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Submerged Floating Tunnel

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Abstract:
A Submerged Floating Tunnel, also known as an Archimedes Bridge, may be employed at a number of crossings with a range of various conditions. However, the presence of considerable dynamic oscillations was threatened by swell, vortex shedding, and slowly changing internal waves caused by salinity-differentiated layers. In addition to these complex conditions, common incidental events like fire, sinking ships, falling anchors, and unexpectedly large amounts of water entering the tube must be avoided in all applications. The development of research in the areas of potential risk and influence of actors, risk index system, and risk level of SFT is of considerable theoretical and practical value when combined with the features of submerged floating tunnel (SFT) and the surrounding environment. The possible hazards of SFT in terms of investment, design, and environmental conditions throughout the planning and feasibility study stages were then the main topic of discussion.In terms of risk control strategy, certain recommendations and steps were made. Based on the design technology of immersed tunnel, bridge, and tunnel engineering, merging the current pertinent design codes segment is offered according to safety, applicability, economy, fine appearance, and environmental protection. By carefully taking into account the design load, flow resistance performance, durability, and other factors of the submerged floating tunnel, the choice of tube cross section type, structural analysis, design load, waterproofing and resistant corrosion, tube joint design, and tunnel ventilation, etc. are described and explored.

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I. INTRODUCTION

1.1 HISTORY:

Although floating tunnels are much more contemporary, the first underwater tunnel was constructed over a thousand years ago. Undoubtedly, S. Préault, an engineer and railroad builder, suggested but did not construct an SFT over the Bosphorus in 1860, an attractive underwater railway viaduct with spans of about 150 m established on piers, positioned approximately 20 m below the surf line. In 1976, Per Hall suggested a deeper SFT for the Bosphorus, but by 1977, his idea had changed to a subterranean, immersed tunnel because of environmental concerns (fish habitat). The last of the TBMs has finally arrived at the submerged tunnel under the Bosphorus. A submerged railway tunnel supported by caissons across the English Channel was planned by Edward Reed in 1882, but it was rejected by the English Parliament because of concern for invasion. It was given a patent, and many more have been obtained for SFT since then, including some in the UK, USA, Norway, Sweden, and Italy. The road was cleared for building SFT when the first immersed tunnel was successfully built in 1893, at least those that would be pier supported initially. The potential of an SFT has been understood in Norway since 1923 as a means of constructing a useable coastal highway across fjords that would otherwise be too deep even for bored tunnels to make sense; some of the existing bored tunnel connections are even with 10% gradients very, very lengthy. A thorough investigation and field tests that are still being conducted today were prompted by the necessity for shorter, shallower tunnels or a number of fjord crossings. Hogs' fjord is the most well-known crossing that has been examined in considerable detail in Norway, however the SFT was abandoned due to local political issues. Other areas have been investigated by private investors. The Sula-Hareld crossing is another viable option. In Norway, a series of Strait Crossing Symposia have been held since 1986; the fifth occurred in 2009, and SFT has taken an increasingly significant role in each subsequent symposium.

1.2 GENERAL:

Water-filled tunnels are nothing new in the field of civil engineering. Over 100 immersed tunnels have been built since 1900 or so. The most typical type of structure used to traverse bodies of water is a bridge. In rare instances, tunnels that are submerged in the sea or a river's bed are also used. Submerged floating tunnels are used when the bed is too stony, too deep, or too undulating, etc.The idea for a submerged floating tunnel was initially developed at the turn of the century, but no practical project was ever started. The submerged floating tube has new potential in this broader context as society's needs for regional development and environmental preservation have become more crucial.

An inventive idea for traversing waterways is the submerged floating tunnel, which relies on the law of buoyancy to keep the structure at a manageable depth. The Submerged Floating Tunnel is a tube-like steel and concrete construction that makes use of the law of buoyancy. It was supported by columns or kept steady by tethers fastened to the ocean floor or by pontoons afloat. The Submerged Floating Tunnel makes use of lakes and rivers to transport traffic under the water and to the other side, where it can be simply connected to the rural network or to the underground infrastructure of modern cities.

1.3 REASON FOR CHOOSING FLOATING TUNNEL*:*

The floating tunnel is a brand-new idea that has never been deployed, not even for very short distances. It is evident that there are significant differences in the bed depth from location to location. At some areas, the greatest depth can reach 8 km. The depth is 3.3 km on average. There are two options for construction: a tunnel below ground level or a bridge across water. It is difficult to build concrete columns of that height for a bridge since the depth can reach 8 km. Additionally, the pressure is almost 500 times higher than atmospheric pressure below 8 km from the sea's surface, making it impossible for anyone to survive there. So, it is also impossible to use the submerged tunnels. As a result, a floating tunnel that is 30 meters below sea level and where there is no high-pressure issue is completed. Any large ship can travel over it without being obstructed if the conditions are adequate.

1.4 BASIC PRINCIPLE OF SFT*:*

SFT is a buoyant construction that bobs and weaves in the water. The relationship between buoyancy and self-weight is crucial because it affects both the tunnel's static behaviour and, to some extent, how it responds to dynamic pressures. Ten as the minimum internal dimension yields a nearly ideal design. There are two methods for floating SFT. These are positive and negative buoyancy.

Positive buoyancy: In this case, the SFT is anchored in place using either pontoons on the top or tension legs at the bottom. SFT lies primarily 30 metres below the water's surface in this area.

Negative buoyancy: In this case, columns or piers to the lake or sea would serve as the foundation. The maximum water depth for this approach is 100 metres.

Wave, current, water level vibration, earthquake, corrosion, ice, and marine growth are just a few of the environmental factors that SFT is exposed to because they are typical of the sea environment. It should be strong and stiff enough to withstand all activities, operational loads, and accidental loads. Bottom anchoring provides transverse stiffness.

1.5 OPTIMAL SHAPE OF SFT*:*

The SFT in Fig. 1's shape was selected for the reasons listed below: Variations in buoyancy near the middle of the tunnel cause less bending, so it is easier to shorten the concrete tube during installation when the vertical curvature is concentrated there. The tunnel's unusually large water volume also exerts low bending and axial force.

Fig 1.1 Optimal shape of an SFT

1.6 CONSTRUCTION*:*

Submerged floating tunnels are based on well-known technology used for floating bridges and offshore buildings, but their construction is largely the same as that of immersed tunnels. One method is to construct the tube in sections on a dry dock, then float the pieces to the building site, sink them into place while sealed, and then break the seals once the sections are fixed to one another. Another option is to construct the pieces without sealing them, then weld them together and pump the water out. While immersed tube tunnels are ballasted further to weigh them down to the sea bed, the ballast used is calculated so that the structure has about hydrostatic equilibrium (that is, the tunnel is around the same overall density as water).A submerged floating tunnel must, of course, be secured to the ground or to the water in order to remain in place (which of these depends on which side of the equilibrium point the tunnel is).

1.7 DESIGN PRINCIPLE AND PROCESS OF SFT TUBE*:*

SFT tubes offer traffic space and buoyancy for carrying various dead and live loads. SFT tube application and self-safety are related to its design. During the tube design process, a wide range of variables are taken into account, including the design load, buoyancy to weight ratio, flow resistance performance, durable performance, and others.The best design should make maximum use of the available space to suit the needs of traffic headroom, reliable quality, economical rationality, and cutting-edge technology. This is done by comparing alternative designs from the perspectives of technology, economy, and environmental protection.

The following are the guidelines for tube design:

- According to relevant studies, the buoyancy to weight ratio should be between 0.5 and 0.8. However, it is less than 1.0.
- During the building and operation phases, tubes should be strong, stiff, and stable.
- To withstand hydrodynamic forces, the fluctuation in surface curvature should be mild. Satisfy the criteria for a building's designation as seismically safe.

II. STRUCTURAL COMPONENTS OF SFT:

A submerged floating tunnel has a large number of structural parts. These elements should be strong and rigid enough to withstand the numerous forces operating below the water's surface.

Following are the three basic structural components:

- **Tube.**
- **Anchoring.**
- **Shore connections.**

2.1 Tube: -The equipment and the lanes for traffic should fit there. External shape options include polygonal, elliptical, and circular. Concrete or steel could be used in its construction. The key problem is corrosion protection. The tube is made up of segments with lengths ranging from 100 metres to 500 metres.

2.2 Anchoring: -

The four main types of anchoring are as follows:

- **SFT with pontoons.**
- **SFT supported on columns.**
- **SFT with tethers to the bottom.**
- **SFT unanchored.**

- **SFT with pontoons**: The system is sensitive to wind, waves, currents, and potential ship collisions. It is independent of sea depth. The construction should be designed so that even if one pontoon is lost, it will still stand.

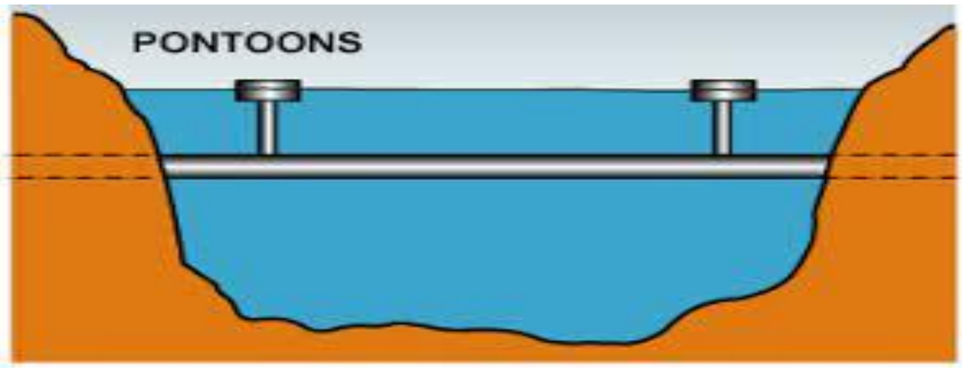

Fig. 2.2. SFT with pontoons

- **SFT supported on columns**: It is an "underwater bridge" with foundations on the bottom, the columns are typically in compression but it could also take the tension type. In this situation, water depth will be important, and at the moment, a few hundred metres of depth is considered to be the upper limit. However, current research is looking at much deeper roots.

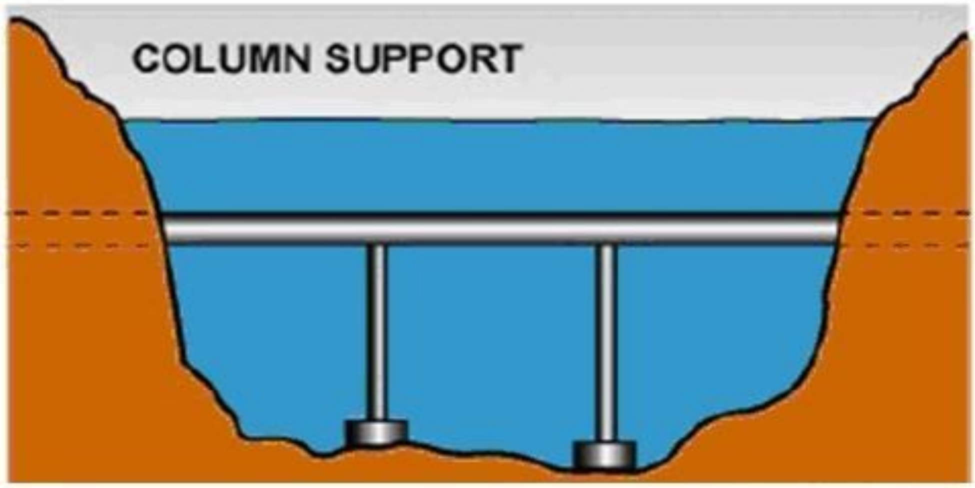

Fig.2.2. SFT supported on column.

❖ **SFT with tethers to the bottom**: It is predicated on the assumption that tethers will be in tension in all future conditions; no slack in these tethers will be permitted in any future load cases. Whether the tethers are vertical or a combination of vertical and inclined, the current viable depths for this form of crossing may be several hundred metres.

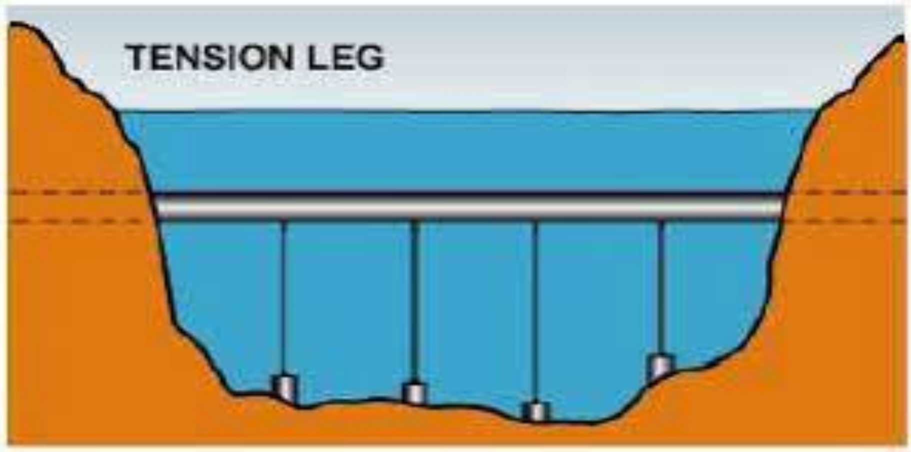

Fig.2.2. SFT with tethers to the bottom.

❖ **SFT unanchored**: It is intriguing since, other from at landfalls, there is no anchoring at all, and depth is not a factor thereafter. The length certainly has a limit, but the answer won't come until more research is done. A 100or 200-meter-long alternate route for light traffic may need to be built.

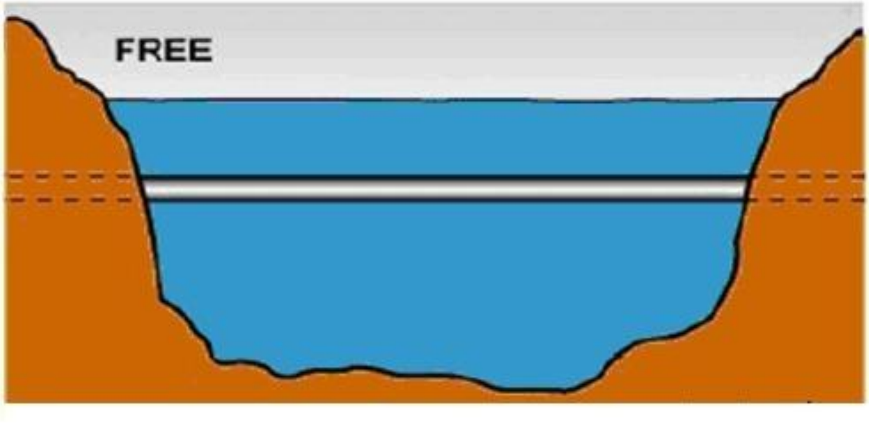

Fig.2.2.SFT unanchored.

2.3 Connection: To associate the flexible water tube with the considerably more rigid tunnel bored into the earth, the connections of the tube to the coast require the proper interface parts. Without experiencing an unsupportable increase in loads, this joint should be able to limit tube movements. However, to be able to stop water from entering, the joints must be watertight. Due to the possibility of undersea landslides, shore connections must be made with extra caution, especially in seismic regions.

2.4 Structural design of SFT tube: Under the influence of buoyancy, the SFT tube maintains its balance while the cable tension supports loads such as temperature, wave-current, and vehicle loads. The stress on the tube is complex during system transformation during prefabrication, floating, installation, and operation, thus the tube design should include longitudinal and transverse analysis under these operational circumstances.

Permanent, variable, and accidental loads are the three types of loads for SFT tubes. Structure weight, buoyancy, hydrostatic pressure, concrete shrinkage, and other permanent factors are included.

Vehicle load, water head load, wave-current load, temperature load, construction load, etc. are examples of variable loads. Accidental loads might be earthquake, sunken ship, blast, leak, etc.Similar to typical hydraulic structure design, SFT tubes are built under serviceability and ultimate limit states. In addition, stress and displacement should be analysed and checked under progressive damage. According to structural reliability theory, limit states and fatigue limit states.

2.5 Tube joint design*:*

Four principles should be followed when creating SFT tubes' joints:

- Watertightness and durability with no seepage during building or operation. Clearly defined, independent work, and simple design.
- Effectively transferring construction load during construction and practical construction.
- Excellent seismic performance, efficient transfer of stress and deformation during construction.
- Based on stiffness and deformation, tube joints can be made in either a rigid joint or a flexible junction.

2.6 Waterproofing and corrosion protection design of SFT tube:

Tube ventilation design is a crucial component of SFT design, and the effectiveness of the ventilation plan and its impact during operation are directly related to the engineering cost, the operating environment, the function of disaster relief, and the operational benefit. The purpose of tube ventilation is to ensure that harmful gas concentrations, such as carbon monoxide, are within acceptable limits, to provide a healthy environment and adequate visibility for people and vehicles inside the tunnel, and to control smog infiltration and heat for fire extinguishment and evacuation.

Tube ventilation should accord with following requirements:

- A one-way traffic tunnel's design wind speed cannot exceed 10 m/s, while a two-way traffic tunnel's design wind speed cannot exceed 8 m/s.
- Ventilation fan noise and exhaust emission are acceptable with environmental protection guidelines.
- When a fire breaks out or the transportation situation changes, the ventilation type remains constant. Ventilation is stable when operating downstream.

III. COMPETITIVE FEATURES OF SFT:

3.1 Invisible:

Crossing waterways, such as those leading from the mainland to islands in the sea or perhaps more significantly crossing an inland lake like the one, we are currently on, will frequently be met with opposition from groups representing the interests of tourists as well as from the general public. The crossing of such landscapes and lakes with SFT may make this possible. Lakes of particular beauty or perhaps historical value should be maintained for the future.Fig. 3.1 provides an illustration of this.

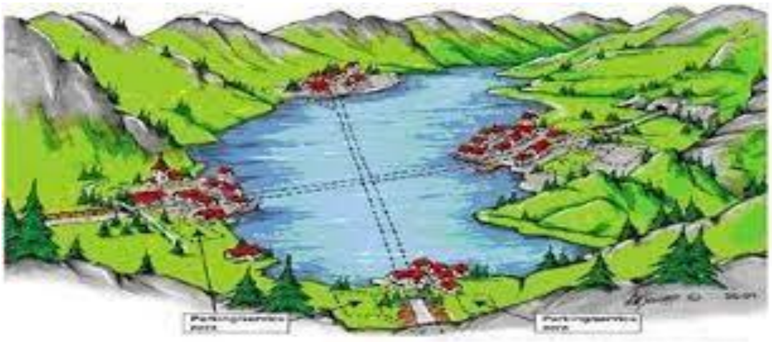

Fig.3.1.SFT crossing of lakes.

3.2. Length only from shore to shore:
The SFT structure itself is only as long as the distance between the coasts. The SFT can be immediately connected to tunnels if needed, after which it can disappear for any duration of time.

3.3. Very low gradient:
Undersea tunnel or bridge crossings typically involve longer constructions and higher expenditures, which may more than make up for the higher cost per metre for another SFT. A SFT crossing may have a very mild gradient or be almost flat, saving vehicles a significant amount of energy.

3.4. Access to underground service-parking space at ends:
As the SFT may continue in tunnels after crossing the river, it is conceivable to set up parking spaces or service areas underneath and give surfers immediate access by lifts into towns or recreational areas, as shown in Fig. 3.2. In fact, for all sorts of tunnels, these options may turn out to be one of the biggest benefits in the future.

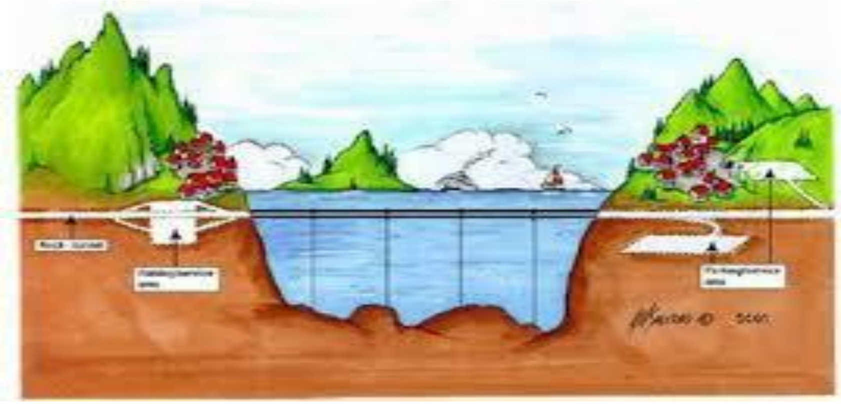

Fig.3.2. Parking and service areas.

3.5. May surface just above shoreline:Since an SFT can be placed at any depth below the surface, arrangements can be made so that the SFT surfaces are at or very close to the beach. This may be advantageous for connections to new or existing road systems and allows the planners flexibility in determining where connections should be placed.

3.6. Constructed away from densely populated areas:
Infrastructure development is a significant daily issue in many cities, contributing to traffic congestion, the creation of new one-way streets each day, and the overall annoyance of millions of people. One extremely noteworthy feature of SFT is that the actual construction may be done away from heavily or highly inhabited areas, which is also a feature of immersed tunnel construction. Once the tunnel's parts are complete, they can be towed to their final location where they will be put together and installed at the desired depth. In some cases, the entire length of the SFT might be built at the building site before being towed to the final location and installed. As a result, the neighbourhood would be disturbed as little as possible, and the entire process might take months rather than years.

3.7. Easy removal at end of life:

All structures must be removed or replaced at some point, and as the number of structures increases, it is critical to plan for these operations at the planning and design stages. In the future, it will be more and more necessary to remove, recycle, or reuse materials or components of the constructions for both financial and environmental reasons. In most circumstances, SFT is a floating structure as a whole and may thus be towed away to a location where components of the SFT can be reused. A hypothetical process may involve adding bulkheads to the original components before cutting the SFT into manageable lengths that could be transported to various sites for reuse or destruction.

3.8. Some possibilities of reuse or recycling SFT:

Depending on the size and condition of the tunnel, individual sections may serve a variety of functions. One obvious option is that a portion of tunnel, say, 12 metres in diameter shortened to a length of 10 to 15 metres would not offer any trouble to get up on dry land if that was needed for various types of storage facilities, whether in the sea or on dry land. It wouldn't be too difficult to cut a concrete tube into portions either; rather, the issue is one of general economics rather than technology.

IV. CONCLUSION:

With technological developments that will shorten travel times, the submerged floating tube will establish new trends in transportation engineering. Additionally, you can improve mobility by submerging the traffic, which preserves the beauty of the terrain and frees up important space for other uses. Less energy use, less air pollution, and less noise production are all advantages. The submerged floating tunnel may be the only practical fix link for vast and deep crossings, replacing current ferries and offering local communities' new options for increased communication and regional development.

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