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Review Paper

Use of underground space for future needs of Mumbai, India

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Abstract

Mumbai is economical capital as well as most populated city of India and landlocked by sea. Most of the surface land obtained through filling of sea, started from mid-18th century. Mumbai's population is increasing at rapid rate and government bodies are trying to facilitate the basic infrastructures for local public. But due to limitation of open surface land, underground space is utilizing for development. Many underground projects such as drinking water supply, road and railway transportation projects are under progress. But present infrastructures look little bit, compared to population increasing rate in Mumbai and nearby areas. In this paper, tried to discussed about benefits and challenges for using underground space in Mumbai, list of present underground projects and on the basis of previous population increase rate, projected the Mumbai's future population in coming 15 years, as well as tried to short out the basic infrastructure issue by proposing the more combined utilization of underground space as multipurpose large diameter tunnel. This proposed tunnel would be beneficial in future transport as well as flood/storm water management also.

Keywords: Surface land, population, underground project, tunnel, transportation system, flood water.

Introduction

Mumbai (old name Bombay), the economical capital; most populated city of India as well as 4th most populated city in the world. First human evidence deducted from the time of stone age[1and2].Mumbai is built by connecting of old seven Island, i.e. Colaba, Little Colaba (Old Woman's island), Island of Bombay, Mazagaon, Parel, Worli and Mahim[3]. The Bombay were planned to developed as major seaport at Western-Central India, under the Hornby Vellard project[4], for business from western and gulf countries and joined all the seven island by filling of sea[5] during the mid-18th century. Accordingly, Bombay developed as economical and educational hub of India in the 19th century.

Due to economical and education hub, Mumbai infrastructure as well as population has been increases at rapid rate, now the population density of Mumbai is about 73,000 per square mile. To provide the basic immunity and facilities, government bodies are planning and starting various infrastructure projects (road, bridges, railways, Metro etc.) on surface, sub surface/ underground and coastal/sea area.

Climatically Mumbai is falling under tropical zone having wet and dry weather with moderately hot and high humidity percentage. The average temperature is about 27-28°C and normal annual rainfall varies between 1800 millimetre (mm) to 2400 mm. The Mumbai have varying topographical features, most of area is flat and Mumbai is surrounded by north-south trending hill range, coastal area and having creeks. Mahim river, Mithi river, Polsar and Dahisar river with Pawai, Vihar and Tulsi lake are major water bodies in Mumbai. Apart from these water bodies Thane creek, Manori, Malad and Mahim creek are present and increases the mud flanges and swamps at main land area. Geologically Mumbai is make up of Basaltic lava flow, which dipping towards west about 10°-20°. Sethna S.F.[6] has identified seven distinct lava flows in different time period from Upper Cretaceous to lower Eocene (60 to 50 million years). Basalt, Volcanic breccia, Rhyolite, Trachytes, shale are the main rocks exposed at various location in Mumbai. As per geotechnical and geological parameters insitu rock strength varies from very hard to poor (grade 1 to IV) in nature.

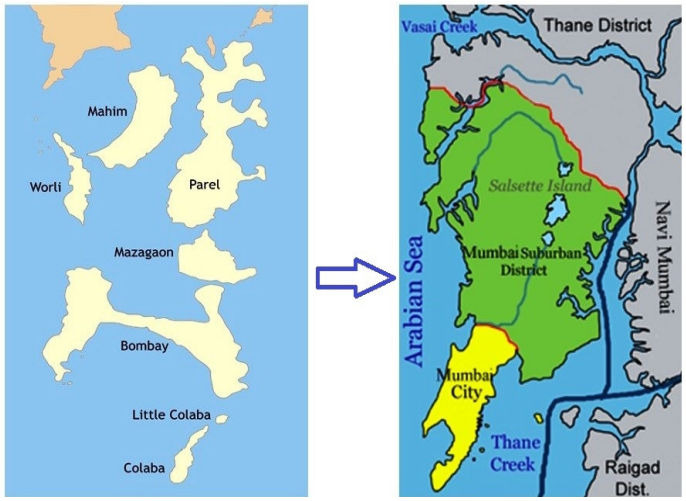

Figure-1: Seven Island modified into present Mumbai (After).

Present underground projects

Mumbai is landlocked by sea and have limited surface area. Mumbai's development has started by connecting of seven island by filling of sea and got the surface land. This process is continuous going on. But this surface area becoming less due to rapid increase in population. Government bodies trying to give the better facilities to public and now they started to use the underground space for various purpose.

Benefits of using Underground space: Using of Underground space means provide safe, environmental friendly, damage free and timesaving transport or other utilities systems to public[7]. Main benefits of underground space are following: i. Main concern of developing underground space is increasing the public related facilities, such as transportation connectivity, shopping mall, vehicle parking, environment friendly, energy-saving and many more, which are impossible to build on surface. ii. Underground structures are best precautionary structures from natural disasters such as Earthquake, flood water, avalanches, storm, noise pollution etc. iii. Underground structures are energy efficient due to earths thermal properties. iv. Tunnels are best option for constructing roads, railways, canals in mountainous region, crossing river, creeks, sea or other large water bodies in reference to shorten distance, less maintenance, access throughout season.

Present underground projects in Mumbai: In Mumbai, providing the jam free traffic, less transportation timing and multiple options for connecting the suburban areas and providing drinking water; are the major challenge and for solving these issues, government is working on road, railway and water tunnel projects in Mumbai. Summarise project details are given below in Table-1.

Challenges during Underground projects in Mumbai: Mumbai is very old and densely populated city. All the area covered by existing structures. Thinking about underground project is itself starts with challenges. Challenges during the tunnelling in Mumbai divided into two parts: one is surface and another is sub-surface and subdivided accordingly. Major Challenges during tunnelling in Mumbai is given below as Table-2.

Table-1: List of Underground Projects in Mumbai.

Type of Tunnel	Tunnel	Tunnel details	Remarks
Water Tunnel	Ghatkopar-Wadala-Parel tunnel	9.7km long, 2.5m finished diameter	-
	Ghatkopar-Trombay tunnel	5.5km long, 2.5m diameter	-
	Veravalli Mumbai Tunnel Project	6.1km long, 2.2m finished diameter	Threevertical Shaft depth is 48.0m, 50.0m and 89m respectively
Underground Metro Project	Colaba–Bandra-SEEPZ line	33.5 km long, 5.8m finished diameter	26 underground and one at-grade station.
Railway	Mumbai-Ahmedabad high speed rail corridor	21km long in which 7km under sea tunnel (between Thane to Virar)	Corridor will begin at the underground station in the Bandra- Kurla Complex in Mumbai
Road Tunnel	Coastal Road (Marine lines to Priyadarshini park)	6.8km Undersea tunnel, Twin tunnel each 3.4km.	-
	Borivali- Thane Tunnel	11km long, 6 lane express way, twin tunnel	-

Table-2: Challenges during the tunnelling in Mumbai.

Challenges during tunnelling in Mumbai

Surface				Sub surface			
Finalization of Alignment	Space for Construction	Safety of present civil structures	Muck Disposal	Utilities and Overburden	Flood and Water Seepage	Geological features/ structures	Tunnel/ ground settlement

Finalization of alignment is first step towards project feasibility and in Mumbai, there are not much options available for finalize the project alignment and considering the construction facilities. During considering the construction facilities safety of old civil structures would also be considered. During tunnelling muck will be generated and safe mucking in Mumbai or near by the area, is also one challenging job due to traffic restriction during day/peak time.

Utility identification before and during the excavation would be the basic challenge for starting the underground activities. We have to proper identification of utilities and divert/safe it. Second challenge during the tunnelling may be the water seepage. Apart from ground water seepage, monsoon season flood, high tide may create the problem. As Underground Mumbai Metro tunnel is crossing the Mithi river, Coastal road tunnel and Mumbai – Ahmedabad high-speed tunnel is passing under the sea; chances of high water seepage would be there. Geologically weak rock such as Volcanic breccia, shale and other geological features may create the problem in form of shear zone, cavity, ground and tunnel settlement and affect the tunnel progress.

Future prospects of development

As Mumbai is India's highest populated city and very limited space for infrastructure; public has started migrating towards nearby sub urban area i.e. Navi Mumbai, Thane, Kalyan, Vasai, Virar subsequently and travel to Mumbai city via road and local trains. The Maharashtra state government had observed that migration trend and for development of basic infrastructures in that area; formed separate Authority, called Mumbai Metropolitan Region Development Authority (MMRDA). Population of Mumbai Metropolitan Region (MMR)has increased 270% within 30 years (77.92lakhs in 1971 and 207.48lakhs in the year 2011[8]) and World's most populated metropolitan region in the world[9]. This increasing trend is still continuing and expected that Mumbai population would be 30 million till year 2035 shown in Figure-2.

As population expected to reaching 30 million in coming 15 years, basic facilities for public such as drinking water, road and other transportation system would be planned and implemented for future years. Apart from increase in population, chances of frequent flood, sea level rise would not be avoided due to climate change and global warming. Mumbai had faced worst flood in year 2005 and 2017 and expected that frequency of flood would also be increases in future. Many low line area such as Kurla, Sion, King Circle, Matunga, Hindmata, Juhu, Santacruz, Kalina, Vasai, Virar, Thane etc, flooded every year in monsoon season and it would be more havoc in coming future.

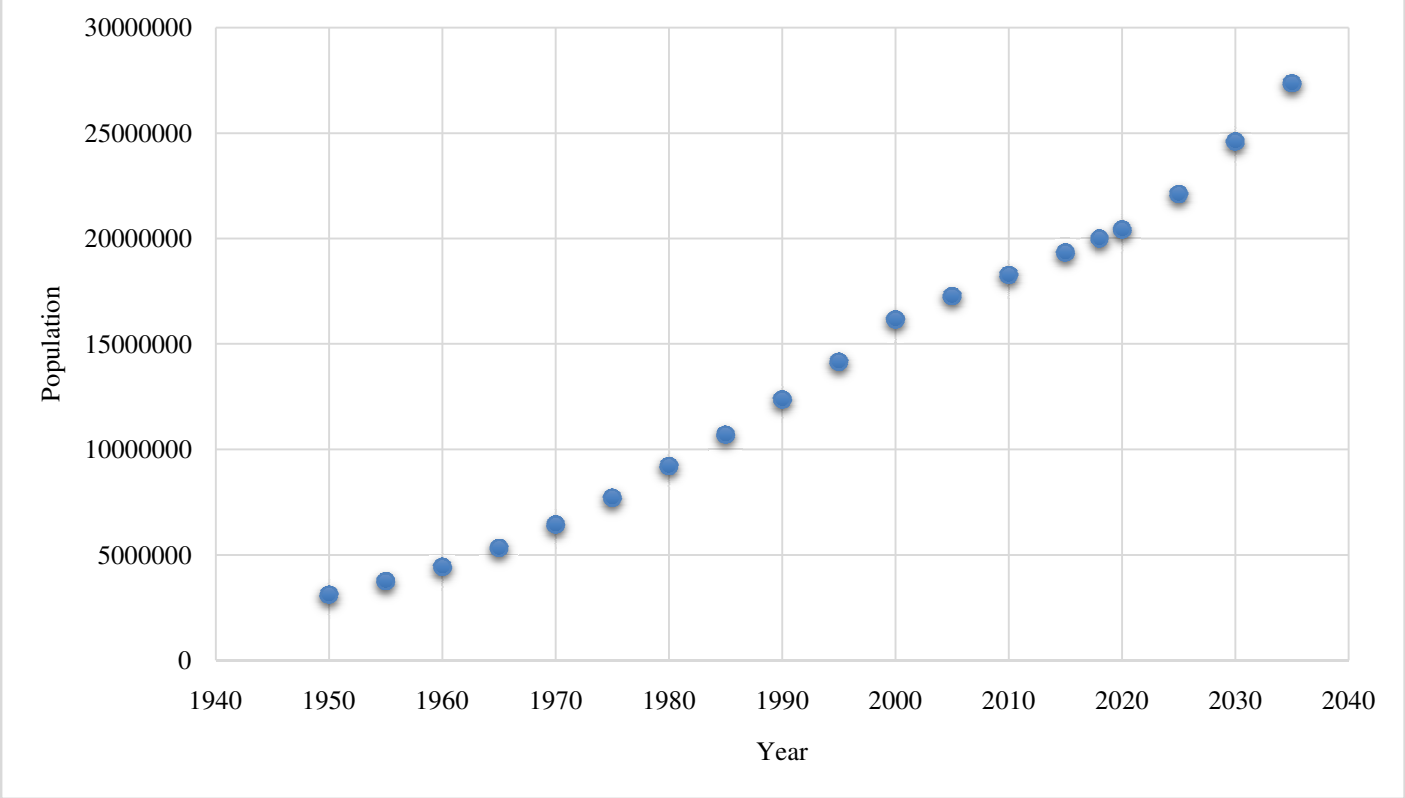

Figure-2: Mumbai Population increasing trend[10].

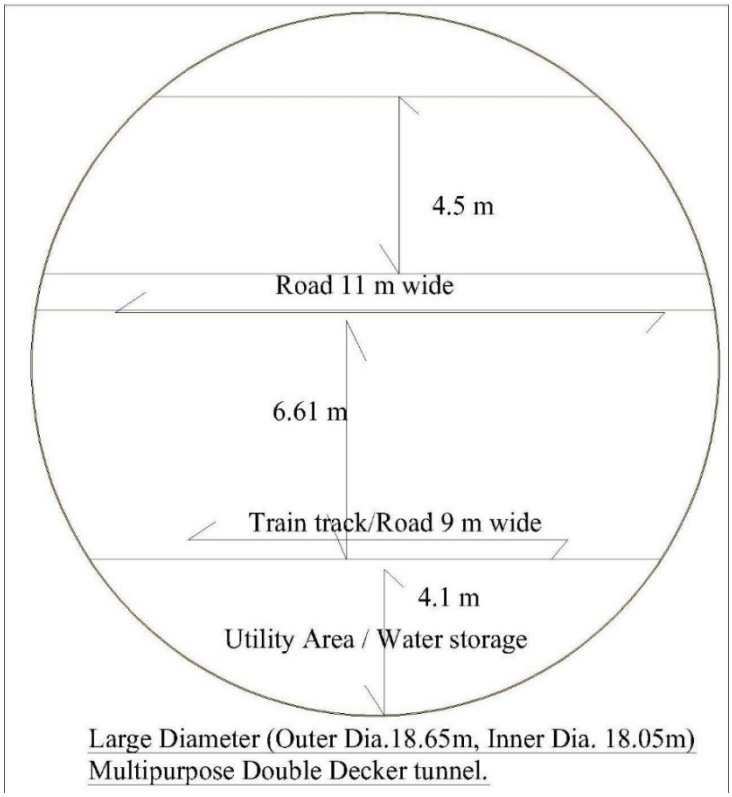

Figure-3: Conceptual plan for large diameter multipurpose double decker tunnel[11].

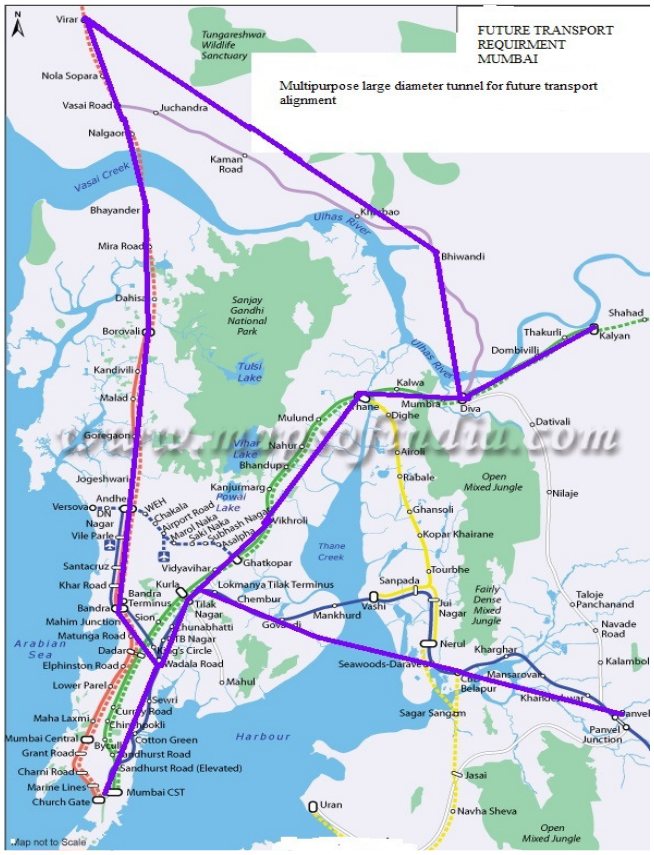

Figure-4: Tentative alignment for large diameter multipurpose double decker tunnel as per future transport requirement[12].

Infrastructure Development for future: In view of future needs of Mumbai, more underground space to be utilized and public transport system to be time saving, we should also plan for flood management, dewatering of low line area and mitigate the high flood/tide situation. We have to learn from the World's other major cities, how they used its underground space with proper planning and flood management. Many countries, such as Turkey, France, Netherlands, USA, United Kingdom, Australia, Hong Kong, Malaysia and China have prepared the multipurpose large diameter double -deck tunnel and same would be suitable for Mumbai also.

Multipurpose double-decker road/rail/metro with utility/water storage/Storm water Management Tunnel' would be best solution for Mumbai future need, which provide smooth traffic and occasional dewatering of flood/high tide water from low line area. In case of flood on surface, floodwater could be diverted into the water storage space into the tunnel through shafts located underneath double-decker tunnel without impacting the traffic and in case of heavy flood, lower deck could be closed for traffic and that area will also be used as water storage. When water level becomes low, dewatering can be done and lower deck would be again start for traffic. In that case Mumbai will not be repeating the worst flood condition as year 2005 and 2017. One typical conceptual plan for large diameter multipurpose tunnel is shown in Figure-3, which prepared on the basis of world's other multipurpose large diameter tunnels, construct by Tunnel Boring Machine (TBM) only. This conceptual plan has shown the 18.05m finished diameter including two decks for transportation and bottom part for Utilities/water supply/water storage. Top area, which is about 2.4m can be used for ventilation and lighting cables of tunnel, first deck has 4.5m clearing from top area and about 11m wide; second deck have 6.61m clearance from first deck and 9m wide, both decks can be used for road/rail or both for smoothing of transportation system. Lowest/bottom space, clearance from second deck is 4.1m can be used for utility/water supply/ storage space for storm/flood water during emergencies. Clearances between decks and utilization of these area may be various as per final planning of tunnel.

As public moving towards suburban area for residence and daily coming towards Mumbai town for job, business and other daily needs; we have to plan to connect the suburban areas to Mumbai. One tentative alignment has been mentioned in figure 4 for connectivity and development of smooth transportation system.

Conclusion

In view of present scenario, it's time to develop Multipurpose large diameter Underground tunnels for fulfill the future need of Mumbai. As public is moving towards suburban areas and smooth connectivity will be required for saving the transportation timing, storm/flood water management and Utility and Water supply. Proposed alignment for large diameter multipurpose tunnel would be better underneath the rail track or express way, due to open space and government land. Tunnel would be connected to Eastern and Western Express way by multiple entry and exit points. This proposed alignment would be minimum 25-30m below the ground level and safe tunnelling practices will be implemented after the detailed geological, geotechnical and design studies. Definitely it will be costly but preparing various tunnels for different purpose can be planned jointly and first we can start constructing it near the low line area for storm/flood water management and control the traffic.

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