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ANALYSIS OF UNDERWATER TUNNEL

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ABSTRACT

Tunnel Construction for transport courses has gotten progressively significant around the world. Transport has been sped up and ideal insurance is accommodated the climate and the scene. Such countless tunnels are viewed as mechanical showstoppers and governments have regarded tunnels designs as legends. Building a tunnel, notwithstanding, is quite possibly the most perplexing difficulties in the field of structural designing. Tunnels are appealing answers for rail lines, streets, public utilities, and broadcast communications. Since, Overall populace is expanding quickly so the need of fast or speedy transportation to counter this roughly 3/fourth of earth floor which is submerged is to be utilized. This brings about development of submerged tunnels. A submerged tunnel is a section, exhibition, or street underneath a waterway. Submerged tunnels are utilized for interstate deals, railroad, and trams to move sewage, oils, gas, or vehicles and for military and common protection reason. Current submerged tunneling starts by developing an inundated cylinder inside a pre- tunneled channel on the waterway or ocean bottom, to do these pre-assembled areas of steel and solid cylinder are coasted into position and deliberately sunk into the channel. Drenched tunneling is a craft of controlling the extraordinary characteristic power, the water, to do Designing works: "managing" lightness for transportation, "directing" water loads for inundation, and "managing" hydrostatic pressing factor for association.

Keywords: Transport, Submerged, Research.

I. INTRODUCTION

Tunnel is an underground or undersea passageway. It is dug through surrounding soil, earth or rock, or laid under water, and is usually completely enclosed except for the two portals common at each end, though there may be access and ventilation openings at various points along the length.

Underwater tunnels can be used for a variety of purposes, including:

- Roadways
- Railways
- Public transportation
- Vehicles
- Oils and gases
- Military and defense

II. METHODOLOGY

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).

Design of water tunnels

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 geotechnical and condition, 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.

Cut and Cover tunnels

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).

Tunnels 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)

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.

Tunnel and storm 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.

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.

Tunnel viscus 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.

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 asthe Hampton Road Bridge-Tunnel that connects City of Norfolk and Hampton

III. 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 (Wikipedia, 2005). the tunneling shieldse fires. They can trigger landslides and tsunami

Tunneling Process:

When the genuine exhuming of the tunnel is completed, field examinations proceed at the tunnel face. Development examination comprises a center snippet of data for the dynamic interaction in regard to other burrowing exercises, profoundly reliant, of the real stone or soil conditions experienced at the tunnel face. The actions identified with the water control and the conclusive stone help ought to be evaluated and choose, thinking about the genuine boundaries. estimated at the tunnel face.

Some applicable data to be enlisted at the face rock planning is as per the following:

- Rock Stresses and Strength
- Q Esteems
- Lugeon Worth

As the tunnel project progress in its cycle, various cycles are executed to build up the fundamental idea and acquire more practical estimate of the venture scope. All the data gathered as a component of the topographical examination is incorporated, as important contribution, in the designing and plan and venture the executives' measures.

The expectations of both will help chiefs to choose the task execution or its scratch-off. The burrowing interaction is characterized in this work as the execution of four (04) distinct exercises, which are as per the following:

- Excavation
- Ground Water Inflow Control
- Rock Mass Help
- Tunnel Coating

The exercises identified with the burrowing cycle are exceptionally delicate to unsettling influences produced by land and development vulnerabilities. Consequently, unsettling influences, produces in the burrowing interaction, influence significant venture standards, for example, cost, time, or security. As indicated by Isaksson (2002), the principal reason of this significant degree of affectability to unsettling influences is because of sequential nature of the burrowing cycle, which is essentially because of the by the accompanying requirements:

- Limited ability to change work environment area.
- Limited ability to perform equal exercises.

Figure.1 Tunnel base

Hyperloop :

Hyperloop is a proposed very high-speed ground transportation system for both passenger and freight that has the potential to be revolutionary, and which has attracted much attention in the last few years. The concept was introduced in its modern form relatively recently, yet substantial progress has been made in the past years, with research and development taking place globally, from several Hyperloop companies and academics. This study examined the status of Hyperloop development and identified issues and challenges by means of a systematic review that analyzed 161 documents from the Scopus database on Hyperloop since 2014. Following that, a taxonomy of topics from scientific research was built under different physical and operational clusters. The findings could be of help to transportation academics and professionals who are interested in the developments in the field, and form the basis for policy decisions for the future implementation of Hyperloop.

Method of Hyperloop :

Technology assessment consists essentially of the following major steps (MITRE framework according to Martin Citation1994):

- (1). Define the assessment task
- (2). Describe relevant technologies
- (3). Develop state-of-society assumptions

- (4). Identify impact areas
- (5). Make preliminary impact analysis
- (6). Identify possible action options
- (7). Complete impact analysis.

IV. RESULTS AND DISCUSSION

Traffic control and safety

The claimed higher intrinsic safety of Hyperloop in comparison with airplanes and trains is not evident, because the risks of a possible failure of the extremely high emergency braking rates on the integrity of all vehicles operating and on the braking system itself have been underestimated. The integration of the propulsion system into the vacuumed tubes and the vaguely described speed supervision system cannot guarantee that the capsules can be accelerated to speeds that, according to Musk (Citation2013), are safe in each section The elimination of risks through human control error or unpredictable weather is insufficient, unless safe headway distances, speed and acceleration supervision are continuously assured by an automatic vehicle operations control system with the same functionality as for existing automatic train operation (ATO) systems (Yin et al. Citation2017) like communications-based train control (Siemens Trainguard MT, Seltrac Thales CBTC] on modern driverless metro trains (e.g. in Lille, Paris, London, Singapore).

The recent claim of Hyperloop Transport Technologies and other companies to offer the safest form of transportation on the planet seems premature unless it will have demonstrated successfully a sufficient number of test runs at maximum speed to prove the required safety integrity level SIL4 and acceptable levels of passenger travel comfort. The very short minimum headway time of 30 s between Hyperloop vehicles operated at very high speed, assumed maximum acceleration of 1g, and 0.5g for braking up to 1g for emergency deceleration, respectively (Musk Citation2013; Decker et al. Citation2017) will not guarantee fail-safe operation according to proven standards of high-speed railway ATP and ATO safety systems.

Even the proposed service deceleration rate of 0.5g may not be realized in practice, because the intended linear motor can be applied for braking only at locations spaced at large distances (70 miles), whereas it will be necessary at every position in case of incidents and the mechanical braking may fail due to overheating. In fact, there will be no alternative braking system available along the intermediate route sections between the distributed accelerators apart from mechanical braking. The missing of a redundant braking system along the whole line will be an unacceptable risk if the first one is not working properly and can cause serious lethal accidents and damage. Thus, for safety reasons, a linear motor will need to be built at least along the whole route.

Furthermore, the extremely high deceleration rates will guarantee neither high performance of the braking system at any time, nor vehicle integrity through safe headway distance in case of, for example, a combination or sequence of sudden technical failures (like power outage, lack of radio-based communication, rise of air pressure in tubes, malfunction of linear motor or mechanical braking) or missing of essential automatic vehicle control functions (movement authority, braking curve supervision, vehicle integrity, route setup and clearance), because the proposed relative braking distances between two Hyperloop vehicles are not fail-safe (i.e. may overlap and lead to collisions).

The required minimum safe distance between two Hyperloop vehicles travelling at a top speed of 1220 km/h will be approximately 58 km instead of only 37 km proposed by Musk (Citation2013), if a continuous service deceleration rate of 1.0 m/s^2 is achieved from top speed to rest for assuring operations safety and vehicle integrity where a preceding vehicle had stopped in the vacuum tube due to, for example, a technical failure, sudden air leakage or lack of movement authority (Figure 6)

The standard safety integrity level SIL 4 (Charlwood, Turner, and Worsell Citation2004) according to IEC standards 61508 and 61511 requires a minimum safety rate of 10^{-8} for electrical, electronical and software products and processes, which needs to be proven explicitly by a safety case. The proposed use of auxiliary electrical on-board motors for driving Hyperloop vehicles on small wheels to the terminal after a vehicle has been stranded in the tube (Musk Citation2013), will not be sufficient to enable safe passenger evacuation, because a vehicle may be stranded due to the danger of a collision with a preceding stranded vehicle, damage to the track or failure of the on-board power supply. Therefore, safety scenarios for, for example, handling the emergency evacuation of passengers from several Hyperloop vehicles stranded along a route by accessing their locations via emergency doors from outside the tubes have to be developed through risk analysis and state-of-the-art safety cases. Developers will need to demonstrate the required standard safety integrity level SIL 4 for the Hyperloop transport system before for a concession to build a Hyperloop line in Europe can be awarded.

The proposed spacing of compressor stations along a Hyperloop line every 70 miles (Musk Citation2013) will not be sufficient to avoid a disaster in case of a major leakage in the evacuated tubes, if a continuous electromagnetic braking system was lacking in the tubes. The operation of Hyperloop vehicles may be decelerated instantaneously by dangerous jerks due to air turbulence by the sudden increase in air pressure, which may lead to a rise in temperature, mechanical contact between Hyperloop vehicle body shell and tube inner surface, damage, accidents or other calamity in a tube. Even in the case of a minor tube leakage the air pressure would rise exponentially over such a distance if the near vacuum tube sections were not separated rapidly by automatic closure of bulkheads situated at much closer distances than 100 km. Thus, more frequent vacuum pump compressor stations (say every 10 km) will be needed for potential operation of the bulkheads to create temporary airlock chamber sections and evacuation of air from accidentally ventilated tube sections after technical failures.

Guideway alignment, stations and spatial integration

The very high speed of Hyperloop will require very flat vertical radii of the tubes (30 km at 480 km/h speed and almost 200 km at 1200 km/h) and rather long ramps when gradients change, as well as very large horizontal radii for Hyperloop (approximately 7 km at a speed of 480 and 45 km/h, respectively at ideal superelevation in curves of 400 mm) to offer standard passenger travel comfort similar to conventional railways. The initially proposed minimum horizontal bends (3.7 km at 480 km/h and 23.5 km at 1220 km/h, respectively) would be too tight and lead to passenger stress by capsule and guidance magnets in curves with an intolerably high lateral acceleration of more than 2 m/s^2 even at 400 mm superelevation.

Major technological challenges confront the design and development of the platform sections, including two airlocks per tube situated close to the terminal stations, as well as the construction of durable vacuum resistant dilation joints between all tube sections. The design, development and construction of vacuum-resistant elevated twin tube sections for the split of tubes at very flat angles including very long turnouts allowing the Hyperloop capsules to branch/connect at high speed to/from different terminal stations, tracks and platforms are also major unresolved technological problems.

The airlocks for the Hyperloop tubes will segregate the first/last two tube line sections after/before the station, such that the platform areas and gates required for boarding/alighting, waiting and passenger processing will be operated at normal air pressure. When the Hyperloop vehicles approach a terminal they will enter the second last tube section, stop in front of the pressure bulkhead between the second last and last tube section (second chamber), the pressure bulkhead behind the vehicle will be shut and air from the last tube section will enter through valves until the bulkhead in front of the vehicle can be opened. Then, the Hyperloop vehicle may proceed to the last tube line segment (first chamber), which will still be segregated from the platform and station space by another pressure bulkhead. After the pressure bulkhead between the second and first chamber will have been shut, the air in the second chamber can be removed, while the air pressure of the first chamber may increase until the pressure is equal to the terminal section and the vehicle may proceed to the platform for passenger alighting and boarding.

The departure process of the vehicle and the shutting/opening of the air chambers would simply be the reverse of this arrival process. It is obvious that the processing of passengers, vehicles and (de-)vacuuming of two air chambers is very time consuming and impacts significantly on the throughput of the terminal station. Apart from that, the design and operation of the arrival/departure junction of Hyperloop terminal stations with multiple platforms and tubes – including parking, maintenance and rotation of the vehicles – will be very complicated. This means the dispatching of Hyperloop vehicles from one terminal gateway, passing through two airlocks, control of vehicle speed, acceleration/deceleration and integrity at very high speed in vacuumed tubes, including the approach to the airlocks and gateway of the opposite terminal station, would be more time consuming than, for example, the corresponding approach times of high-speed trains and Maglev at open air stations. A more detailed explanation as to how specially designed slip joints at stations will be able to take any tube length varia3805nce due to thermal expansion (Musk Citation2013) is missing. Dilation joints mounted only at stations would not be sufficient to reduce the risk of air pressure leakages due to, for example, damaged welded joints between vacuum tube segments. Additional emergency airlock chambers and hermetic entry/exit evacuation doors, as well as robust dilation joints spaced regularly at shorter distances along the route, will be necessary for safety reasons to reduce the risk of accidents and time of disruptions in case of unexpected tube leakages and the sudden rise of air pressure.

The accommodation of elevated tubes in denser settled urban areas is also a major societal problem, because of lack of space available and potential opposition by land owners, who would need to permit access for the geotechnical exploration and boring of shafts, construction of pylons, mounting of tube sections, regular inspections and maintenance. Legal procedures for granting the required rights-of-way over private and publicly owned land in the vicinity of the Hyperloop route may impact on the definitive alignment, time schedule and investment costs for the construction of the guideway. People living in the vicinity of the route may not find the visual barrier of the Hyperloop tubes and pylons acceptable and/or oppose the project because of the risk to the environment and people due to leakage, accidents or terrorist attacks. So far, such considerations have been missing from the preliminary technical design (Musk Citation2013).

V. CONCLUSION

The analysis of underwater tunnels highlights the complexity and challenges associated with designing, constructing, and maintaining these structures. Key findings include:

Challenges:

1. Water pressure and structural integrity.
2. Corrosion and durability.
3. Geological and geotechnical complexities.
4. Environmental concerns (marine life, water quality).
5. High construction and maintenance costs.

Future Directions:

1. Advanced materials and construction techniques.
2. Improved tunnel boring machines.
3. Enhanced safety features and emergency response plans.
4. Increased focus on sustainability and environmental mitigation.
5. Integration with emerging technologies (e.g., autonomous vehicles).

Recommendations:

1. Conduct thorough feasibility studies and risk assessments.
2. Invest in research and development for innovative solutions.
3. Implement robust safety protocols and emergency response plans.
4. Collaborate with experts from various disciplines.

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