Under Water Tunnel Bridge

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Abstract— Underwater tunnel bridges represent a vital advancement in civil engineering, providing innovative solutions for crossing large bodies of water where traditional bridges or tunnels are impractical. These structures combine both bridge and tunnel elements, allowing uninterrupted passage of vehicular and rail traffic while accommodating waterway navigation. Key engineering challenges in their construction include maintaining structural integrity under extreme water pressure, addressing seismic activity, and ensuring environmental sustainability. Notable examples, such as the Chesapeake Bay Bridge-Tunnel *and the* Øresund Bridge, highlight the evolution of design and materials used in these projects. Recent innovations, including submerged floating tunnels and advanced immersed tunnel techniques, continue to push the boundaries of what is possible in the realm of underwater infrastructure. The increasing complexity of coastal and deep-sea transportation projects underscores the importance of interdisciplinary collaboration between structural engineers, geotechnical specialists, and environmental scientists in designing these hybrid systems. This paper reviews the history, design principles, and future prospects of underwater tunnel bridges, focusing on their role in modern transportation networks.

Keywords- Underwater Tunnel Bridge, Civil Engineering, SFT

I. INTRODUCTION

Tunnels in water are by no means new in civil engineering. Since about 1900, more then 100 immersed tunnels have been constructed. Bridges are the most common structures used for crossing water bodies. In some cases immersed tunnels also used which run beneath the sea or river bed. But when the bed is too rocky ,too deep or too undulating submerged floating tunnels are used . The Submerged Floating Tunnel concept was first conceived at the beginning of the century, but no actual project was undertaken until recently. As the needs of society for regional growth and the protection of the environment have assumed increased importance, in this wider context the submerged floating tunnel offers new opportunities. The submerged floating tunnel is an innovative concept for crossing waterways, utilizing the law of buoyancy to support the structure at a moderate and convenient depth .The Submerged floating Tunnel is a tube like structure made of Steel and Concrete utilizing the law of buoyancy .It supported on columns or held in place by tethers attached to the sea floor or by pontoons floating on the surface. The Submerged floating tunnel utilizes lakes and waterways to carry traffic under water and on to the other side, where it can be conveniently linked to the rural network or to the underground infrastructure of modern cities.

Fig. 1: Underwater Bridge

Underwater concrete construction is a critical component of the entire project. It is technically demanding, usually on the critical path of the project. It is technically demanding, usually on the critical path of the project schedule, and involves complex construction logistics. Therefore, its significance in the project far beyond the concreting operations themselves, in essence, underwater concrete can be constructed with the same degree of reliability as abovewater construction. But if it is not carried out properly, with the proper concrete mixture and placement procedure, underwater concrete construction can result in a major cost and schedule overrun. This is the area where sound design and competent construction planning can achieve a meaningful reduction in risk and cost. For those used to concreting on dry land, concreting under water presents various challenges. Transporting, compacting, quality control, finishing and accuracy must all be carried out successfully in this different, and often difficult, environment.

Fig. 2: Model of Underwater Bridge

There are, however, many common aspects, chief of which is that air is not required for the setting and hardening of concrete – it sets and hardens just as well, and often even better, under water – but it must be fluid enough to flow into position and be self-compacting as conventional vibration is not practicable under water.

II. STRUCTURAL COMPONENT OF SFT

Submerged Underwater tunnel consists of many structural components. These components should provide strength and stiffness against the various forces acting under the water surface. The three basic structural components are:

- Tube
- Anchoring
- Shore connections Tube:

It should accommodate the traffic lanes and the equipments. External shape can be circular , elliptical or polygonal. It may be constructed of steel or concrete. Corrosion protection is the main issue. Tube is composed of elements of length varying from one hundred meters to half a kilometre.

Anchoring: There are basically fours types of anchoring:

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

It is independent of water depth, the system is sensitive to wind, waves, currents and possible ships collision. Design should be such that if one pontoon is lost, then also the structure will survive. SFT supported on columns: It is an "underwater bridge" with foundations on the bottom, in principle the columns are in compression but they may also be a tension type alternative. Water depth will play an important role in this case and a few hundred meters depth is considered a limit at the present time. However, much deeper foundations are at present under investigation. SFT with tethers to the bottom: It is based on tethers being in tension in all future situations, no slack in these tethers may be accepted in any future load cases.

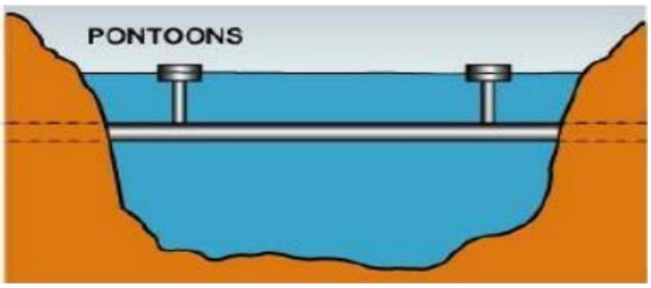

Fig. 3(a): SFT with pontoons

The present practical depths for this type of crossing may be several hundred meters, whether the tethers are vertical or a combination of vertical and inclined. SFT unanchored: It is interesting as it has no anchoring at all except at landfalls and is then independent of depth. There is obviously a limit to the length but only further development will answer this. Perhaps an alternative for light traffic should be designed, possibly a 100 or 200 meter long.

The four types of anchoring are given in FIG 3(a), 3(b), 3(c), 3(d)

Fig. 3(b): SFT supported on columns

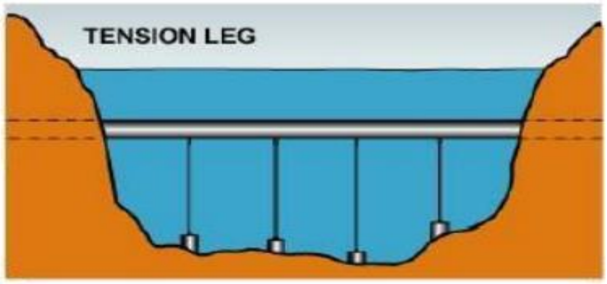

Fig. 3(c): SFT with tethers to the bottom

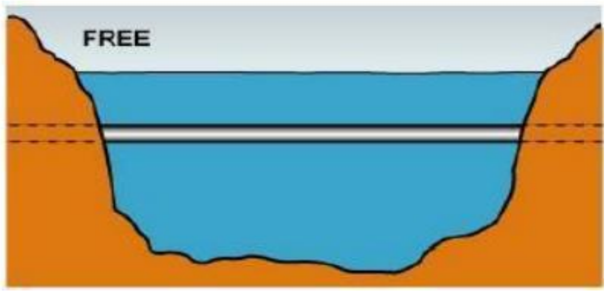

Fig. 2(d): SFT unanchored

III. FEATURES OF SFT

Invisible Crossing waterways, whether being from main land to islands in the sea or maybe more important crossing an inland lake, perhaps the one we are at now will in many cases meet protests both from tourist interests and also from the public in general. Lakes of special beauty or perhaps historical value should be preserved for the future, the crossing of such areas and lakes with SFT may make this possible. An illustration of this may be seen in Fig. 4 Length only from shore to shore The actual SFT structure is only as long as the distance between the shores. If desired the SFT may be connected directly to tunnels and then be completely out of sight for any desired distance.

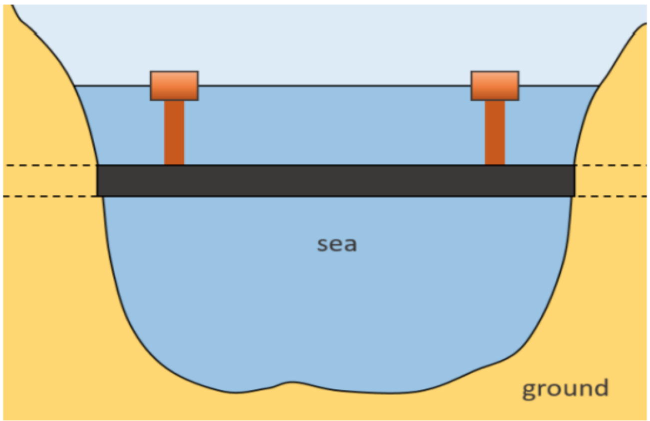

Fig. 4: SFT crossing of lakes

Very low gradient Crossings with undersea tunnels or bridges will frequently mean longer structures with consequently higher costs and this may offset the higher cost per meter for an alternative SFT. An SFT crossing may have a very gentle gradient or being nearly horizontal giving considerable savings in energy used by traffic. Access to underground service-parking space at ends As the SFT may continue in tunnels having crossed the waterway, it is possible to arrange parking places or service areas under ground and provide access to the surface by lifts directly into cities or recreational areas as. These possibilities may be one of big advantages in future, in fact for all types of tunnels.

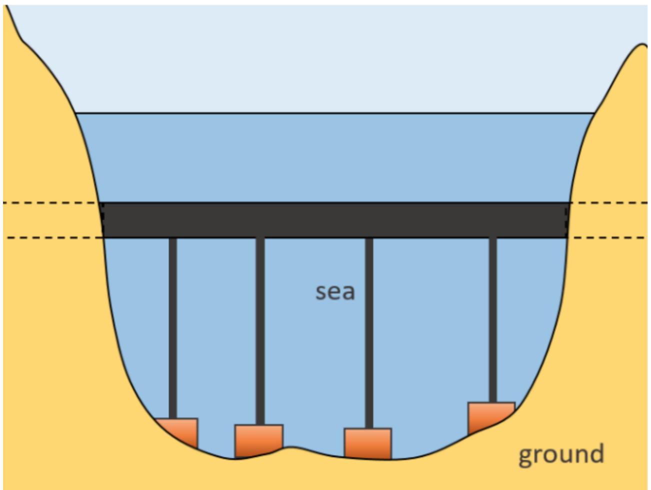

Fig. 5: Parking and service areas

May surface just above shoreline As an SFT may be positioned at any depth below the surface arrangements may be made that the SFT surfaces at or very near the shoreline. This may be an advantage for connections to new or existing road systems and gives the planners freedom to locate connections in a very flexible way. Constructed away from densely populated areas Construction of infrastructure is a major everyday problem in many cities, traffic is piling up, new one way streets daily and generally great frustrations by millions of people. One very interesting feature with SFT is that the actual construction may be done away from the densely or highly populated areas, a feature also for immersed tunnel construction. After the sections of the tunnel are finished they may be towed to the actual site and there joined together and installed at the desired depth. In some instances the whole length of the SFT may be assembled at the construction site and the complete structure towed to the actual site and installed. This would ensure minimum disturbances to the local area and perhaps the whole operation may only take months instead of years. Easy removal at end of life All structures will have to be removed or replaced sooner or later and as the amount of structures increase it is important to prepare for these operations already at the planning and design stage. Removal, recycling or reuse of materials or parts of the structures will become increasingly necessary in the future, for both economic and environmental reasons. SFT is in most cases a Underwater structure as a whole and may therefore be towed away to some place where parts of the SFT may be reused. One may imagine such an operation by for instance placing bulkheads in the original elements and then separating the SFT in suitable lengths to be perhaps towed to different locations for reuse or destruction. Some possibilities of reuse or recycling SFT Sections of a tunnel may be used for many purposes, depending on its size and condition. One obvious possibility is for various types of storage facilities, whether in the sea or on dry land, a section of tunnel ,say 12 meters in diameter cut to a length of 10 to 15 meters would not present any difficulty to get up on dry land if that was desired. To cut a concrete tunnel into sections would not present big difficulties either; it’s more a question of overall economy than technology.

IV. CASE STUDY ON BRIDGE FOUNDATION

This section provides brief descriptions of the under concrete construction for Akashi Kaikyo bridge.

- The Akashi Kaikyo Bridge also known as the Pearl Bridge, is the world's longest suspension bridge (measured by the length of the center span of 1,991 metres). It is located in Japan and was completed in 1998.
- The two main tower foundations of the Akashi Kaikyo bridge, Japan, are large double-wall steel Tunnels filled with tremie concrete. The project required that a large volume of tremie concrete be placed up to 57m below the water surface.
- The steel Tunnel is divided in to an inner core and 16 segments of the outer core. While the tremie concrete in each segment of the outer core was placed at one time, the concrete in the inner circle was placed in 11 lifts. Each lift was about 3 to 4m in thickness and 54m in diameter.
- Prior to the construction, extensive tests were conducted to select the tremie concrete mixture. The concrete selected was self-leveling with a slump flow of 525mm. the concrete mixture selected was a ternary mixture with cement:slag:flyash proportions of 20:60:20. In addition, a significant portion of limestone powder was added to

control the bleeding and improve the cohesion of the mixture.

- All the tremie concrete was produced on a floating batch plant. The concrete materials required for one lift of concrete (about 9,000m3) were collected together on two material barges that were moored to each side of the Tunnel.
- Each tremie placement was carried out continuosly day and night for 3days. Each tremie pipe covered a 100-m2 area.
- The rate of placement in the inner circle was relatively slow at about 5 to 8cm/hr. due to the fluid characteristics of the concrete, the slow placement rate was necessary to prevent washout. o The construction joints between the lifts were prepared with underwater robots and airlifting.
- A 3cm thick layer of antiwashout mortar was aced over the construction joint prior to placing another lift of tremie concrete. The total of 50,000m3 of concrete was placed in the steel Tunnel.

V. CONCLUSION

- Cofferdams are temporary structures and used in cases where the plan area of foundation is very large, depth of water is less and for the soft soils, where soils allow easy driving of sheet piles.
- Tunnels are permanent structures and becomes economical in cases where the plan area of foundation is small, large depth of water and for loose soils.
- Suction Tunnel anchors are gaining considerable acceptance in the offshore industry. The suction Tunnel is a highly versatile and efficient anchor concept that can be installed easily as compared to driven piles, especially in deep waters. The installation procedure is simple and requires no heavy lift vessel. The geometry to be used is dependent on the soil type.
- At present, the tremie placement method is the standard way of placing high-quality concrete underwater. The other placement method are not able to reliably place highquality underwater concrete for major structures, although they may find application in special cases
- For massive underwater concrete construction of navigation structures, the pump method should be prohibited

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