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Feasibility Study on the Construction of Under Water Tunnel Between Visakhapatnam and Andaman Nicobar Islands

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Abstract :

Technology used for the ease of transportation is growing faster in all the modes of transport. Construction of huge structures across the water to provide transportation for the exchange of goods and provide connectivity is growing at an alarming rate in recent times. The number of travelers traversing between Visakhapatnam and Andaman and Nicobar Islands in India are increasing due to the increase in demand for tourism and livelihood. The existing modes of transport are found to be deficient to meet the travel demand. Hence, there is a need to provide alternate modes of transport to travel from Visakhapatnam to the Andaman Nicobar Islands. Therefore, the objective of the study was to study the feasibility of providing an underwater tunnel (UWT) between Visakhapatnam and the Andaman Nicobar Islands, India. The methodology included the review of existing underwater tunnels in the world that are used for transportation. Next, the capacity of existing modes of transport was evaluated. The existing modes of transport were compared with the underwater tunnel mode of transport facility in terms of socio-economic, and environmental aspects. The results showcased that the UWT between Visakhapatnam and the Andaman and Nicobar islands help improve the transport facilities.

Keywords: Underwater tunnel; feasibility study; transportation;

Introduction

Here Submerged Floating Tunnels (SFT) are the new mode/method of a transport system that connects from one place to another place over the long routes of the sea/oceans. These SFTs are more economical compared to bridges and conventional tunnels. In this new era more and more SFTs construction is being adopted in different countries of the world such as France, England, and UAE, etc. As SFTs are totally or partially submerged in a fluid, it experiences an upward force so, these are also called Archimedes bridges in Italy. These SFTs are adopted when the depth of the sea is greater than of 50 m [1]. In the past, there is the existence of the concept of submerged floating but no country has proven the construction method [2,3]. However, later on, with the development of technologies, these SFTs came into practical existence and many theories and research have been continued [1-10]. Apart from the SFTs the channel tunnels also came into the picture that the tunnels connect two different lands from one place to another by tunneling. The main methodology of channel tunnels is to construct the tunnel under the sea bed without disturbing the beds of the sea [6]. Compared to the SFTs these channel tunnels connect less distance and it is constructed under the bed level of the sea. For channels, it is very important to know the depth of the water level and the bed level of the sea or the oceans [7].

Mostly, the water-based transportation systems are becoming critical to reduce the use of on-land transportation. In most of the coastal cities, the exchange of goods and trade happen through water-based modes of transport. The use of SFTs is typically important for coastal regions so that they could enhance the trade operations. SFTs are intrinsically slender structural systems that share some of the problems affecting other more traditional flexible systems for crossing water bodies, such as suspended or cable-stayed bridges. The dynamic behavior shows some features which are typical of slender bridges as well, since in both systems the interaction between the main element (deck or tunnel) and the supporting elements (stays or anchoring elements) plays an important role and the performance under dynamic loads represents one of the most important factors affecting both feasibility and basic design choices. However, differently from bridges, earthquakes induce in SFTs not only inertia forces but also hydrodynamic fluid-structure interaction effects (seaquake). The term seaquake denotes here the hydrodynamic excitation related to the vertical transmission of compressive fluid waves activated by the seabed, which moves under seismic conditions [8]. SFT consists of the following elements:

The tunnel tube that provides space for road and/or railway traffic.

Tethers, vertical or inclined fixing the tube to the seabed at a certain spacing

Pontoons mounted on top of the tunnel and "anchoring" it to the sea surface

Gravity anchors on the seabed providing support for the tethers

Shore connections at the ends of the tunnel

The tubes may be constructed of steel, concrete or a combination of the two. In Norway, the tube has up till now mostly been designed with circular cross-sections, primarily from hydrodynamic reasons. Other shapes as elliptical, rectangular or multiple-sided may also be of relevance.

Tethers and pontoons are alternative ways of controlling the vertical position and motions of the tube. They may also be used in combination. Typically, the tube is a long and very slender structure thus requiring special measures to provide sufficient horizontal stiffness to the system. Up till now, this has normally been done by forming the tube as a horizontal arch or by inclining the tethers [8-10].

If the crossing is wide and there for some reasons may be difficult or too costly to use inclined tethers due to e.g., very deep waters, the horizontal stiffness may be significantly increased by using a horizontal arch comprised of two more or less parallel tubes being connected at certain intervals by rigid riegels. Each tube may then give space to traffic in one direction and provide escape possibilities in case of fire and alike in the other tunnel.

As an alternative to the double tube increased horizontal stiffness may be provided by some kind of horizontal stiffening tendon system, a simple and promising system. Major elements of such systems would have to be pretensioned, and it will be necessary to develop reliable anchorages at the shore which in Norway normally would be of good rock quality.

In order to provide better transport facilities between Visakhapatnam and Andaman and Nicobar Islands, the literature pertaining to the construction and operation of the SFTs in such cities were studied and reported in the following sections. Also, the principles of construction of SFTs, design issues, and their existence in the field of transportation is presented. Next, the proposed tunnel details, and the comparative study on the efficiency of the existing modes of transportation and the proposed mode of transport are presented.

1.1. Principle of sets

Files Based on the mass and density of the floating objects, the SFTs are constructed using two principles:
Positive Buoyancy
Negative Buoyancy.
Positive Buoyancy: If the object or the body is less dense compared to water then the object floats on water is called as positive buoyancy. In similar with that, the SFTs are arranged to be stable with the help of anchoring or pontoons.
Negative Buoyancy: If the object or the body is denser when compared to the water the object sinks. In similar the SFTs are brought into stable with the help of piles or foundations into the deep water. Figure 1 represents the tunnels that are constructed using positive and negative buoyancies.

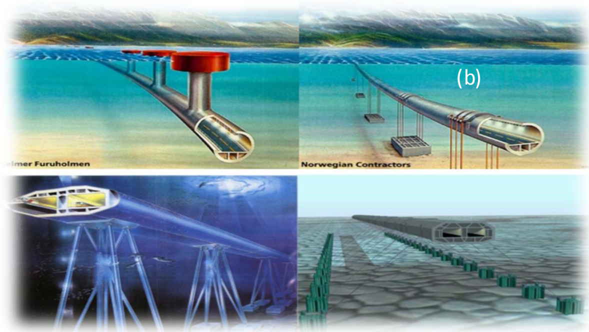

Figure1: SFTs design based on (a) Positive and (b) Negative buoyancy [11]

As described above, pontoons (Figure 2) penetrating the water surface will add vertical stiffness to the system, but they will not add anything to the horizontal stiffness. For long and slender tubes other measures then have to be added to give sufficient horizontal strength and stiffness. This will be necessary to resist forces from wind, waves and current, and possibly also to prevent resonance with long-periodic sea loading.

Vertical tethers (Figure 3) down to the sea bottom will also give vertical stiffness, but virtually no horizontal stiffness. In order to also get horizontal stiffness the tethers have to be inclined. Then, the tethers should be neutrally buoyant in order to avoid reduced stiffness due to geometry deviating significantly from straight lines.

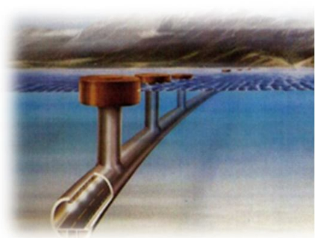

Figure2: SFTs with pontoons

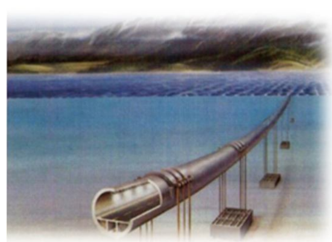

Figure3: SFTs with tethers

The first SFT was constructed in Norway. The project had used tethers for supporting the tunneling system. The points that were in favor and disfavor of tethers are listed below.

Points were advocated in favour of the tether alternative:
No restrictions to ship traffic and represents no collision risk for ships.
No visible parts above water.
Easier installation of additional measures to cope with possible unforeseen behaviour.
Eliminates slowly varying dynamic response.
Less excited by first order wave forces.
Less excited by wind and current.
Probably less complicated dynamic response including less torsional excitations.
Less vulnerable for possible closing of roadway in case of accidental loss of one anchoring element.
Safer and less costly installation of tube since tethers can be used as mooring systems during installation.
May have both straight and curved horizontal alignment.

In disfavour of the tether alternative, the following were emphasized:
They may be subjected to collision by submarines.
They can require large net buoyancy of the tube in order to prevent slack in tethers.
Tethers are subjected to dynamic loading both from current, waves, and possibly earthquake.
Foundations are dependent on soil conditions on sea bottom and may be vulnerable to underwater land-slides.
For the brief studies that have been made in Norway since the Hogsfjord-project, tethers have been used as the preferred alternative [12].
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1.2. Design Issues
For design of an SFT the following basic considerations should be taken into account:
The cross-section must give sufficient space for traffic, evacuation, ventilation, ballast, inspection, maintenance and repair work.
The alignment must be such that there is no interference with ship traffic passing above.
The tunnel must have a simple static system which can be properly represented in the design calculations.
The joints should have no less strength or integrity than the tube between the joints.
The structure must have a ductile behaviour in the potential failure modes.
The anchoring system should be redundant.
The tunnel must not be unduly susceptible to local damage.
The structural details must be simple and designed to avoid undue stress concentrations.
The structure must be robust against changes in the static system, variations in the material properties and corrosion.
The tunnel must behave in a satisfactory manner with regard to deformations, settlements and vibration.
The tunnel must have a satisfactory safety against fatigue.
The tunnel should be designed such that the water inflow rate is so limited that people have time to safe evacuation in case of massive water ingress.

Challenges for the construction SFTs:
Risk assessment need to be carried.
The action of the wave force is to be found.
As the SFTs remain in water the chloride content in water can affect.
SFTs need to be sustained against natural calamities and the accidents like collisions.
Safety alternatives need to be searched.
It is still a challenge to construct foundations in 50-200m deep.
Vortex induced vibrations need to be studied.
Obstacles for the construction of SFT need to be identified.

1.3. SFTs Existence

Before the construction the SFTs risk assessment needed to be carried in order to reduce more risks. All the countries in the world are now looking for this type of constructions and by the first Norway and China proposed for the construction of these SFTs. In the year 2020 UAE announced the floating underwater train connecting from Dubai to Mumbai by Abdulla Alshehhi. For this they may construct the route by using the SFTs methodology. Here this covers nearly 2000 km and the major idea for the construction of SFTs is for the goods exchange and the tourism. For the construction of the SFTs many challenges need to be overcome so as to sustain all the challenges and the perfect completion of the constructions. The proposed route between Mumbai and Dubai for SFT is shown in Figure 4.

Figure 4: Proposed route between Mumbai and Dubai, UAE

Over the past many years, the concept of Submerged Floating Tunnels (SFTs) have been gaining its popularity particularly in places such as Norway, Italy, and Japan--because of the advantages SFT's incorporate with resistance to earthquakes, long distances, more economical constructions and ease of more serviceability. One of the most well-known SFTs projects in Japan is the proposed crossing of the Funka Bay in Hokkaido. The Floating

Tunnel Studies Association in Hokkaido has already carefully investigated the feasibility of the construction of a SFTs by studying various aspects of technical problems, as well as economic efficiency [13].

In the Kansai area, an SFTs is being proposed that will connect the Kansai International Airport (KIX) with the Kobe Airport, construction of which is now being planned. The two airports are located on opposite sides of the Osaka Bay. The distance between the two airports is approximately 30 km, and the sea depth ranges from 20-40 m. The KIX Airport, which is located on a newly reclaimed man-made island, started its operations as a 24-hour operating airport in September 1994.

1.4. Review on existing international channel tunnels and the submerged floating tunnels

The channel tunnel that connects England to France is about 50.48 km where the tunneling route of this channel is about 37.9 km under the water. The channel is located at the depth of 115m below the sea level and 75m below the sea bed. This channel tunnels carries high speed Eurostar passenger trains and the Eurotunnel settle for road vehicles. In the year 2017 through the route services carried 10.3 million passengers and 1.22 million tons of fright. A machine named as tunnel boring machine is used to excavate the soil under the beds of the sea in an circular cross section.

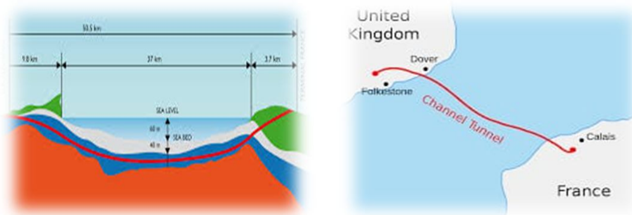

Figure 5: Cross-sectional view of construction and the route map [12]

Projects working on tunnelling and SFTs:

India's project from Mumbai to Ahmedabad:

National High Speed Railway Corporation Limited (NHSRCL), India has invited bids for the construction of a 21-km-long tunnel, seven km of which will be under the sea, for the Mumbai-Ahmedabad High Speed Rail Corridor. The work on the corridor has gained momentum after the change in government in Maharashtra, with tenders, which were previously floated and withdrawn, being renewed again, sources said. Considered the highlight of the project, the tunnel will be built between the underground station at Bandra-Kurla Complex and Shilphata in Thane district of Maharashtra. The tunnel will be built using tunnel boring machine and the New Austrian Tunnelling Method (NATM), according to the tender document. The seven-km undersea tunnel at Thane Creek will be the first undersea tunnel to come up in the country. In November last year, NHSRCL had invited bids for underground tunnelling works for the project. But it was cancelled this year with officials citing "administrative reasons". In 2019, NHSRCL had first invited tenders for the project but didn't attract any bidder. It again floated tenders in November 2021 [14].

Denmark and Germany now building the world's longest immersed tunnel:

The tunnel, which will be 18km (11.1 miles) long, is one of Europe's largest infrastructure projects, with a construction budget of over 7 billion euros ($7.1 billion). By way of comparison, the 50-kilometer (31-mile) Channel Tunnel linking England and France, completed in 1993, cost the equivalent of £12 billion ($13.6 billion) in today's money. Although longer than the Fehmarnbelt Tunnel, the Channel Tunnel was made using a boring machine, rather than by immersing pre-built tunnel sections. It will be built across the Fehmarn Belt, a strait between the German island of Fehmarn and the Danish Island of Lolland, and is designed as an alternative to the current ferry service from Rodby and Puttgarden, which carries millions of passengers every year. Where the crossing now takes 45 minutes by ferry, it will take just seven minutes by train and 10 minutes by car. [15]

Advantages of SFT:

SFTs are more economical compared to the bridges and the conventional tunnels.
These SFTs are submerged in water that experience the upward thrust and these are connected with pontoons.
The cost of the construction is more reliable compared to the other mode of constructions.
SFTs can achieve all weather operation making the traffic to be smoother.
These can be laid easily with by means of floating and the transportation can be done on cargos.

Disadvantages of SFT:

More risk assessment should be carried.
Effect on durability due to the more presence of chlorine in the sea water.
Vortex induced vibrations are more in the SFT as they are connected with the cables to the pontoons.
For attaining the stability more analysis needed to be carried.
Wave force effects the stability of the SFTs.

Environmental benefits and aspects:

Resistance to the earthquakes.
Doesn't affect aquatic life and environment conditions during the construction of the SFTs.
Easy and fast mode of transportation can be achieved.

The primary objectives of the channel alignment are to:

Reduce the transit trip times.
Increase the ease of good service and more reliability

To increase the good mode of transportation that connects. In addition to these, the basic differences between channel tunnelling and SFTs are presented in Table 1.

Channel tunnels	Submerged Floating tunnels (SFTs)
1.channel tunnels are constructed under the beds of sea/ocean.	1.SFTs are constructed under the sea level i.e. below 50m of level of the sea.
2.For the construction of channel tunnels big tunnelling machines are used.	2.SFTs are prefabricated and immersed in water.
3.Depth of the water need to be identified.	3.Depth of water may or may not be found.
4.These have very less risk assessment.	4.These have high risk assessment.
5.These connect short distances.	5.SFTs connect long distances.

Table 1: Difference between Tunnelling and SFTs

Proposed SFT between Visakhapatnam and Andaman Nicobar Island

Water is the major obstacle for the construction of different bridges and different types of constructions across seas/oceans. The SFTs are the new methodology of constructions that is being adopted by different counties from different corners of the world in order to connect different places across these seas/oceans. These are newly adopted construction method. As per the data collected and the analysis an idea ignited that why can't connect Andaman Nicobar to Visakhapatnam by SFTs as many people from different countries started visiting as tourists and many people from Andaman are travelling to Visakhapatnam for better health care, facilities, works, education etc. The distance it nearly covers is 1358 km from Andaman Nicobar to Visakhapatnam by mean of SFTs. As mentioned above many countries in the world are starting with many odd ideas and planning to connect two different places by means of this methodology. Here we have few reasons for proposed route by analysis of the population, mode of transport modes, cost analysis and the people travelling analysis per year.

Environmental Effects may be developed after the constructions:

As the SFTs are constructed across the Bay of Bengal the structure may be affected by the climatic conditions and the major focus should be on the travellers those are travelling. Risk assessment during travelling of ships near the SFTs may develop high water pressure and the structure may damage. The connecting cables to the SFTs and the pontoons need to be protected. As it crosses the sea all the wave and wind force that is developed because of the cyclones need to be analysed. Many journals came regarding the construction of SFTs and the challenges that they need to overcome to become an sustainable and durable structures.

Expected flow of traffic in this mode of construction:

As the needs and demands of the people are increasing, after the construction of this structures we may expect high number of people from one place to another. We can collect the reliable charges from them for the using the SFTs.

On an average nearly 4lakhs including foreginers are travelling by mean of sea and air transportation. People can travel by mean of two modes of transportation i.e., by ship and airplanes. By ship nearly it covers 1500km from Visakhapatnam to Andaman and vise-versa and by means of air planes it covers nearly a distance of 1231km. Majority of the people living in Andaman face many problems during their travel because of the time consumption and the cost of travelling. The journey by mode of water nearly takes 3 days of time to travel and the price of travelling is mainly depended on the facilities provided in the ship. The journey by mean of air take 3hours for the travel and the problem is on the cost of the travelling and prebooking. It even costs more at an instant emergency booking. Incase if SFTs are constructed between these then the cost of the travel can be easily reduced and the payback period of the project/the construction can be easily returned in few years itself. As on the date gathered the goods price in Andaman is so high when compared to other cities. If SFTs are constructed the goods can be bought with the less prices and many benefits can be added as it is the tourist spot. For the construction of SFTs across it covers nearly 1358km and many people start using these but, mainly should focus on the challenges for the construction of this SFTs. The several projects that used SFTs for the mode of transport are presented in Table 2. Also, the travel behavor of the travellers is presented in Table 3.

Table 2: SFTs constructed and under operation mode

Project	Location	Distance covered	Market value	Cost of the Project
Dubai Under water train	Mumbai to Dubai	2000 km	Majorly for the transportation of goods and tourist attraction.	-
Channel Tunnels	England to France	50.45 km	10.3 million Passengers.	14.75 billion dollars
Palk Strait	India to Sri Lanka	37 km	-	2400 Cores

E39 Rogfost	**Rogaland to Norway**	**17 km**	**-**	**1.9 billion dollars.**
Taihu Tunnel	**China**	**24 km**	**-**	**9.9 billion dollars.**

Table 3: Data collected by the observed moments of people travelling from Andaman Nicobar to Visakhapatnam and vise-versa:

S.no.	**Information that collected**	**Data Analysed**	**Problems**	**Cost**
1	**Total people travelling to Visakhapatnam to Nicobar every year on average.**	**On an average nearly 4lakhs including foreigners are travelling by mean of sea and air transportation.**	**Problems in pre booking of aero planes and ships at an instant**	**NA**
2	**Total distance that is covered by mode of air transport.**	**1231km**	**Cost defect**	**Cost varies with jet, min of 7500/-**
3	**Total distance that is covered by mode of water transport.**	**1500km**	**More time takes to trave nearly 3 days.**	**2630/- to 10,240/-**
4	**The distance that we expected to be covered by the mode of SFTs**	**1358km**	**The mode of construction to adopt.**	**NA**
5	**Problems faced for the construction over/under sea.**	**1.Obstacles to construct.** **2.Route analysis.** **3.mode of construction to be adopted.** **4.Wave force and wind analysis on the SFTs** **5.Cost analysis.** **6.Problems over coming methods.**	**Cost and time for the construction.**	**NA**

Conclusion

SFTs and the channel tunnels are the underwater construction technologies that are being adopted in this new era. Recently new projects and proposals have been started and the constructions also began to complete the projects as early as possible. What are the challenges, advantages and disadvantages of SFTs and channel tunnels are discussed. Mainly by the help of this constructions and the methodology used in the construction are directly connect with the proposed route from Andaman Nicobar to Visakhapatnam which it nearly covers 1358 km. SFTs methodology can be adopted to the Proposed route as because the SFTs cover the long distances and these are more effective when compared to the Channel tunnels. These SFTs are more economical compared to the bridges and conventional tunnels. What is the reason and the needs of the proposal route is important are analysed by the data that is collected. Earlier projects cost analyses have been done and the depth of the tunnels that arranged under water are studied. Which mode of construction should be adopted for tunnels is based on the depth of the sea and the distance that the route covers.

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