RESEARCH ON DESIGN OF SEMI-POLYGONAL SEGMENT OF SUBMERGED FLOATING TUNNEL

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Abstract - *From the mid of 19th century, many countries initiated their research on this typical project called Submerged Floating Tunnel (SFT). This structure is submerged in the water and eventually floats with the help of large sized pontoons and tethers. This conceptual design is given according to the safety, economy, fine appearance, waterproofing, applicability and environmental protection. In this design it describes the other factors like corrosion resistance, design of joints between the sections and type of ventilation. The main consideration in this research is about the structure's buoyancy and it is successfully satisfied which is the key factor for tunnel to float with the help of pontoons. This paper provides the applicable and meaningful suggestions regarding the design of submerged floating tunnel which includes both architectural and structural design of the tunnel and pontoons.*

***Key Words*: Archimedes Bridge, Buoyancy, Pontoons, Submerged floating tunnel.**

1. INTRODUCTION

Submerged Floating Tunnel is ingenious structure used to cross the water bodies which have greater bed depths and this structure is different from traditional concrete bridges supported with columns and the bridges which are suspended or anchored. This tunnel floats because of buoyancy and is suspended in place by means of tethers or bracings between the two tunnels.

1.1 Supremacy of the tunnel:

- It doesn't obstruct any naval transportation.
- Distance and Time of travel for the destination decreases.
- There will be minimal amount of slope, vertical and horizontal gradients.
- It is an all-weather construction and doesn't get effected by the change of climate.
- The cost of construction of the tunnel segments doesn't increase with an increase in the tunnel length.
- The design of this tunnel includes high knowledge on the different topics including materials sciences, waterproofing of concrete, seismic analysis and hydrology etc.

1.2 Codes used for Design:

- For the designing of practically possible and sustainable tunnel segments IS: 5878 (Part IV)-1971t is the code used for the design and construction of the tunnel segments of SFT.
- For the resistance and durability against the waves IS 4651-3 (1974) Part III is used for the designing of the water exposed part of the tunnel.
- For the provision of ventilation, lighting and dewatering of the tunnel IS 5878-2-2 Part II Section 2 is the code taken into consideration.
- IS SP 35 1987 is the code used for the plumbing elements inside the tunnel.
- IS 8147 is the code used for the designing water proofing and outermost layer of the tunnel segment which is made up of aluminum alloy.

3. Preliminary survey of the materials:

3.1 Aluminum 6061:

This is an aluminum alloy which has high resistance to the pressures and its tensile strength is high compared to the different types of steel. It also overtakes many metals and alloys when considering the resistivity against the corrosion. The main reason behind this is that the percentage of ferrous composition is less than 0.7, so that the metal doesn't get oxidized.

Usually, this material is used in the in the fittings of airplanes, ships and in pistons. In this project, aluminium6061 has been used as the outer covering for the tunnel, to protect inner layer of concrete from deterioration and wave action. Other properties including physical, mechanical and thermal are perfectly satisfied to use this material for water proofing and outermost cover for the tunnel.

3.2 Concrete:

In this design, [1] reinforced concrete has been used in the main structural components like tunnel outer segments, shear walls, beams, columns and for traffic deck. A portion of reinforced cement is used in the construction of footpaths, platforms, supporting beams and in the concrete shafts.

M50 grade reinforced concrete is made use of in the construction of tunnel segments and shear walls.

M30 grade partially reinforced concrete is used for sidewalks or footpaths.

M40 grade Reinforced Cement Concrete pavement is used as traffic flowing deck in this tunnel.

3.3 Steel:

Steel is mainly used in reinforcement and some of the steel cables are attached to the pontoon as an extra support.

For the reinforcement Fe 550 is used as the structural contains n number of tension members.

As the steel cables are exposed to water, they are coated with the aluminum alloy or by the use of nano coating procedure.

3.4 Construction Foam:

Construction foam blocks are used as insulating and filling materials to reduce the usage of concrete and to promote the light weight structures. In this design Expanded Polystyrene (EPS)46 grade has been used. It is used as [8] filler material in the platforms, shaft. In pontoon it is used to increase the ability of floating.

4. Calculating the Ratio of Buoyancy to Weight:

The ratio of the tunnel should be in the range of 0.5 to 0.8. As it is not possible to construct to full tunnel as single segment, the design of tunnel segments has been done using different lengths.

- 100 meters tunnel segments as the initial and final segment and for connection to the shore or land.
- 250 meters tunnel segments are used all over except in the center of the river and this width is helpful for passage of small yachts and fishing boats.
- 450 meters tunnel segment is used in the middle for passage of cruise and cargo ships.

4.1 For 100 meters:

For the calculation of buoyancy to weight ratio we should assume the volume of each structural member which is the multiplied by the density of the material used in construction of structural element.

Let us assume the Buoyancy Force ($v \times \rho \times g$) is 35×10^3 KN.

Some of the structural and mechanical elements like Aluminum – 6061 lining, Concrete lining, Concrete Deck, Shear Wall, Footing, Foot Path, High Speed Electric Train, Platform, Heavy Load Truck, Light Weight Vehicles and 4 Wheelers contribute the maximum weight of the structure.

For the above structural and mechanical the total weight of tunnel will around 45×10^3 KN.

The Buoyancy to Weight ratio of the tunnel is 0.75 which satisfies the assumption of the previous researches.

Assuming the pontoon of dimensions 80×34×12 could possess the weight of 13×10^3 KN and its buoyancy will be around 32×10^3 KN.

So, the total weight to be balanced by Pontoon Buoyancy is $(12.7+45-35)\times10^3$ which is equal to 22.7×10^3 KN.

Considering 'h' be depth of submerged Pontoon.

So, h = $22.7\times10^7/2.7\times10^7$= 8.7 mts,

h = 8.7 m. So, in equilibrium state 8.7m depth will be submerged of a total height = 12m.

Total buoyancy of tunnel and pontoon to Total weight of tunnel and pontoon ratio ~ 1.17.

If the ratio of buoyancy to weight for any object is greater or equal to 1, it will float and the designed tunnel segment will submerge up to 8.7m from mean sea-level.

The calculation is similar for 250 and 450-meter segments only difference is the above values buoyancy and weight values are multiplied by 2.5 and 4.5.

For 250 meters, the height of submersion of the tunnel will be around 1.19 meter from mean sea-level.

For 450 meters of tunnel section, the height of submersion will be around 1.78 meter from mean sea level and a couple of pontoons are placed at both ends.

5. Submerged Floating Tunnel Design Model:

5.1 Tunnel layers:

In this design tunnel consists of two layers, first layers is made of aluminum 6065 of 0.5 to 1-meter thickness and this layer is exposed to the surrounding water. The second layer made use of reinforced concrete inside the aluminum layer with 1meter thickness. These two layers were continued throughout the tunnel length.

5.2 Roadway:

For this, the design used two types of decks; first one is made of traditional reinforced concrete and finished with asphalt and the second type deck is made of steel this is helpful for ease of construction and carrying. Thickness of the deck should be around 0.5 to 1 meters, as conventional slab and asphalt layers should be finished with thickness not greater than 0.075 meters. The deck is of width 13 meters with 3 lanes for free flow of traffic.

5.3 Sidewalks:

This design consists of a couple of sidewalks [3] on both sides of the pavement with the widths 1 meter on the left and 2 meters on the right and each with thickness 1 meter. These can be made of full concrete and steel or can be made of construction foam and finished with concrete over the surface with thickness of 0.1 meters.

All the above-mentioned tunnel elements should be constructed throughout the tunnel segments. Some of the tunnel elements are given below which are to be constructed at some stipulated place depending upon the need and for supporting the load.

5.4 Shear walls:

These are placed under the deck as a vertical support to control the deformation of the deck due to traffic loading. For shear wall, dimensions for height and width are 6 meters and 2 meters respectively. These shear walls dimensions can be modified depending upon the type of load acting over the deck.

[4] Some of the other elements like supporting columns and beams of dimensions 1 meter×1 meter are used. Columns are placed for every 7.5 meters in Z- direction.

5.5 Platforms:

These are constructed in the partition cell at the corner of the concrete layer with construction foam inside and are finished with concrete of thickness 0.1 meter. Overall dimensions of the platform are height of 3 meter and width of 1.8 to 2 meter.

5.6 Stair cases:

These are used for movement between the two levels of tunnels. These are shafted in the sidewalks with required dimensions.

5.7 Shafts:

These are the cylindrical supporting connections between the tunnel and pontoon which resist the tunnel movement and drowning, Shafts are made of two layers same as tunnel with aluminum and highly reinforced concrete. Overall shaft diameter is 8 meters. Aluminum layers is made up with the thickness of 0.5 thickness and concrete layer of thickness 4.5 to 5.5 meters and the remaining is filled with ventilation ducts, power cables and with construction foam for insulation. The height of the shafts should be max of 20 meters.

5.8 Pontoons:

These are connected at the shaft top and the outer layer is made of aluminum, later total area is filled with construction foam for floating and to support buoyancy. The dimensions of the pontoons are 80×34×12 meters with respective to length, breadth and height.

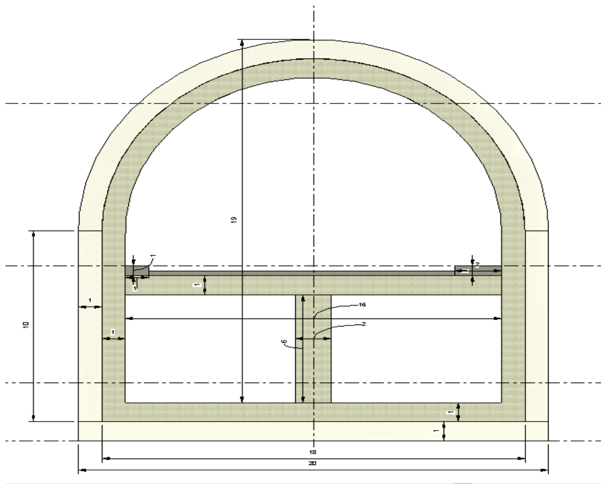
6. Mechanical, Electrical and Plumbing (MEP) Equipment:

[5] Mechanical systems present in this tunnel design are elevators, escalators, ventilation fans or ducts and the locomotive train.

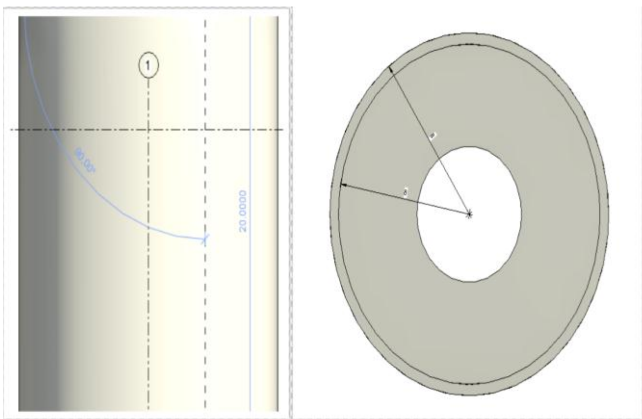
Electrical systems present in this tunnel include the overall lighting of the tunnel, power supply boards, and generator electric connections.

Plumbing systems in this tunnel are water draining systems, hoses of drinking water and restrooms etc.

The overall cross-sectional view of the tunnel from the north direction are shown in the Fig (1) and the cross-sectional view of the shaft is shown in the Fig (2).



Fig(1)



Fig(2)

*all the above values are in meters

7. Advantages of the design:

7.1 Levels:

This design consists of two levels in tunnel where top level consists of only a deck and foot paths and bottom level is partitioned into two parts where one side is given for medical emergencies and transportation on road and other side is given for railway transportation.

7.2 Ventilation:

Ventilation can be provided in both horizontal and vertical ways. But in this design, we are providing vertical ventilation and the ventilation fans and ducts are fixed to the tunnel ceiling and end of the hoses are connected to a shaft, continued up to pontoon. The quantity and dimensions of the axial fans are determined after the calculation of different factors like amount of production of smog, carbon monoxide in normal working condition and in damaged or destructive condition. In that emergency cases we can use jet fans for fast diffusion of gases.

All the electrical and plumbing works are to be implanted in the concrete lining of the tunnel for safety and aesthetic look of the tunnel.

8. Conclusion:

As [6] the submerged floating tunnel is a complicated structure and there is no practical construction done, there is so much of possibility for researches on this structure. This paper has done research on the polygonal tube design of the tunnel, materials, corrosion resistance, ventilation, waterproofing and various calculations like buoyancy to weight ratio of tunnel and pontoons. Other elements like structural analysis, joint design is to be studied further for practical applicability.

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