A REVIEW OF THE LITERATURE ON THE EVALUATION AND ROLES OF TUNNELS TECHNOLOGY IN MANAGING ENVIRONMENTAL DISASTER

Nuhu Isah and Maimunah Ali
Department of Technology Management
Faculty of Technology Management and Business
Universiti Tun Hussein Onn Malaysia

ABSTARCT

Managing environmental disaster requires the use of technology into how technology is used to minimize the casualties and loss incurred when disaster strikes. This paper involves the discussion on the evaluation and roles of tunnel technology in managing environmental disaster with a specific focus on the evaluation and roles tunnel play as the tool in flood prone areas. One particular example is SMART, an acronym for "Stormwater Management and Road Tunnel". The SMART tunnel plays a very vital role in flood management as well as the traffic congestion in the city center of Kuala Lumpur Malaysia. The project is undertaken as a joint venture projects between the government and the private sector corporation and SMART tunnel receives so many accolades due to its unique feature and distinct roles in managing flood disaster in the Klang Valley.

Keywords: Tunnels technology, environmental disaster management, SMART, Malaysia

1. Introduction

A tunnel is an underground passageway, completely enclosed except for openings for entrance and exit, commonly at each end. A tunnel is a passage way that carries people or vehicle across a destination that shortens the travelling time. Tunnels in the olden days are used for mainly mining works. As a result of technological development with time, tunnels construction had become more commonly used as transport routes that links places, rails links, vehicles and also as canals for water diversion. Tunnels are constructed all over the world. This paper will focus on the SMART Tunnel in Kuala Lumpur Malaysia. This tunnel is very unique because it is the type of tunnel in the world that combines the wet and dry system. The tunnel is used as a pathway to transport vehicle and also a channel for stormwater diversion from Kuala Lumpur Malaysia. The system is very unique as the tunnel is built using two Slurry Shield TBM machines that allows the drilling and tunnel lining work to be done continuously without setbacks. The machine also eliminates the hazard of tunnel stability during construction and also the ground water drawdown that cause sink holes. The entire paper is about the tunnel construction method, technology used, tunnel design, purpose and efficiency of the tunnel.

2. Literature Review

2.1 Tunnels

Underground tunnels in early days are used especially in mining. Tunneling and mining are together since beginning of the industry. Before mining, tunnels in ancient history were used for water carriage. In cities such

as ancient Rome, tunnels were designed to carry water supply from aqueduct nearby. The technology of tunneling developed from ancient days until now. Sometimes tunneling becomes solutions to so many challenges, but constructing tunnels are still under major studies because we need to upgrade the design according to time and needs.

The development rock tunneling is influenced by these major parts. There are rock drilling machine, drill bits, and explosives (Megaw& Bartlett, 1981). When the scientist from China invented the gun powder, it gave way to new methods for tunneling work to presume. Gunpowder since that has developed into more severe usage in the tunneling industry. Gunpowder gave way to much more powerful nitro-glycerine, quickly followed by dynamite, introduced by Nobel in 1967(Megaw& Bartlett, 1981). In rock drilling, compressed air became the accepted motive power, although the usage of the hydraulic powered machines was preferred for a time period commonly in Europe.

The use of explosive in hard layer is common in order to blast through the hard surface. Blasting is the easiest methods in constructing tunnel, but there are weakness such as the safety and problems of excessive caving in of the layer. There are different types of tunnels constructed from different soil layer or location, such as: Hard Rock; Underwater; and Soft ground.

Tunnels also are the major solution for the purpose of pedestrian crossing, road traffic, for the usage of the vehicles, railway links and also for canals. Most of the tunnels are designed and constructed specifically for carrying water for daily consumption, for the purpose of generating electricity such as the hydroelectric or as sewers for major cities to ease the flooding problems and for telecommunication cables. Brunel's great Thames Tunnel is the first tunnel that was ever built to cross under a tidal river and the first shield driven tunnel (Labor Law Talk Encyclopedia, 2005).

Tunnels are usually constructed in different type of ground soil layers that varies from soft clay to hard rock layer. In soft clay layer the tunnel digging are done using New Austrian Tunneling Method (NATM) and in hard layers Tunnel Boring Machine (TBM) are used widely ((Megaw& Bartlett, 1981).

2.2 Tunnel Design

In a contemporary situation, tunneling is one of the common solutions to solve the design problems in existing cities with a lot of obstruction or heritage path, in nature such as mountain areas, cross the channel or ocean etc. All this had an influence on the development of tunneling technologies in the recent years. There are some characteristic features that had to be considered when considering the area of tunneling. The entire factor below will finally decide the suitable construction method in that area to complete the tunnel project (Kusakabe et al., 1999). The key factors are:

1. The environmental condition, geotechnical and hydrogeological characteristics of the soil layers.
2. The impact of the construction of tunnels to the underground utilities and on the surface such as streets and buildings.
3. Availability of possible surface traffic for all vehicles or traffic control.
4. The cost of tunnel, the technical aspect, and the construction time schedule of the tunnel.

2.3 Cut and Cover Tunnel

In constructing tunnel using the cut and cover method, the shape of tunnel will usually be rectangular and stations and the followings are the basic technologies been used:

1. Reinforced concrete walls with steel struts, pre-stressed tie-backs or self-supported.
2. The ground water in the soil is lowered by introducing the water well systems.

The diaphragm of the tunnel installed using machineries and the bottom depth ranges from 20-30m below ground surface. Then the well is to eliminate water, it will be placed inside or outside the excavation (O.Kusakabe, K.Fujita, & Y. Miyaki, 1999).

2.4 Tunnel Boring Machine Technologies

The Tunnel Boring Machine (TBM) was introduced in 1975. The transport and evacuation of the excavated mucks and the mounting the reinforced concrete lining was done using this machine. Since then the technology has developed widely. For instance for 1m tunnel, the technology comprises;

1. The excavation phase and the TBM advance.
2. The pre-casted concrete segmental lining is erected.
3. Soil grouting and water proofing works outside the lining ring.

The TBM is launched in larger tunnels that later were used as the water pumping station or ventilation shafts (Kusakabe, et al., 1999)

2.5 Underground Road Tunnel

Development of some countries brought about new technologies particularly on engineering. Innovation in engineering also plays a vital role in upgrading existing services and invention of infrastructures such as tunnels, long bridges etc. Development of road tunnels is widely known in Europe compared to Asia. But currently it is getting more attention in Asia as there are numerous advantages from this type of development.

In Malaysia, the use of road tunnels are very less compare to other European countries. There are numerous tunnels such as The North-South Expressway Tunnels (Jelapang) and currently SMART Tunnel. Penchala Tunnel is the first breakthrough in tunneling technologies in Malaysia, when the government joint ventured with GAMUDA Berhad to construct the 710m long tunnel

2.6 Tunnel as Stormwater Sewers

Stormwater sewers are defined as storm filter. Most major cities around the world are using sewer system to transport rainwater to nearby outlet such as stream or rivers. Storm sewers are pipes that transport water runoff from streets to natural water source such as stream and rivers. Commonly catch basins are provided in order to store the water before gradually releasing it to rivers. The catch basin also functions as the trap for water floating debris such as rubbish, sands and other unwanted materials that not supposed to be in the natural rivers.

Some storm sewers are treated and some are not treated. This depends on area and jurisdiction. Treatment of water helps to clean and purify the water in order to release in the natural rivers. This is very important as every engineering structures or planning have to consider the environmental issues as one of the priority status.

3.0 History of Storm Sewers

The earliest sewer that was found was in the Indus Valley civilization. In ancient Rome, the Cloaca Maxima was considered a marvelous engineering design and construction. In the medieval European cities, small natural waterways are built to channel wastewater and as time passes this were upgraded to cover channel that is known today as sewer systems (Labor Law Talk Encyclopedia, 2005).

3.1 Tunnel versus Bridges

The development in construction technologies have resulted in development of major structure such as skyscrapers, roads, highways, airports, ports, tunnels bridges and etc. The main reason bridges are more preferable because of the cost and the simplicity of the design and construction. Simplicity doesn't mean that bridges are easy to build than tunnel, but in certain circumstances it does look easier. There are advantages and disadvantages of using bridges compare to tunnels.

The advantages are it is cheaper compare to tunnel that needs expensive budgets. The disadvantages are navigational consideration may limit the use of high bridges or draw bridges spans when intersecting with shipping channels such as the Penang Bridge that intersects the Penang Straits from the island to the mainland Butterworth with length at 13.5km.

Figure 1: Penang Bridge, Malaysia

However, the tunnel construction are more expansive compare to the bridges but the advantages are for navigational crossing, it will be easier and more convenient to build as it does not interrupt the movement of busy channel Such tunnels are constructed around the world such as the Lincoln Tunnel (Between New Jersey and Manhattan Island in New York City . There are also combination of bridge and tunnels such as the Hampton Road Bridge-Tunnel that connects City of Norfolk and Hampton.

3.2 History of SMART tunnel

The Atlantic Avenue Tunnel, Brooklyn, New York that was built in late 1844 by cut and covers method for the Long Island Rail Road. This is New York's oldest underground tunnel for rail link (Labor Law Talk Encyclopedia, 2005).

The Channel Tunnel between France and England under the English Channel is the second longest tunnel in the world with a total length of 50km, out of which 39km are under the sea (Labor Law Talk Encyclopedia, 2005).

The Thames Tunnel was built by Marc IsambardBrunnel together with his son Isambard Kingdom Brunnel which was completed and inaugurated in 1843. This is the first underwater tunnel and also the first tunnel using the tunneling shield (Wikipedia, 2005).

Figure 2: Thames Tunnel, London, 1943

The North Cape Tunnel in Norway that was opened in 1999 is one of the world longest undersea road tunnels. It connects the island of Mageroya with the main land that spans around 7km and reaches the depth of 212m below sea level. The construction period was around 4years from 1995 to 1999(Labor Law Talk Encyclopedia, 2005).

SMART Tunnel in Malaysia was initiated by Malaysian government under the leadership of the former Prime Minister Tun Dr. Mahatir Mohammad with the aim of solving flooding and traffic congestion in

the city center of Kuala Lumpur. According to Siao (2003) The SMART tunnel project are located nearby the confluence point of Sg Ampang river and Sg Klang river in the north and ends at the lake at Desa Water Park .The total tunnel length is 9.7 km with a bore diameter of 13.26m. Therefore there are two components of this tunnel, the StormWater tunnel and motorway tunnel. It is the longest multi-purpose tunnel in the world. This project included the cooperation of local authorities, private sectors, and some international engineer consultant. The Government Departments involved in this project are the department of irrigation and drainage Malaysia and Malaysian Highway Authority. For the private sectors are MMC Berhad, GAMUDA Berhad and Mott MacDonald.

4.0 Roles and Function of SMART tunnel

SMART tunnel played a vital role in the city center of Kuala Lumpur Malaysia due to its technical feature. The 13.2m diameter tunnel consists of a 9.7km storm water bypass tunnel, with a 4km dual-deck motorway within the storm water tunnel. The main purpose of SMART is to solve the problem of flash flooding in Kuala Lumpur from the Sungai Klang and Kerayong rivers and also to reduce traffic Congestion during the daily rush hour. The dual-purpose SMART tunnel begins at Kampung Berembang lake and ends at Taman Desa lake, diverting floodwaters away from the confluence of the two major rivers that run through the city of Kuala Lumpur. The 4km motorway tunnel incorporated into SMART acts as an efficient alternative route from the Southern Gateway of KL-Seremban Highway, Federal Highway, Besraya and East-West Link from entering and exiting the city center. However, the tunnel greatly reduces the travel time between the Jalan Istana Interchange and KampungPandan from around 15 minutes down to just four minutes.

5.0 Evaluation of SMART tunnel

Kuala Lumpur sits on karstic limestone with a high ground water table. For this kind of geology it was decided that tunnel boring machines (TBMs) would be the most cost-effective and least damaging method to construct the tunnel.

After much research, 13.2m Diameter Slurry Shield TBMs were chosen. In terms of diameter, these are among the worlds' largest. The Slurry Shield TBM consisted of four main parts:

- **Rotary Head Cutter**, with tungsten pick bits used for excavation of soil and disc cutters used for the excavation of rock
- **Bulkhead**, where a pressured bentonite slurry shield is formed to provide stability during the tunnel excavation
- **Hydraulic Rams**, which were used to drive the machine forward and keep the tunnel in its correct position
- **Tunnel Lining Erector**, used to install the pre-cast concrete wall lining

In addition to the above, the TBM featured two bogies on rails that house electrical, slurry pumping, ventilation equipment and cables/pipes.

Both Slurry Shield machines started from the JKR field area in Jalan Chan Sow Lin. One machine bored northwards, under JalanTunRazak and JalanDesaPandan and ended at the lake at Ampang, behind Gleneagles Hotel. The other TBM bored southwards, under the Jalan Chan Sow Lin and the KL-Seremban Highway alongside the SgBesi airfield and terminated at the lake in Taman Desa.

Tunneling began in 2004 and was completed in August 2006.

5.1 Three modes of operation

The SMART tunnel works on a three-mode system:

- **MODE 1**
  Normal conditions. When there is low rainfall and no storm. The motorway section is opened to motorists
- **MODE 2**
  Moderate storm. The SMART system is activated and floodwater is diverted into the bypass tunnel in the lower channel of the motorway tunnel. The upper channel will still be open to motorists.
- **MODE 3**
  The tunnel will be closed to motorists. Once all vehicles have vacated the tunnel, automatic water-tight gates are opened to allow floodwater to pass through.

5.2 Safety Features of SMART tunnel

Escape Route

The tunnel is fitted with escape route every 250m of the tunnel. This passageway connects not only from the decks to external of the tunnel but also it acts as the crossway from one deck to another deck of the tunnel. This facilitates people to escape from the lower deck of the tunnel to upper deck in case of emergency at the lower deck. The entire passageway is fitted with smoke doors and also fire resistant wall in order to facilitate the evacuation of the tunnel in case of fire.

Fire Fighting System

The tunnel is fitted with automated sprinkler system the reacts when the fire sensors and smoke sensors activated. This sensor does not react with the vehicle smoke but only the smoke from real Fire Fighting equipment such as hose reels, fire hydrants and fire extinguishers are located at every intervals of the tunnel.

Ventilation System

There are four ventilation shafts that split the tunnel into three major divisions. There are located approximately 1km intervals. The powerful ventilation suction fans will constantly renew the air and maintain the air quality within the motorway. The lowest channel where the Storm water is diverted during normal storm does not equipped with any electrical devices. In case of the major storm where the three decks of the tunnel are closed the mechanical ventilation will automatically shut down in order to make way for the flooding of the tunnel.

5.3 Importance of the project

The project was specifically started because of the frequent flooding in the metropolitan city because of the current drainage system could not cater the increment of the yearly rainwater in the city. The city is located in the valley there for drainage system is very important to channel the water out to the nearby stream. Currently the water is channeled into the Klang and Gombak River that is passing through the city.

These are the two important rivers that brought up the city. Kuala Lumpur is the capital city of Malaysia that is developing into a major business, administration, education and living hub. The project mainly initiated after numerous studies conducted in Klang River that proves the confluence of the Klang River/Ampang River and also Klang River/ Gombak River is at the critical level and the river is prone the flash floods includes all the surrounding vicinity. This process is further worsened by the existing Tun Perak Bridge at the corner

Masjid Jamek which causes the flash flood to happen almost frequently after heavy rain fall in the city.

To overcome this problem a new water channel is needed to overcome the frequent flash floods in the city. SMART Project was the solution to overcome the problem. This system will divert excess stormwater away from the existing water catchments area that is the Ampang/Klang River through a holding pond, a bypass tunnel and a storage reservoir before it will released back into the Klang River. This is one of the proper solutions to solve this problem because the existing rivers could not cater the large amount of water during heavy storm. Another major task of the SMART Project is to reduce the traffic congestion at The Kuala Lumpur's southern gateway. A portion of the tunnel about 3km will be a dual-usage, which is the stormwater management and road tunnel. This portion of the tunnel starts from KampungPandan roundabout and ends at the Kuala Lumpur-Seremban Highway near the Istana Road junction.

Conclusion

Tunnels play a vital role in our way of life as it ease the method of transportation in urban cities in the world. Tunneling works came in to being in eighteen century, the technology and the construction method had developed over time. The current technologies used in tunnels construction around the world are becoming greatly develop and very efficient. In recent years technology has introduced new sets of tunneling technologies such as the tunnel boring machine (TBM). In this paper, SMART Tunnel in Malaysia had shown the new steps taken by the Malaysian Government to upgrade the national's urban transportation system in the capital city of Kuala Lumpur. This tunnel is a recipient of so many accolades, it is the only kind in the world that introduces the wet and dry system. This tunnel is used to drain out the flood water from the Kuala Lumpur city center and also to reduce the traffic congestion in the Southern Gateway (Sg. Besi Highway).

References

Thames Tunnel, "Wikipedia-The Free Encyclopedia", retrieved from http://en.wikipedia.org/wiki/Thames_Tunnel on DATE 2013.

Penchala Tunnel, "Sprint", Sprint Info Centre, retrieved from http://www.sprint.com.my/cms/AllProduct.asp?CatID=80 on DATE 2013.

Laerdal (2002) "Worlds Longest Tunnel", Public Roads Administration, SoanogFjordane, retrieved from http://home.no.net/lotsberg/data/norway/laerdal/tunnel.html on DATE 2013.

Lincoln Tunnel, "Lincoln Tunnel- Historic Overview", Eastern Roads, retrieved from http://www.nycroads.com/crossings/lincoln/ on DATE 2013.

Scott M. Kozel, (2003), "Hampton Road Area Interstates and Freeways", Roads to the Future, retrieved from http://www.roadstothefuture.com/HR_Interstates_Freeways.html on DATE 2013.

TM Megaw& JV Bartlett, (1981), "Tunnels (Planning, Design, Construction)", 1st edition, Ellis Hardwood Ltd, Chichester.

O. Kusakabe, K. Fujita & Y. Miyazaki, (1999), "Geotechnical Aspects of Underground Construction in Soft Ground", A.A. Balkema, Rotterdam.

Hancock, N. (2005),"Research Project ENG4111/4112" - USQ Study Book, University of Southern Queensland, Australia.