in the northeast, the central plain and the southern peninsular. Geologically, Thailand has diverse stratigraphic formations from Precambrian to Quaternary deposits. Depending on the geologic complexity and ground behavior excavation and support methods are selected for each tunnelling project. Tunnel excavations were mainly done manually in early days; however, today, tunnels are constructed by applying state-of-the-art technology, especially in soft-ground tunnelling.

Deep excavation works of major underground structure projects are summarized in this publication. Six key areas of tunnelling works such as railway tunnels, road tunnels, MRT tunnels, flood drain tunnels, water transmission tunnels and utilities tunnels are briefly reported. Overview of projects in the planning stage is also presented.

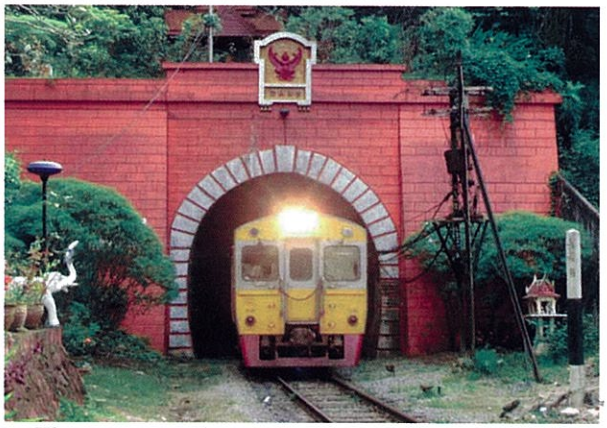
2. Historical Tunnelling in Thailand

The Khun Tan tunnel is the first railway tunnel in Thailand, which was built in 1907 through the Khun Tan mountain range. It contributes to bridging of transportation between Bangkok, the country's capital and Chiang Mai, the country's major city in the north. The tunnel is 5.20 m wide and 5.50 m high with 1,352 m length. It took as much as eleven years to complete as a result of various technical difficulties during construction. The Khun Tan station, located at the northern end of the tunnel, is the highest railway station in Thailand at an elevation of 578 m above mean sea level.

The first road tunnel in Thailand is the Betong Mongkollit tunnel in Betong, Yala province. It is a curved tunnel of 273 m length, connecting the central part of the town with the newer part of the town in the southeast. The tunnel is 9.0 m wide and 7.0 m high and the construction was completed in 2001.

Soft ground tunnelling in Thailand was firstly adopted in Bangkok in 1970 for a storm drain tunnel to enhance drainage capacity in the area of Rama IV road. The tunnel is 3.3 m in diameter with 1,700 m in total length and located at shallow depth in soft clay layer. Initially, an open-face shield was used but a blind-type shield was later employed to solve the stability problem. It was until mid-1990 that Bangkok turned around and started construction of its enormous wastewater tunnel and flood drainage tunnel system.

The First Railway Tunnel in Thailand
Khun Tan tunnel constructed between 1907 and 1918



Khun Tan tunnel constructed 105 years ago is still in operation

The First Road Tunnel - Betong Mongkollit tunnel, southern Thailand

Tunnel constructed in soft ground

Tunnel inner lining installation
MWA Water Transmission Tunnel

Newly completed flood drain tunnel in Bangkok

Metropolitan Waterworks Authority (MWA) has steadily developed its underground utility network since 1975. The network comprises main water supply tunnels of 2.0 to 3.5 m diameter with a total length of over 200 km throughout Bangkok metropolis. Tunnels were mainly constructed by shield tunnelling method – only a small portion of the network as constructed by the cut-and-cover method using steel sheet piles. Earth Pressure Balance TBM have been used in recent years. The tunnel alignment of the most of the projects is bound by regulation that required MWA pipelines are to be constructed in public land.

The MWA tunnel in the Construction stage

Metropolitan Electricity Authority (MEA) has started its underground power distribution in 1999 in Bangkok area. The first project covered construction of 21 manholes and 2.6 m diameter tunnels with a total length of 8 km. The tunnels were constructed using pipe jacking/micro tunnelling technique.

Utility tunnel of Bangkok Metropolitan Electric Authority

The major underground transportation infrastructure project in Bangkok was the first mass rapid transit (MRT) system in Thailand. The Chaleom Ratchamongkol Line, known as the MRT Blue Line, consists of 22 km long twin bored tunnels and 18 underground stations from Bang Sue to Hua Lamphong and has been in service since 2004. The underground stations are typically 200 m long and 23 m wide, located generally beneath street easement. The tunnels are of 5.7 m inside diameter with single staged concrete segmental lining.

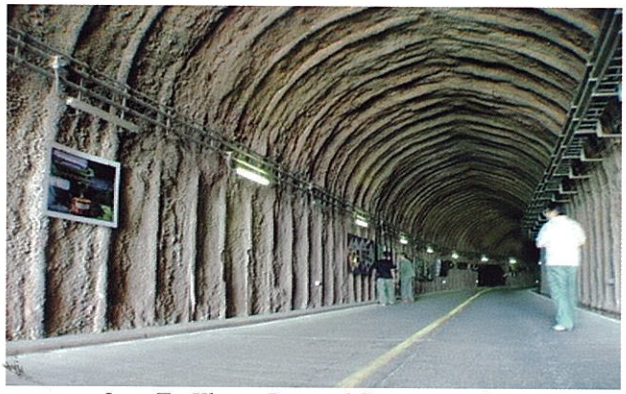
The 1000-MW Lam Ta Khong Pumped Storage project by Electricity Generating Authority of Thailand (EGAT) is the first underground powerhouse project of Thailand. The project

involved construction of a powerhouse cavern with 25 m wide, 48 m high, and 175 m long dimension, tunnels and shafts of various sizes from 3 to 8 m and depths of up to 360 m for a total length of almost 12 km. The project started in 1995 and completed in 1998.

MRT first subway tunnel in Bangkok was constructed by EPB tunnel boring machines

The first MRT subway tunnel under was opened for the public in 2004

Lam Ta Khong Pumped Storage project - the first underground power house project in Thailand



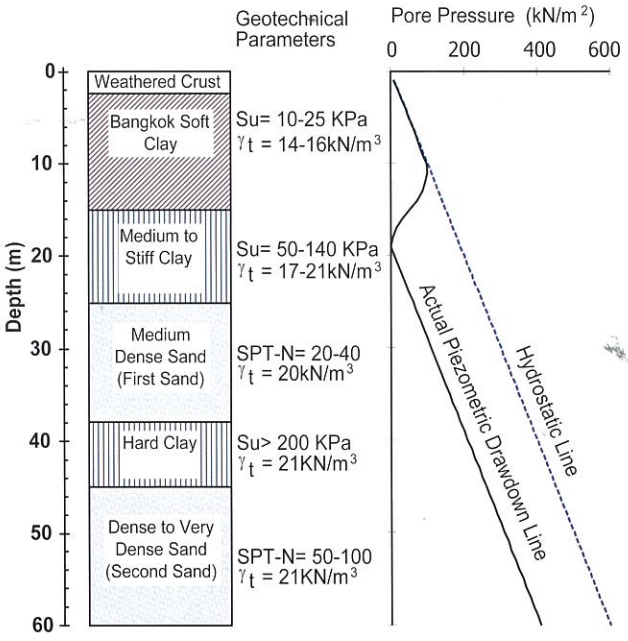
Lam Ta Khong Pumped Storage project

3. Status of Deep Excavation Works in Thailand

As in other fast developing countries, growing land prices and need of underground space for commercial and infrastructure developments necessitated deeper underground excavation works in Thailand especially in Bangkok. Though sheet piles, contiguous-pile walls, secant pile walls and sinking caisson are alternative retaining structures available in Bangkok, advantages offered by diaphragm walls weigh more favorably for both technical and economical reasons while other methods have distinct limitations for the deep excavation works in urban area of the growing metropolis. Hence, the information contained in this session is mainly from the deep excavation works in mega projects constructed in Bangkok and adjacent areas.

Among other technical reasons, the key factors for using diaphragm walls for deep basement excavations in Bangkok are due to the prevailing subsoil (existence of very soft to soft clay) and ground water conditions. The subsoil profile in Bangkok is primarily characterized by presence of thick soft to very soft marine clay on the top 12-18m followed by alternating layers of stiff to hard clay and sand deposits. Existing pore water pressure conditions in upper part of Bangkok soft clay are hydrostatic from nearly 1 m below ground level. The hydrostatic condition changes to piezometric drawdown near the bottom level of the Bangkok soft clay. Excessive ground water abstraction from deep aquifers was found to be responsible for the significant drawdown of the piezometric pressure.

The first deep excavation for basement structure supported by diaphragm wall in Bangkok is believed to be constructed in the late 1970s for the basement retaining walls of the Bangkok Bank Head Office Tower on Silom road. In 1985, using diaphragm wall 0.82m thick, basement of 18.50m depth was constructed for International Trade Center.



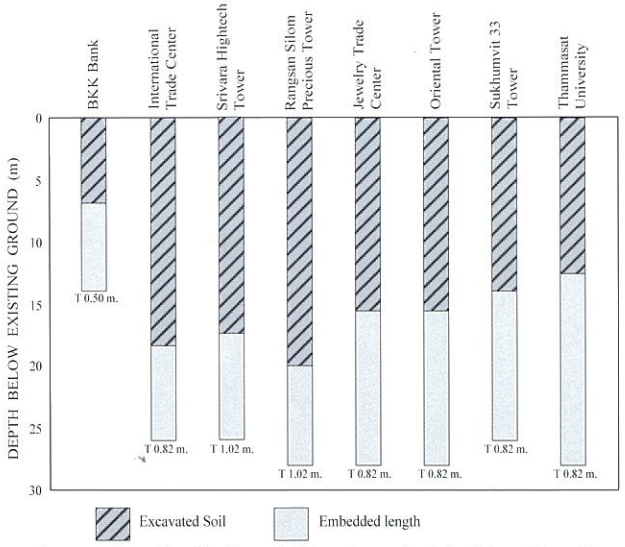
Typical Subsoil profile in Bangkok

With the booming of construction industry since 1991, usage of diaphragm wall for deep basements of high-rise buildings in Bangkok has been significantly increased. From 1997 to 2001, due to the economic crisis and significant decline of the property sector, the diaphragm wall construction was used mainly for major infrastructure projects.

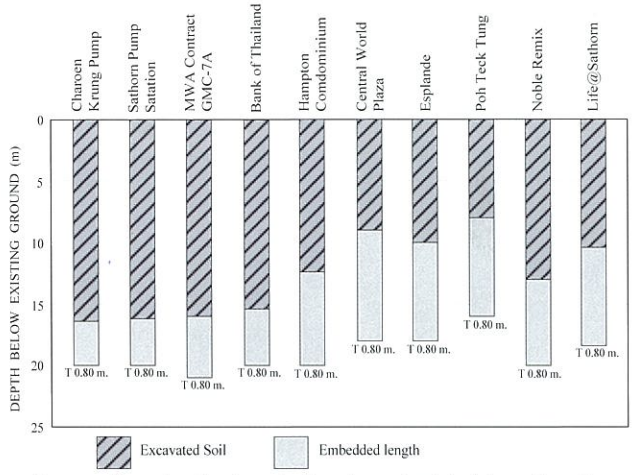
Extensive construction of underground structures with deep excavations can be noted between 1997 and 2001 for the first Bangkok subway project. 18 deep underground stations and associated structures plus a number of cut-and-cover tunnels were constructed with diaphragm walls support. An excavation depth of over 30 m at Silom Station set the deepest excavation ever carried out in Bangkok subsoil. All 18 deep underground stations were constructed by the top-down method using diaphragm walls as permanent structural support.

One of the key advantages of using underground space is that available land area can be utilized for multiple-purpose and environmental preservation. This concept has been applied not only for tall buildings but also for other structures as in the following projects :

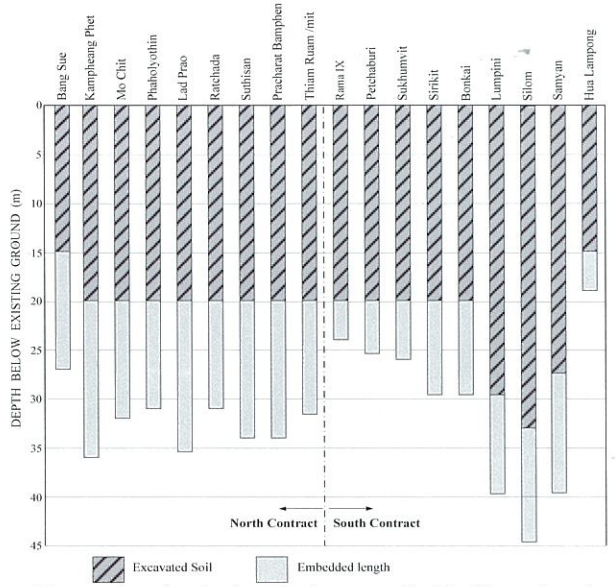
- Underground car park for Bangkok Metropolitan Authority (BMA)
- Underground car park for Central General Hospital
- Underground car park for Srinakrin Viroj University.



Excavation depths in relation to embedded lengths of diaphragm walls in the early days (1977 to 1994)



Excavation depths in relation to embedded lengths of diaphragm walls from 1997 to 2008



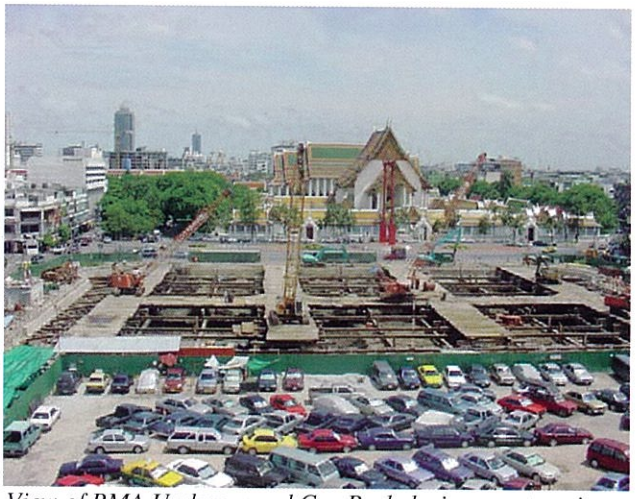
Excavation depths in relation to embedded lengths of diaphragm walls of 18 subway stations of the first Bangkok Mass Rapid Transit Project

MRT Subway station box constructed by top-down method

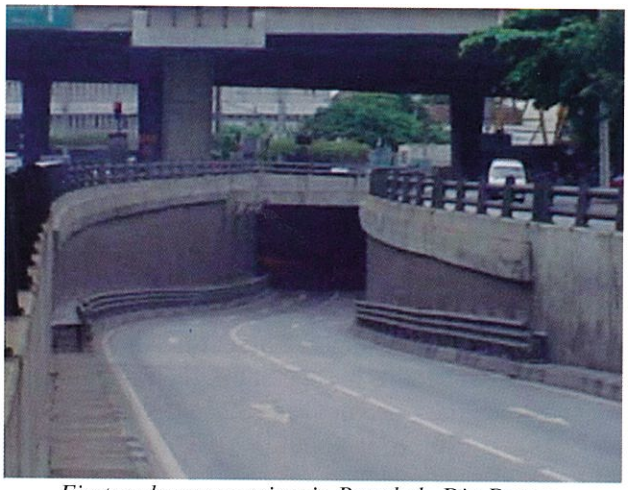
View of BMA Underground Car Park after completion (project with multiple land-uses)

Project with multiple-land-use

Project Name	Use of Space		No. of Basement	Basement Area (m2)
	Ground Level	Underground		
BMA Car Park	Public Park	Car Park	2	18,552
CGH Car Park	Garden	Car Park	5	17,020
SVU Car Park	Soccer Field	Car Park	2	45,000



View of BMA Underground Car Park during construction stage (project with multiple land-use)



First underpass project in Bangkok, Din Daeng

Underpass project constructed by diaphragm wall support cut-and-cover method (twin bored tunnels of the first Bangkok MRT is located underneath this underpass)

These projects demonstrated the effective use of underground space in congestive urban areas of Bangkok and exemplified good solutions for environmental preservation. The development of underground space is important for mega city like Bangkok to keep valued surface public spaces.

Besides deep basement structures for high-rise buildings and projects with diaphragm wall and other forms of retaining structures, a vehicle underpass at major intersection in urban area is another type of underground space use in Thailand.

The first underpass was constructed by BMA at Din Daeng intersection in 1994 using diaphragm wall for the deep section. Since then more than 20 underpasses have been constructed by other agencies in Bangkok and other major cities in the country.

4. The Status of Tunnels in Thailand

Railway Tunnels

Tunnelling in Thailand dates back to early 20th century. The first railway tunnel was built 105 years ago in 1907 at Doi Khun Tan National Park. Having total length of 1.35 km, the tunnel was constructed with approximate dimension of 5.20 m in width and 5.5 m in height. This very first tunnelling project took 11 years to complete. According to the available report and literature, there were numbers of difficulties such as excessive groundwater intrusion and instability of the tunnel itself.

Three additional tunnels namely Pang Tup Khop Tunnel, Khao Phlung Tunnel, Huai Mae Lan Tunnel were constructed to complete the northern railway route. Ron Phibun Tunnel situated in southern part of Thailand in Nakhon Sri Thammarat was constructed almost same time as tunnels in the north. These 5 railway tunnels marked tunnelling history of Thailand. Tunnels were constructed by drill and blast methods using timber as main temporary supports. Below table shows the summary of tunnels constructed in early days. These tunnels are well maintained and still in operation under the State Railway Authority of Thailand (SRT).

50 years after completion of the first 5 tunnels, few more tunnels were built for the North Eastern railway route. During that time more up-to-date methods and technology imported from overseas were applied. Experience gained from construction of tunnels for various dam projects across Thailand helped better understanding of tunnelling in different types of rock. Over the past three decades, along with the development of tunnelling technology in other parts of the world, equipment, construction technique and design methods have significantly improved in Thailand.

Completed railway Tunnels in Thailand

Tunnel	Year of Construction	Length (m)	Province
Khun Tan	1907-1918	1,352	Lampang
Pang Tup Khop	1909	120	Uttaradit
Khao Phlung	1910	362	Phrae
Ron Phibun	1910-1912	236	Nakhonsri Thammarat
Huai Mae Lan	1912	130	Phrae
Khao Phang Hoei	1965-1966	230	Lopburi
Phra Phutthachai	1993-1994	1,197	Saraburi

Railway Tunnel under construction (as of March 2012)

Location	Length (m.)	Route	Province
Chiang Saen	300	Den Chai-Chiangrai-Chiang Khong	Chiangrai
Song	900	Den Chai-Chiangrai-Chiang Khong	Phrea
Phra Phutthachai	1,200	Cha Choeng Sao Khlong Sip Kao-Kaeng Khoi	Saraburi

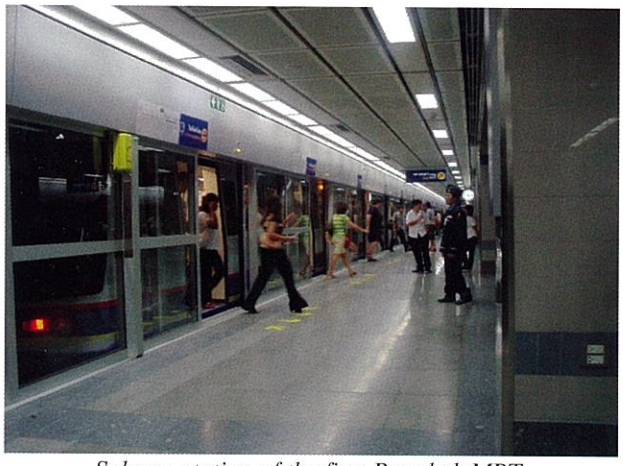
Subway Tunnels

Bangkok, the capital of Thailand has grown to one of the most populated cities in the world. Together with this development, the traffic problem was tremendously affecting the way of life of Bangkok urban population. The environmental impact from the Bangkok traffic, especially air pollution causes health problems. In addition, there are certain immeasurable costs of the quality of urban life that are becoming more and more critical for people of this mega city. As in other major cities in developed countries, Mass Transit System particularly underground system is only a final solution to all these problems. The first subway in Thailand was then initiated by the Thai government who drew up in 1995, the Bangkok Mass Transit Master Plan based on the 7th National Economic and Social Development Plan (1992–1996). This master plan was aimed at developing a mass transit network and a network of ordinary roads and expressways to achieve steady economic growth and resolving the traffic congestion and air pollution problems. It was also specified in the subsequent 8th National Economic and Social Development Plan (1997-2000) and positioned as an extremely important national project in Thailand.

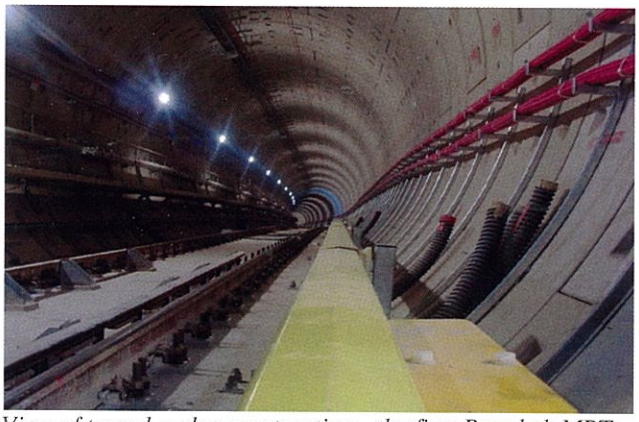
Design and construction of underground structures of the Blue Line Initial System Project (ISP) were divided into two contracts, namely the South Contract (Hua Lamphong – Rama IX) by Joint Venture BCKT consisted of Bilfinger + Berger Bauaktiengesellschaft, Ch Karnchang Public Company Limited, Kumagai Gumi Company Limited and Tokyu Construction Company Limited and North Contract (Rama IX – Bang Sue) by ION Joint Venture consisted of Ital-Thai Development Public Co., Ltd, Obayashi Corporation and Nishimatsu Construction Co., Ltd. The actual construction works of South and North Contracts were started in 1996 and 1997 respectively and the MRT line was opened for the public in 2004. In December 1999, the Blue Line ISP was graciously named by His Majesty the King of Thailand as M.R.T. Chaloem Ratchamongkol Line.

Metro Network of Bangkok – MRT Subway, BTS Sky-train, SRT airport link elevated train, MRT elevated train

EPB Tunnel Boring Machine being assembled



Subway station of the first Bangkok MRT



View of tunnel under construction - the first Bangkok MRT

The M.R.T. Chaloem Ratchamongkol line is a conventional heavy rail underground transit system of two approximately 22 km long parallel single-track tunnels with 18 stations and a major depot facility. The route starts from the Hua Lamphong station to Bang Sue station. The internal and external diameters of the tunnels are 5.7 and 6.3 m respectively, with the tunnel axis at 16 to 23 m depths from ground surface. At present, the project is operated by Bangkok Metro Public Company Limited (BMCL) with the concession granted by the Mass Rapid Transit Authority of Thailand (MRTA).

One of the major challenges of this Bangkok first subway project was the need of stacked-alignment for a major portion of twin bored-tunnel underneath Rama IV road, one of the busiest roads of Bangkok, which called for a stacked configuration at 3 stations, Lumpini, Si Lom and Sam Yan. This requirement led the contractor to design and construct the deepest underground structures of Bangkok at Si Lom Station - four-floor stacked-station of 32m deep right under the existing flyover and adjacent to a number of sensitive structures.

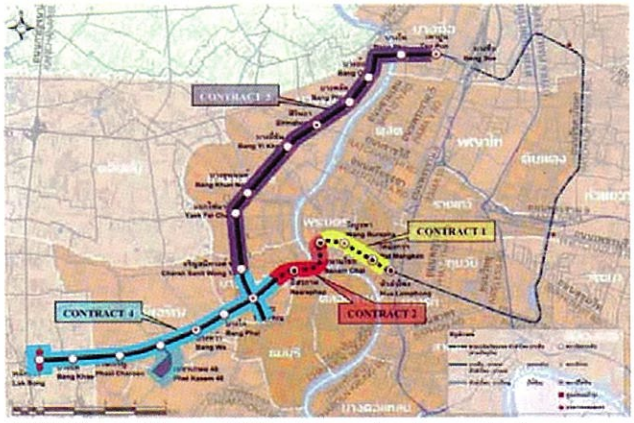
Deep excavation and bored tunneling works in congested urban environment of Metropolitan Bangkok requires a reliable construction method and modern tunnelling technology. Systematic process of ground movement prediction, building risk damage assessment and protection were of key issues. Twin tunnels were bored by the earth pressure balanced (EPB) Method, revolutionizing the soft-ground tunnelling in the industry with techniques allowing the tunnel construction in bad ground conditions with minimal ground movements. The EPB method has opened up new opportunities of tunnelling in congested urban areas like Bangkok. The tunnels were excavated mostly through stiff clay and sand layers. Eight EPB shields of 6.46 m diameter were used - 4 Kawasaki shields in the North Contract and 2 Kawasaki and 2 Herrenknecht shields in the South Contract. About 14 to 15 months in total were spent on the excavation of the tunnels, with an average rate of shield advance at 60 to 70 m/wk. Despite some major mechanical breakdowns for part repair and replacement, all of the shields performed satisfactorily in all types of soils encountered.

The first extension of the M.R.T. Chaloem Ratchamongkol line, namely MRT Blue Line Extension (Bang Sue – Tha Phra and Hua Lamphong – Bang Kae), is under construction at the present time. The project is a 27 km underground and elevated heavy rail transit system with 4 underground stations, 15 elevated stations, 3 intervention shafts, a depot with operation control center, and a park-and-ride facility.

One side of the Blue Line extension project starts at an underground section at Hua Lamphong station, runs along Charoen Krung road, turns at Sanam Chai road, passes under Chao Phraya River at Pak Khlong Talad, continues underground under Bangkok Yai canal, Arun Amarin road, and Issaraphap road, and then transforms to an elevated route to Tha Phra station. The route continues along Phet Kasem road and ends at Lak Song where the park-and-ride facility situates. The depot is located on the south side of Phet Kasem road near Lak Song. The route has a total length of 16 km with 4 underground stations and 7 elevated stations.

The tunnel configurations for the underground section consist of two parallel twin bored tunnels and two stacked twin bored tunnels, with a 110 m long cut-and-cover section from Hua Lamphong and a cut-and-cover section for transition from an underground track to an elevated portion. The tunnels are of 6.30 m in diameter and to be excavated mainly within the stiff clay layer and in some parts in the sand layer.

The other side of the Blue Line extension project begins above ground at Tao Poon station which will connect with Purple Line and Blue Line interchange station, goes along Pracharat 2 road, crosses over the Chao Phraya River at Bang Pho, continues on Charansanitwong road, and terminates at Tha Phra. It runs at a total length of 11 km with 8 elevated stations.



MRT Purple Line and Blue Line extension projects routes

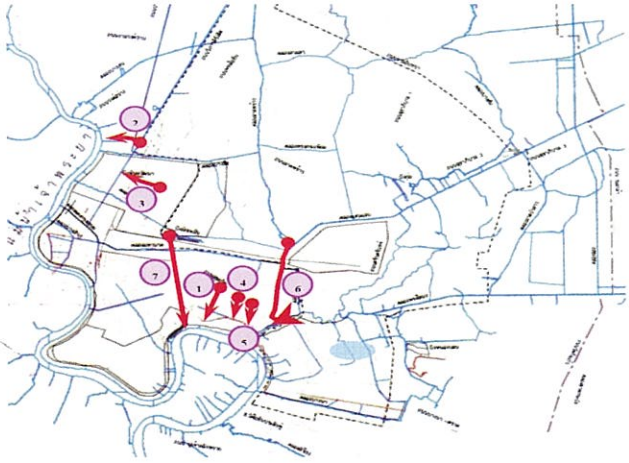
Flood Drainage Tunnels

Construction of underground drainage systems in Bangkok to enhance drainage efficiency in the areas with flood problems is necessary as Bangkok is located on the flood plain of Chao Phraya River and the local drainage system is insufficient.

The underground drainage systems are to reduce water levels in the existing canals and remove flood water to the main river as quickly as possible.

Due to the extensive land use and development in Bangkok areas, the existing main drainage channels were obstructed causing serious flood problems. Department of Drainage and Sewerage (DDS) under Bangkok Metropolitan Administration (BMA) has studied and planned to resolve this ongoing problem and prepare for future city development and expansion by setting up a flood protection master plan. DDS has completed an underground drainage system of seven drainage tunnels ranging in diameter from 1 to 5 m with a total length of about 20 km. The combined maximum drainage capacity of the system is about 155 cms.

The last two of the seven drainage tunnel projects were completed in 2007 - the water drainage tunnel from Sansaeb canal (Khlong Sansaeb) and Ladprao canal (Khlong Ladprao) to Chao Phraya River and the water drainage tunnel from Bung Makkasan (Makkasan pond) to Chao Phraya River. The former is the first tunnel in Thailand that is mostly located in sandy ground resulting in difficulties during construction. The tunnel has a total length of 5.3 km approximately with a maximum drainage capacity of 60 cms using 4 pumps at a pumping station. The project began in 2003 and completed in 2007.



Flood Drainage Tunnels of Bangkok Metropolitan Authority (BMA)

The flood drainage tunnels are crucial to the overall flood control strategy of Bangkok. It is apparent that flooding in low-lying area such as Ramkhamhaeng university area has been alleviated by completed flood drainage tunnel.

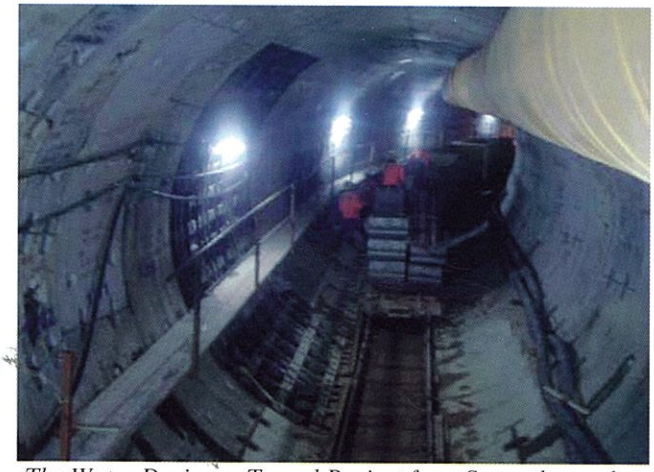
Completed water drainage tunnels

No.	Projects	Drainage Capacity (m^3/second)	Tunnel Diameter (m)	Length (km)	Budget (M.Baht)	Completed year
1	Water Drainage Tunnel Project, Soi Sukumwit 26	4	1	1.1	30	1983
2	Water Drainage Tunnel Project, Soi Sukumwit 36	6	1.5 1.8	0.03 1.32	129	2001
3	Water Drainage Tunnel Project, Soi Sukumwit 42	6	1.5 1.8	0.03 1.1	109	2002
4	Phayathai Drainage System Project	4.5	1.5 2.4	1.9 0.68	339	2003
5	Klong Prem Prachakorn Water Diversion Project	30	3.4	1.88	495	2001
6	Water Drainage Tunnel from Klong Sansaeb and Klong Ladprao to the Chao Phraya River	60	5	5.3	2,336	2007
7	Water Drainage Tunnel from Bung Makgasun to the Chao Phraya River Project	45	4.6	6.2	2,166	2007
Total		155.5		19.54	5,604	

The water drainage tunnel project from Sansaeb canal and Ladprao canal to Chao Phraya River comprises a reinforced concrete tunnel of 5.0 m inside diameter, a launching shaft of 15 m inside diameter, a receiving shaft of 15 m inside diameter, and a ventilation shaft at mid way between the launching and the receiving shafts. Tunnelling started from a receiving shaft at Rama IV pond, near the intersection of Ladprao canal and Sansaeb canal, and went underneath Sansaeb canal, Klong Ton, Sukhumvit 71 road, Sukhumvit road, and Phrakanong canal. It ended at the existing Phrakanong pumping station.

An EPB shield, 5.70 m in diameter and 8.05 m in length, was employed to excavate the entire length of the tunnel. The shield body was designed to have two portions with articulation mechanism at around mid length in order to facilitate the tunnel excavation in curve of small radius. The articulated shield could accommodate a radius of curvature of as small as 40 m. It was capable of providing a maximum jack thrust of 30 MN at a maximum jack speed of 100 cm/min with the manipulation of 20 shield jacks.

EPB shield, 5.70 m diameter for the Water Drainage Tunnel Project from Sansaeb canal and Ladprao canal to Chao Phraya River



The Water Drainage Tunnel Project from Sansaeb canal and Ladprao canal to Chao Phraya River in the Construction Phase

The water drainage tunnel from Bung Makkasan (Makkasan pond) to Chao Phraya River is another project completed to relieve flood problems in the inner Bangkok area.

The project consists of:

- Flood Drain Tunnel
- Intake Stations at Makkasan Pond, Saensaeb Canal, Pai Singto Canal, and Chua Pleung Road
- Pumping station at Wat Chong Lom.

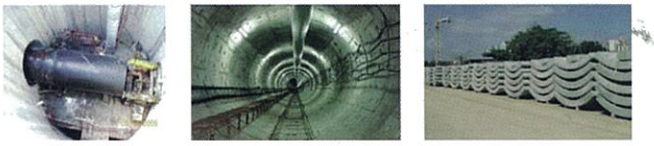
Construction of the tunnel started from the Makkasan Pond intake station to the Sansaeb Canal intake station, the Pai Singto Canal intake station, the Chua Pleung intake station, and the Wat Chong Lom pumping station where water was pumped to Chao Phraya River.

Construction of the intake station shafts utilized the moving slip form to cast the shaft walls of conventional reinforced concrete. Sinking of the shaft structure into the ground was performed in succession by excavating the soil inside the shaft in combination with applying compression forces along the top of the shaft. After the lower tip of the shaft was at the designed level, a concrete plug was cast at the tip of the structure and the reinforced concrete base slab was later constructed to form a platform for the assembly of the tunnel boring machine.

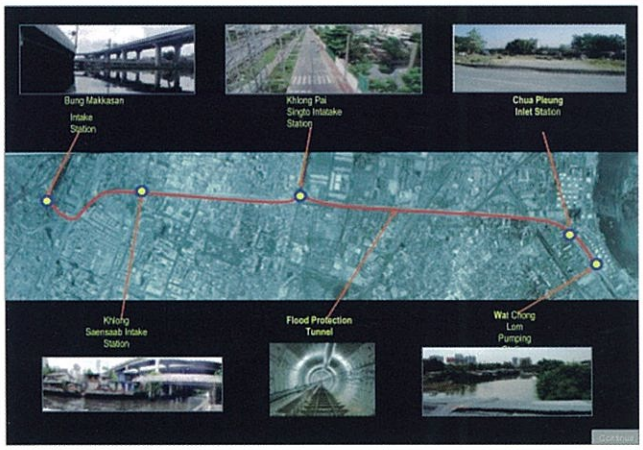
The tunnel boring machine employed in the project was of an EPB type. The excavated soil was removed out of the tunnel using conveyor belts at the excavation area into a series of muck cars attached to a locomotive. As the EPB machine excavated the soil, precast segmental tunnel linings were installed

and cement grout was placed between the tunnel lining and the soil to minimize ground displacements.

The tunnel is of inside diameter 4.6 m and with a total length of 6.2 km running at depths ranging from 20 to 35 m below ground surface. It was designed with a maximum flow rate of not less than 3.0 mps and 45 cms capacity to discharge water from the tunnel into the Chao Phraya River.



(a) Launching shaft (b) Flood drain tunnel (c) stock of precast tunnel segment



The Water Drainage Tunnel Project from Sansaeb Canal and Ladprao Canal to Chao Phraya River

Water Transmission Tunnels

Metropolitan Waterworks Authority (MWA) has been constructing series of clean water conveyance tunnels for Bangkok. More than 200 km of length of tunnels have been constructed in past four decades. The two twin tunnels of 31.5km in length Contract G-MC-7B and G-MC-7C as part of the Seventh Water Supply Improvement Project were completed in 2006. The recently completed project of Metropolitan Waterworks Authority comprises construction of a transmission tunnel of 3.2 m diameter with a 3 km length for Contract G-MC-7D/1 and a 10 km length for Contract G-MC-7D/2. It was aligned underneath Highway No. 351 and the East Outer Ring Road of Department of Highways, with the end point at the Tub Chang Valve Chamber. EPB technology was adopted to advance the tunnel through stiff clay and dense sand layers at approximate depths of 16 to 18 m below ground surface. The tunnel was constructed with segmental reinforced concrete lining and finished with the insertion of steel tube inside the tunnel. The construction begun in 2006 and completed in 2010.

TBM Break-through to receiving shaft in the Water Transmission Project

Water Transmission Project under construction

Diversion Tunnels

The first tunnels in dam projects were constructed in Thailand fifty years ago for the Bhumiphol Dam and the Sirikit Dam. Tunnel excavation for the former project was performed without major problems due to geological condition that consisted mainly of very strong gneiss. In contrast, the latter project involved difficult construction of diversion tunnel, power waterway tunnel, and overflow tunnel, owing to unaccommodating geological and geotechnical conditions. The key geological feature at the Sirikit dam project was composed of weak siltstone with a fault. The excavation of a 14.5 m diameter overflow tunnel faced with many difficulties including instability. Grouting and temporary support measures were employed especially at the fault zone.

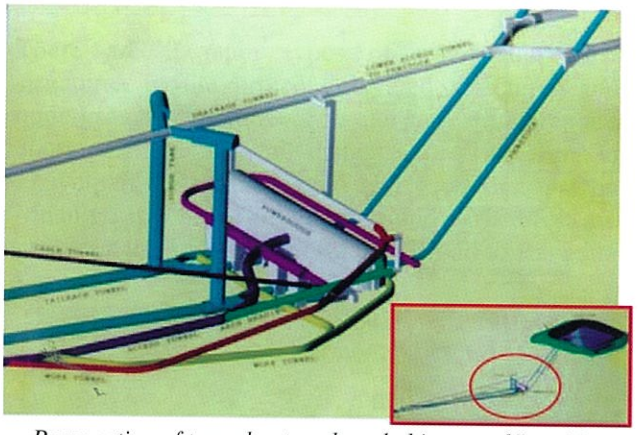
The problem of large rock falls during tunnel excavation of Kew Lom dam project underscores the importance of geological investigation. A diversion

tunnel was drilled through complex geological conditions with a number of rock discontinuities and faults. Lithologically, highly weathered tuff made of consolidated volcanic ash formation was present at the project. The stability of the tunnel during excavation was very low, with the over-break height of more than the tunnel diameter in some areas.

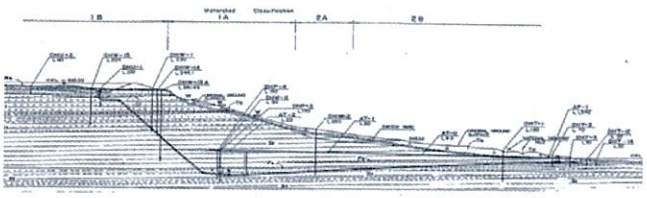
Excavations of mountain tunnels in Thailand were usually performed using drill and blast method, with the exception of upper pond drainage tunnel of Lam Ta Khong pumped storage project that was excavated using roadheader.

Aerial View of Lam Ta Khong Pumped Storage Project

The 1000-MW Lam Ta Khong Pumped Storage project is the first underground powerhouse project in Thailand. The project is situated on an escarpment of Lam Ta Khong Dam, which was used as a lower pond of the project. The project involved construction of more than 12 km of tunnels and shafts. The tunnels were of D shape and horseshoe shape with widths ranging from 3 to 8 m. The first tunnel was a 1.3 m tall and 3 m wide exploratory adit excavated from the outlet site at the rim of the lower pond crossing underneath a national highway to launch borehole investigation from the inside of the adit. The longest tunnels of the project were twin 8 m wide tailrace tunnels. They encountered with both very shallow and deep covers and oriented in various directions, with most perpendicular to the powerhouse, i.e. almost perpendicular to the direction of the maximum in-situ horizontal stress. The deepest tunnel was at 360 m depth in the vicinity of the powerhouse cavern. Rocks at the project site mainly consisted of Siltstone, sandstone and claystone of Phu Kradung - Pra Wiharn formations of the Khorat group. Major tunnel ground response encountered in the excavation consisted of lossening, stress slabbing, slaking, delayed fracturing and squeezing in groundwater affected area.



Perspective of tunnel network and chimney of Lam Ta Khong Pumped Storage Project

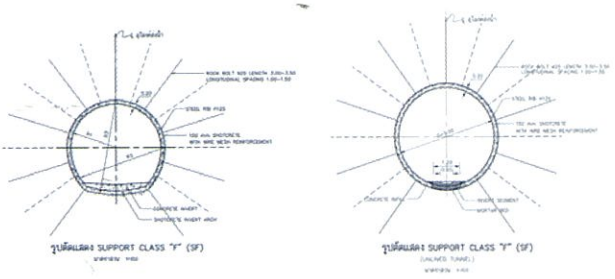


Profile layout of powerhouse cavern, associated tunnels and shafts with position of drillholes, Lam Ta Khong Pumped Storage Project

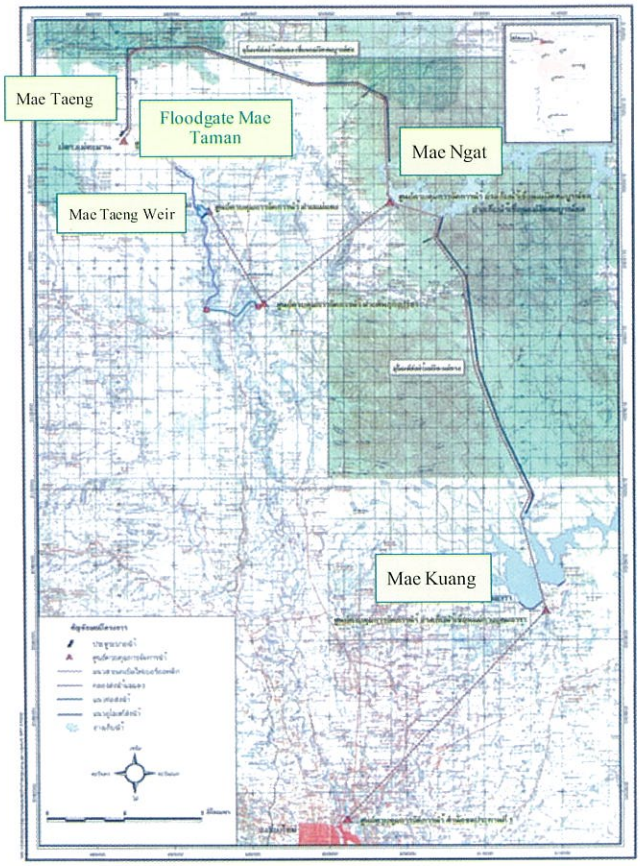
Mae Tang – Mae Ngat – Mae Kuang Diversion Tunnel project is another ongoing underground construction activity. Runoff from flow into the reservoir of Mae Kuang Udom Thara varied significantly from as low as 97 million cubic meters during the lowest period to as high as approximately 265 million cubic meters during the peak period. This resulted in difficulties in water management of the reservoir in order to meet the increasing demand of water due to the expansion of agricultural area and industry.

The diversion tunnel project is designed to help regulate the amount of water at the Mae Kuang Udom Thara reservoir by diverting water from Mae Tang river through the diversion tunnel of 4.0 m diameter and 25.6 km length at a flow rate of 5.28 cms to the Mae Ngat Somboon Chon reservoir. Subsequently, the water is to be diverted through the diversion tunnel of 4.2 m diameter and 23.0 km length at a flow rate of 26 cms to the Mae Kuang Udom Tara reservoir.

The project is expected to commence in the third quarter of 2012 and complete in 2017. At present, the detailed design has been finished and the project has been approved by the Cabinet for the budget in the year 2012.



Typical section of tunnel excavation and supports (SF Class) for Drill-and-Blast and TBM



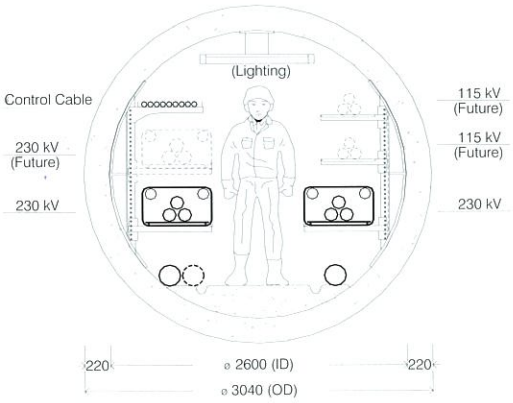
Proposed Mae Taeng – Mae Ngat and Mae Ngat – Mae Kuang tunnel alignments, Chiang Mai Province

Utility Tunnels

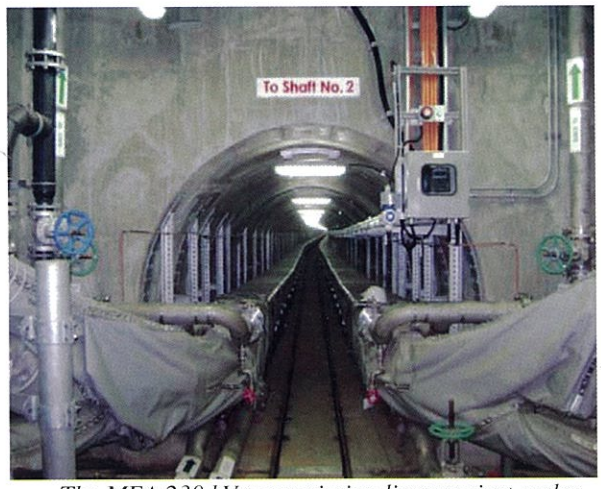
In 2010 Metropolitan Electricity Authority (MEA) completed the construction of 230 kV transmission lines connecting Bangkapi outdoor terminal station of Electricity Generating Authority of Thailand (EGAT) with newly constructed Chidlom terminal stations. The project covered the construction of 10 shafts (8 shafts of rectangular shape and 2 shafts of circular shape), a 2.6 m internal diameter tunnel with a total length of 7.0 km, and a reinforced concrete box gallery of 2.6 m width, 2.6 m height, and approximately 180 m length.

The tunnel depth was approximately 25 m from ground level to the tunnel centre line and was laid in stiff clay layer. The tunnel was excavated with two EPB shields and lined with precast reinforced concrete segments. However, steel segments were installed in a tunnel section with sharp curve of radius as small as 30 m.

The two EPB machines employed in the project were manufactured by JFE Engineering Corporation in Japan and performance tests were carried out upon the completion of machine fabrication at the manufacturer's factory. The machine was articulated at the joint between two sections of front shield and rear shield so as to enable it to manage tunnel drive in a sharp curve section of radius as small as 30 m. The overall length of machine was 6.515 m, with the front shield including cutter head being 3.715 m long and the rear shield including muck pump being 2.800 m long.



Tunnel arrangement for the MEA 230 kV transmission lines project



The MEA 230 kV transmission lines project under construction phase

5. Introduction to Future Projects

MRT Subway Tunnels

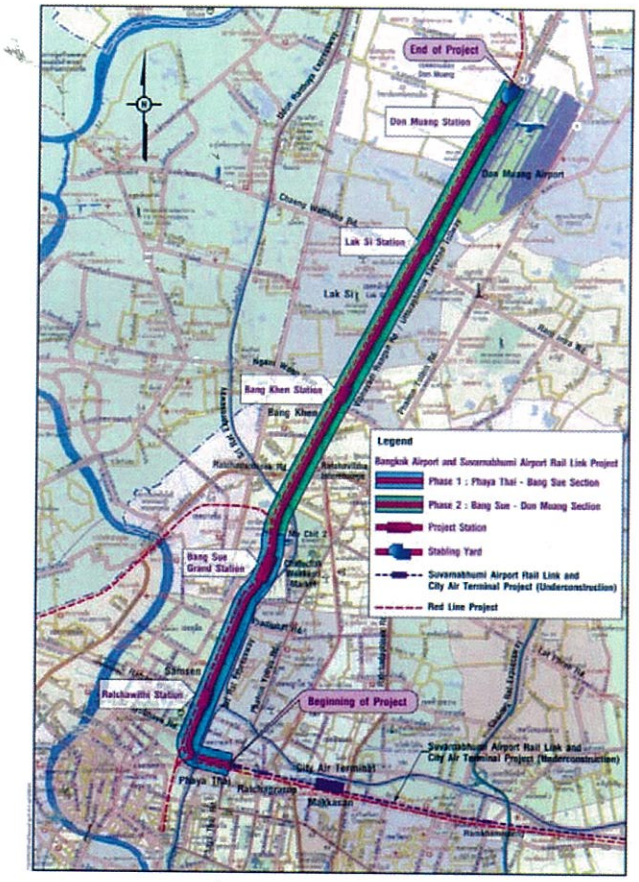
Three routes of the Bangkok Mass Transit System are in service at present. The Green Line has two routes in operation since 1999, the 6.5 km long National Stadium – Saphan Taksin (Taksin Bridge) route and the 16.4 km long Mo Chit –On Nut route. Both routes have a joint station at Siam station. The third route, Blue Line, opened in 2004 is a subway system running from Bang Sue to Hua Lamphong with a total length of 22 km.

Recently, projects on track are four additional routes that have been bid and under construction, namely Purple Line (Bang Yai – Bang Sue), Light Red Line (Bang Sue – Taling Chan), Airport Rail Link Extension (Don Muang – Bang Sue – Phayathai), and Blue Line Extension (Bang Sue – Tha Phra and Hua Lamphong – Bang Kae). The Green Line has been extended from On Nut to Bearing. The resulting route extensions are of a total distance of almost 80 km.

Being one of the most important air-transport hubs, Bangkok is served by two airports - the Don Muang Airport as the domestic airport and the Suvarnabhumi Airport as the international airport. In order to connect the two major airports, the Royal Thai Government has initiated the Airport Rail Link Extension (ARLEX). A consultant group is hired to study and design in details subsequent sections of the ARLEX to continue from the first completed section (Phayathai – Makkasan – Suvarnabhumi Airport). The project is divided into 2 phases, Phase 1: Phayathai – Bang Sue (for tourists and in-town passengers to transfer at Bang Sue interchange station) and Phase 2: Bang Sue – Don Muang (to complete the link between both airports).

The project has an approximately 22 km route length and is an electric heavy railway system that is identical to the initial completed section of ARLEX. The railway line will be constructed underground using the cut-and-cover technique for sections inside the inner city area and built above ground as bridge on piers from Ranong 1 road to Don Muang Airport on the north and east sides of the right of way of State Railway of Thailand (SRT). There are 1 underground station (Ratchawithi station), 3 elevated stations (Bang Khen, Lak Si, and Don Muang stations) and 1 modification work station (Bang Sue station) to accommodate the ARLEX railway line, including Don Muang stabling yard at the north end of the project. All maintenance works will be carried out at Khlong Tan depot.

There are 2 main types of track supporting structures in the project, elevated structures and underground structures. The elevated structures are employed for a total distance of 18.3 km in Phayathai – Rama VI road and Pradiphat – Don Muang sections. The underground structures are provided for 3.5 km from Rama VI road to Ranaong 1 road.



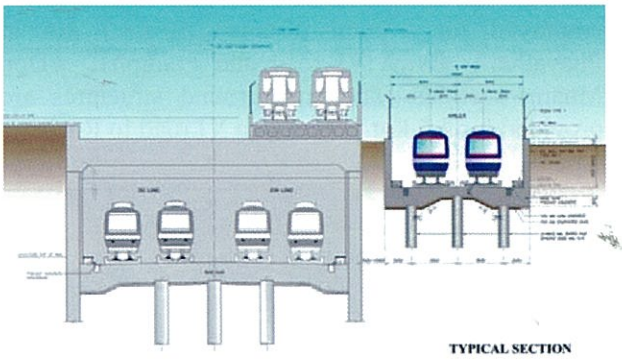
Route of the 2nd phase Airport Rail Link Extension

Two types of underground railway structures are being designed in the project:

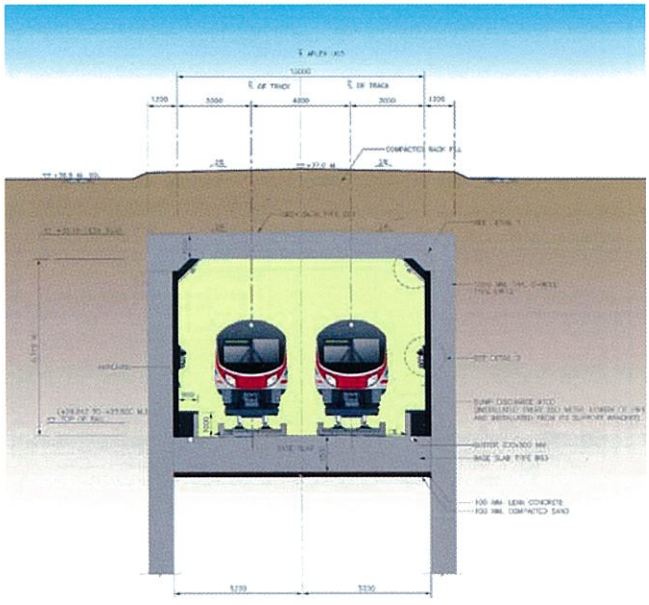
1. Open cut structure using conventional reinforced concrete retaining wall for shallow sections where the top of rails is not deeper than 3 m below ground surface, and
2. Cut and cover tunnels using diaphragm walls permanently braced by top and base slabs.

In 2012, many of the Mass Transit System projects will be prepared for bidding such as Pink Line (Kae Ly – Min Buri) of 36 km, Green Line (Mo Chit – Saphan Mai) of 11.4 km, Light Red Line (Bang Sue – Phayathai – Makkasan) of 19 km, Red Line (Bang Sue – Hua Lamphong) of 6.5 km, Red Line (Bang Sue – Rangsit) of 26.3 km, Purple Line (Bang Sue – Ratburana) of 19.8 km, Orange Line (Thailand Cultural Center – Bang Kapi – Min Buri) of 20 km, and Green Line (Bearing – Samut Prakarn) of 13 km.

In a total distance of 153 km, Bangkok and nearby area will have better transportation system.



Airport Rail Link Extension (ARLEX)- Three main configurations, Surface, Underground and Elevated



Airport Rail Link Extension (ARLEX)- Cut and Cover Tunnel

Moreover, in 2013, four more routes of the Mass Transit System project having total distance of 53 km will be prepared for bidding, i.e. Light Red Line (Taling Chan – Salaya) of 6 km, Red Line (Rangsit – Thammasat University Rangsit) of 10 km, Green Line (Sapan Mai – Kukod) of 7 km, and Yellow Line (Ladprao – Pattanakarn – Samrong) of 30.4 km.

MWA Transmission Tunnels

Metropolitan Waterworks Authority (MWA) has steadily developed its underground utility network from mid 1970's until present. As Bangkok is expanding rapidly more water transmission tunnels will need in this growing metropolis.

Metropolitan Waterworks Authority (MWA) has started the study for water transmission extension for the western Bangkok area. The water transmission tunnel of 3.2 m diameter and 5.1 km length will be started from Mahasawat Water Production Plant to Ratchapruek Valve Chamber. A 3.0 m diameter tunnel will be constructed from Ratchapreuk Valve Chamber to a river structure at Phetkasem road with a total length of 9.8 km. The tunnels will be lined with reinforced concrete segments coupled with an insertion of steel pipe as the innermost lining to prevent water leakage.

Another MWA project is the water transmission tunnel of 2.5 m in diameter starting from a drop structure at the Kanchanapisek – Ratchapruek intersection to Bangmod pump station and ending at Samrong pump station with a total length of approximately 30 km. There will be one valve chamber, 7 construction shafts, 2 risers, and one drop structure.

BMA Flood Drainage Tunnels

2011 flood crisis in Bangkok and other major provinces is considered the worst natural disaster in recent Thai history. Some parts of Bangkok and 65 of 77 provinces, , were declared flood disaster zones with damage covering over 20,000 km^2 of farmlands. The flood resulted in a total of 815 deaths and 13.6 million people affected, with an estimate of US$ 45.7 billion in economic damages and losses. Department of Drainage and Sewerage (DDS) of Bangkok Metropolitan Administration (BMA) has realised the paramount impacts of the flood and planned four additional tunnels of 5 to 6 m in diameter and a combined length of about 34.5 km, increasing the total length of flood drainage tunnels in Bangkok to 50 km and the drainage capacity of the city to 240 cms when completed.

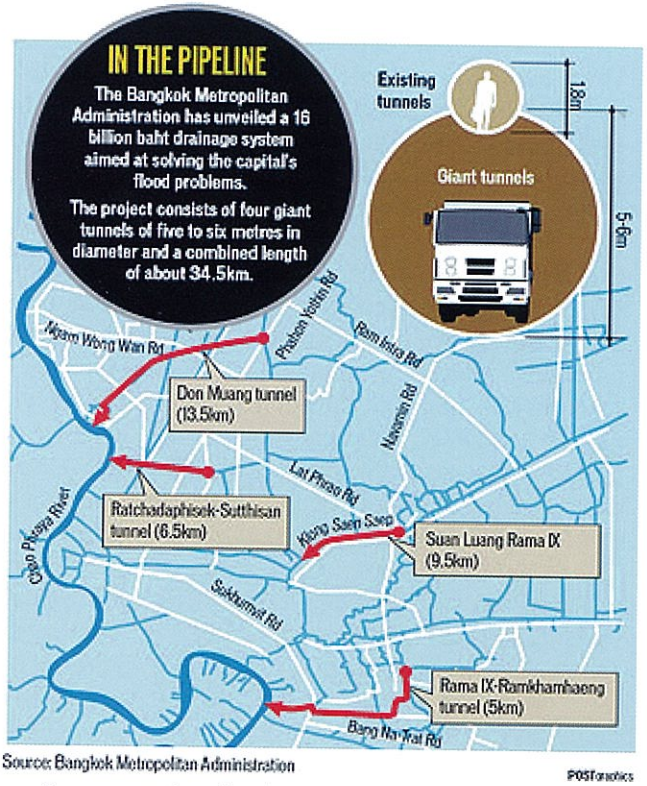
The first tunnel is the drainage tunnel along Bang Sue canal to Chao Phraya River, which has been recently awarded to a contractor for construction. The construction will be commenced in 2012. The tunnel length is 6.4 km with a drainage capacity of 60 cms.

The second tunnel is the drainage tunnel from Bung Nong Bon (Nong Bon pond) to Chao Phraya River. The total tunnel length is 9.2 km, from Nong Bon pond to Chao Phraya River at Klong Bang Or (Bang Or canal) pump station with a drainage capacity of 60 cms.

The third tunnel project is the drainage tunnel from Bang Kapi to the existing drainage tunnel from

Sansaeb canal and Ladprao canal to Chao Phraya River. The tunnel will be of 4 m diameter and 3 km length running from Soi Ladprao 103 to the aforementioned existing drainage tunnel.

The fourth tunnel project, the Bang Kaen canal drainage tunnel, will be 10.7 km long with a drainage capacity of 40 cms, running from Ladprao canal to Bang Kaen canal and ending at Chao Phraya River.



Four upcoming flood drainage tunnels in Bangkok

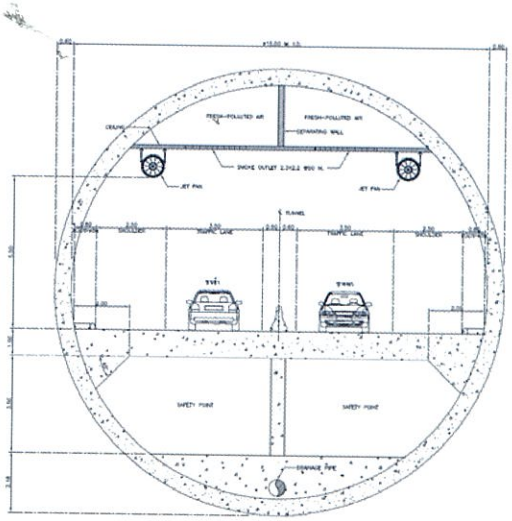
Road Tunnels

According to the available information, Thailand has over 60,000 km paved roads. The highway network links every part of Thailand. Though highway infrastructures in Thailand has been significantly improved in past 10 years, there are still limited road tunnels across the country.

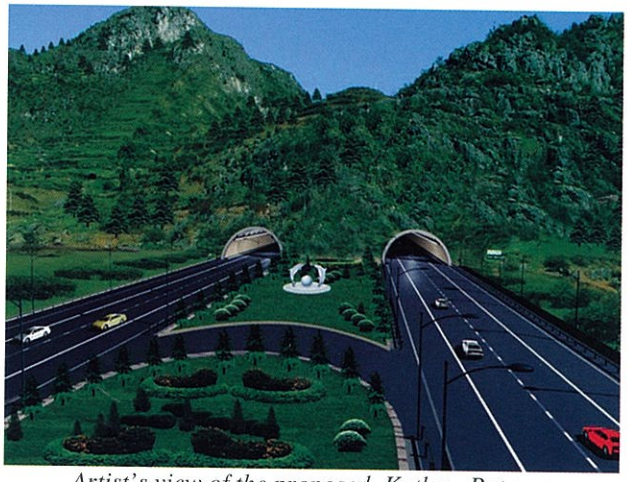
One of the interesting road tunnel in plan is Satun—Perlis Tunnel. Department of Highways (DOH) has a plan to construct a road tunnel connecting Satun and Perlis to serve as a gateway between Thailand and Malaysia.

The tunnel is to be built across mountain ranges with the cost to be borne by both countries. If implemented, it will be the first road tunnel linking the two countries. The tunnel is designed as a single tunnel with a single traffic lane of 3.50 m width with a 2.50 m shoulder in each direction.

The total length of tunnel is approximately 6 to 7 km passing through the Bintang mountain range in Malaysia and the Sankalakiri mountain range in Thailand. According to available geological information, the rock consists mainly of limestone where a cavity problem possibly exists. Two types of tunnel cross sections, a curvilinear shape and a circular shape of 15 m inside diameter, will be considered during detailed design stage.



Cross-section of proposed tunnel connecting Satun- and Perlis



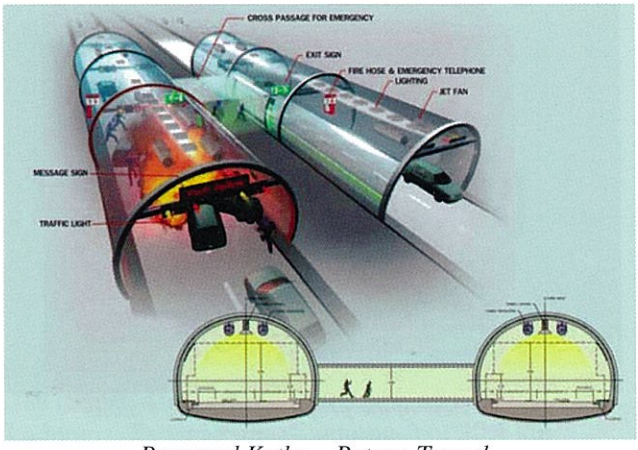
Artist's view of the proposed Kathu - Patong tunnel in Phuket

Patong beach is one of the popular recreation areas in Phuket among Thai and foreign tourists due to its natural beauty. The one and only existing road transportation to Patong beach is via a 2-lane Highway Route No. 4029 that directly connects Kathu district with Pathong beach. The traffic volume on the existing highway is generally excessive and road accident is very common. As the Muang Patong Municipality realised the significance

of these problems, proposed a road tunnel to alleviate traffic congestion and ensure travel time reliability for the road users.

Traffic congestion on existing road along the project alignment, proposed Kathu – Patong tunnel

The proposed six billion baht (US$201 million) road tunnel project will cut through the Nakkerd Hills. The project route starts from the south direction of Highway Route No. 4029 as a 4-6 lane highway at the Kathu side to Phung-muang-ruam Sai Gor road at the Patong side. The overall route is of approximately 3 km length, consisting of road, tunnel, and viaduct sections. The lengths of the tunnel in the Patong-Kathu direction and Kathu-Patong direction are respectively 1.581 km and 1.613 km, with the portal section of 40 to 85 m in length.



Proposed Kathu – Patong Tunnel
Perspective of Fire protection system in the road tunnel

The tunnel is designed as two one-way tunnels. Each tunnel provides 2 traffic lanes, each of 3.50 m width with a 1.5 m wide shoulder serving as a traffic lane for motorcycles and a 1 m wide walkway for emergency and maintenance works. The distance between each tunnel is approximately 25 m.

According to the preliminary studies, tunnel excavation will mainly be carried out by conventional drill and blast method, though in some sections roadheader may be required. In preliminary design proposal, particular attention has been paid to the numbers of safety features including CCTV system, fire protection system and emergency exit.

6. Conclusions

Tunnelling in Thailand dates back to early 20th century with construction of the first rail tunnel in 1907. Five railway tunnels constructed between 1907 and 1912 marked tunnelling history of Thailand. The first phase of shield tunnlling project was started in mid 1970's for the main water supply network of the Metropolitan Waterworks Authority.

Development in both construction and design aspects of tunnelling and deep excavation works in the past four decades have been significant particularly in soft ground. Owners, planners, engineers and practitioners involved in tunnelling industry have gained valuable experience from the completed projects. Thai consulting and design firms as well as contractors are now expanding their services overseas, particularly to neighbouring countries. However, more works need to be done in this growing industry with particular focus on capacity building, training, research and development, constructability issues, safety and quality control.

As a fast developing country, Thailand will need more infrastructure projects such as transportation, flood drain, water supply and power generation which involve different forms of tunnelling and underground excavation works. Underground construction works in the future will be more challenging and complex, especially in the congested urban area due to increasing constraints and restriction from environmental requirements.

Several underground and tunnelling works are being planned not only in Thailand but also in neighbouring countries. There is no doubt that Thailand and Southeast Asia region provide a vast open market for global tunnelling and underground construction society.

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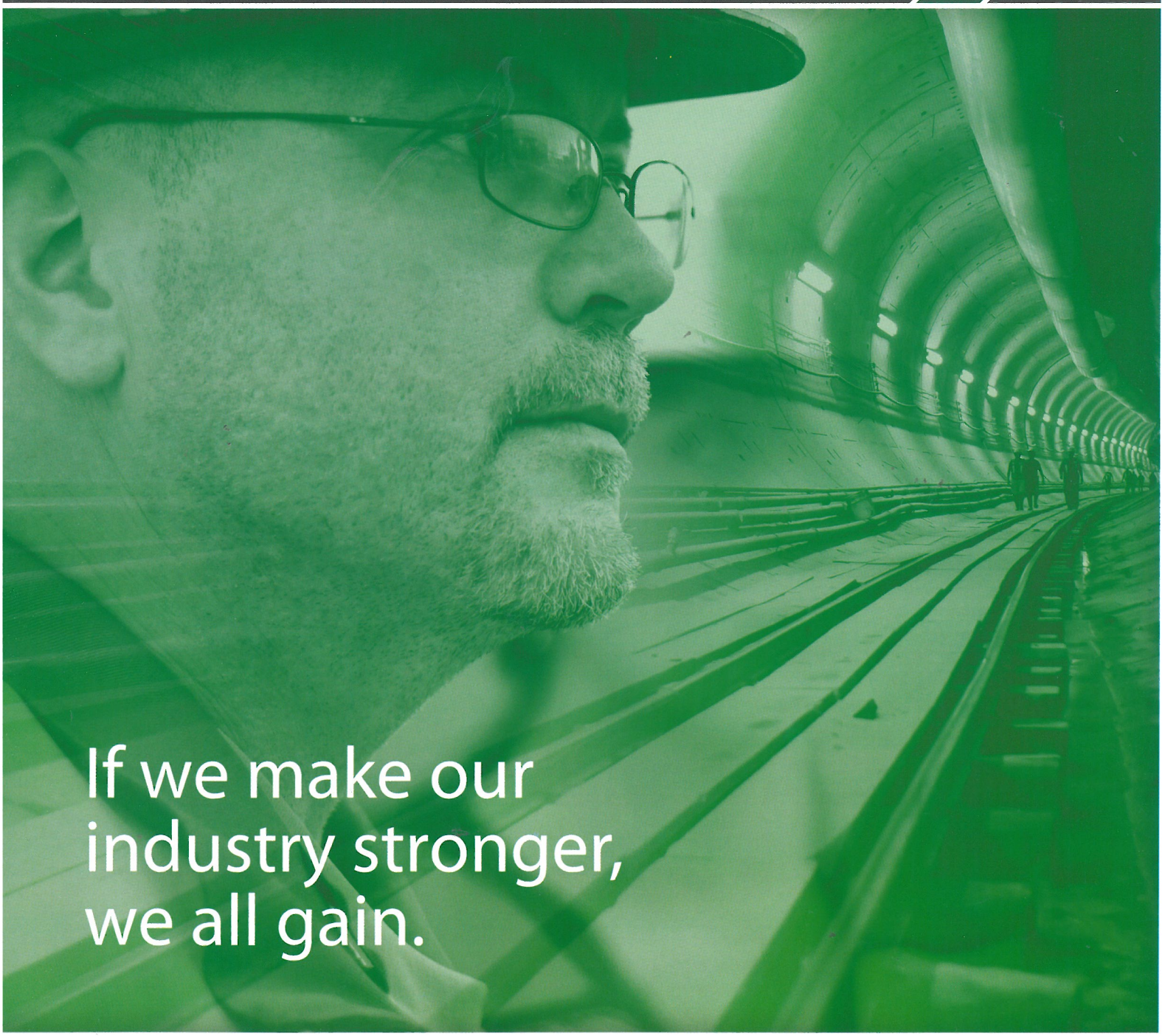

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