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DESIGN AND ANALYSIS OF UNDERWATER TUNNEL

[1]Prof. Preeti Morey, [2]Vishal D. Chopade, [3]Sofiya R. Nagrare, [4]Bhagyashri R. janwe, [5]Sujit A. Mehshram

[1,2,3,4,5]Department Of Civil Engineering Suryodaya College Of Engineering And Technology Nagpur , India.

[1]preetymorey88@gmail.com, [2]04vishalchopade@gmail.com, [3]sofiyanagrare@gmail.com, [4]bhagyashrijanwe@gmail.com, [5]Sujitmeshram001@gmail.com

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ABSTRACT

The development of underwater tunnels is a critical advancement in modern transportation engineering, enabling efficient connectivity across water bodies while minimizing environmental and surface disruption. This study focuses on the structural analysis and modelling of an underwater tunnel using ABAQUS and Autodesk Revit. The tunnel model is developed in Revit to create a detailed 3D representation, including geometry, reinforcement detailing, and alignment. The generated model is then analyzed in ABAQUS using Finite Element Analysis (FEA) to evaluate structural performance under various loading conditions such as dead load, live load (vehicular load), soil pressure, and hydrostatic pressure. The study considers realistic boundary conditions and material properties to simulate actual site conditions. The results obtained include stress distribution, deformation characteristics, and factor of safety of the tunnel structure. The analysis shows that the maximum stress and displacement values remain within permissible limits, indicating that the design is structurally safe and stable. This integration of BIM and FEA tools enhances accuracy, visualization, and efficiency in tunnel design. Overall, the study demonstrates that the combined use of Revit and ABAQUS provides a reliable and effective approach for designing and analyzing underwater tunnels, ensuring safety, durability, and optimal performance.

1. INTRODUCTION

Underwater tunnels are an important development in civil engineering. They are used to provide safe and smooth transportation below water bodies like rivers, seas, and oceans. The idea of building tunnels under water started in the 19th century with the construction of the Thames Tunnel in 1825. This project was the beginning of modern tunnelling methods. Over time, improvements in construction techniques, materials, and design have made it possible to build large projects like the Channel Tunnel and many modern underwater tunnels used in cities.

A tunnel is an underground passage built to cross obstacles without disturbing the ground surface. Today, due to increasing population, urbanization, and heavy traffic, there is a growing need for better transportation systems. Underwater tunnels help solve this problem by reducing travel distance and time. They also reduce the need for land acquisition.

This processing is done in several phases including image acquisition, features extraction and finally expressions classification using different techniques.

2. METHODOLOGY

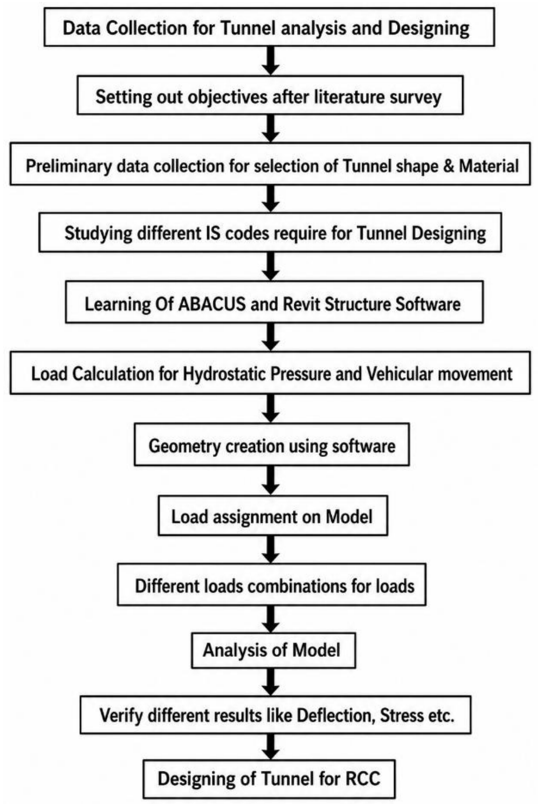

Figure 1: Flowchart of the Methodology for Analysis and Structural Design of RCC Tunnel

3. SOFTWARE USED

In this study, advanced engineering software tools are used to understand how underwater tunnels are designed and analysed. ABAQUS is used to carry out finite element analysis (FEA), which helps in studying how the tunnel behaves under different types of loads such as water pressure, soil pressure, and traffic load. It is useful for finding stress, deformation, and checking the overall stability of the tunnel. Along with this, Autodesk Revit is used to create a 3D model of the tunnel. It helps in better visualization of the structure and gives a clear idea about the design and geometry. It also supports planning and presentation of the tunnel model. Overall, both ABAQUS and Revit help in improving the accuracy and efficiency of tunnel design and analysis.

4. LOADING CONDITION

The below figure shows the different types of loads acting on an underwater tunnel built below a river bed. The tunnel is surrounded by water, so it experiences hydrostatic pressure from all sides—left, right, and bottom. The soil above the tunnel also applies pressure downward. In addition to these external forces, the tunnel carries its own weight, known as dead load. There is also live load inside the tunnel, which comes from vehicles like cars and trucks moving through it. All these loads together are very important to consider while designing the tunnel, as they affect its strength, stability, and overall safety

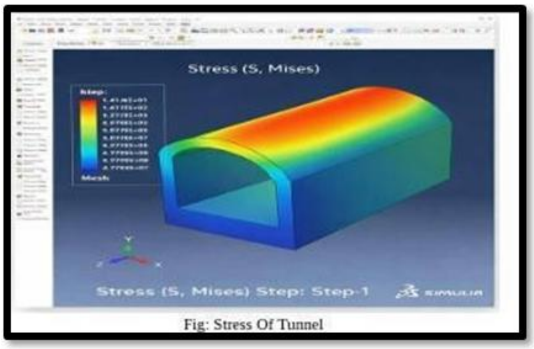

Figure 2: stress of tunnel

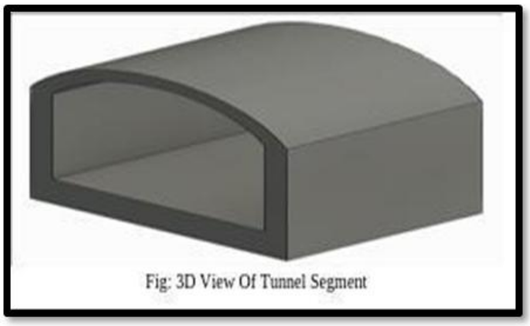

Figure 3: ABAQUS and Revit software image

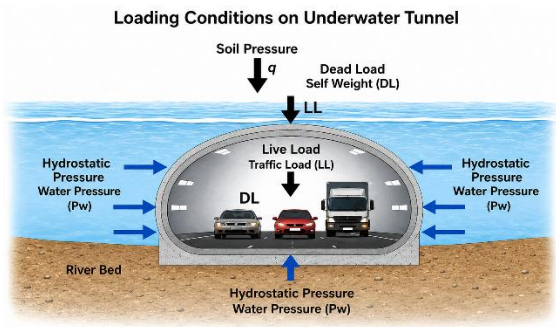

Figure 4: Loading conditions on underwater tunnel

5. DISCUSSION ANALYSIS

The analysis of various research studies on underwater tunnels indicates that these structures are highly efficient for providing safe and uninterrupted transportation beneath water bodies. Different construction techniques such as immersed tube tunnels, bored tunnels, and cut-and-cover methods have been widely adopted based on site conditions and project requirements. Among these, immersed tube tunnels are suitable for shallow depths, while bored tunnels are preferred for deeper and complex geological conditions. From the reviewed studies, it is observed that loading conditions play a significant role in determining the structural behaviour of underwater tunnels. Hydrostatic pressure from surrounding water and soil pressure from the overburden are the major external forces acting on the tunnel. In addition, dead load and live load due to vehicular movement contribute to the overall stress and deformation of the structure. Proper consideration of these loads is essential to ensure safety and stability. The use of advanced analysis tools such as ABAQUS has improved the accuracy of structural analysis by enabling detailed evaluation of stress distribution and deformation under different loading conditions. Similarly, Autodesk Revit helps in developing 3D models and better visualization of tunnel geometry, which enhances planning and design efficiency. Furthermore, studies highlight that the selection of construction materials and proper waterproofing techniques are critical for the durability of underwater tunnels. Leakage and joint failure remain major challenges, especially in long-term performance. Advanced concepts like submerged floating tunnels show promising results but require further research and real-world implementation. Overall, it can be concluded that underwater tunnels are a reliable and effective solution for modern transportation needs. However, challenges related to high construction cost, complex design, and maintenance issues must be addressed through continuous research and technological advancements.

6. RESULTS AND FINDING

- The analysis of the underwater tunnel shows that all important forces acting on it have been properly taken into account, such as its own weight, the load from vehicles, soil pressure, and the upward force from water.
- The total downward force is greater than the upward water force, which helps keep the tunnel stable.
- The Factor of Safety is 1.45, which is higher than the required 1.2, so the tunnel is safe against uplift.
- The maximum stress in the structure is between 6 to 8 MPa, which is much lower than the allowed limit of 13.5 MPa, meaning the material is strong enough and not under too much stress.
- The maximum movement of the tunnel is between 10 to 15 mm, which is also within the safe limit, so there will be no excessive deformation.
- There are no signs of failure, and the stress is evenly spread throughout the structure. The bottom slab and side walls are the most critical areas that need attention.
- Overall, both calculations and software results show that the tunnel is safe, stable, and will perform well under all conditions.

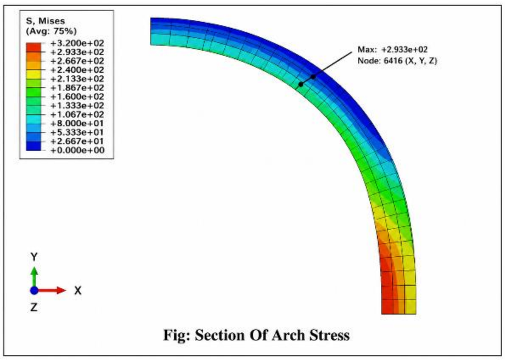

Figure 5: Section of arch stress

Colour shows that: Blue → Minimum displacement Green → Moderate displacement Yellow → High displacement Red → Maximum displacement The obtained results shows that the structure is safe, with maximum stress of 6-8 MPa, displacement of 10-15 mm, and factor of safety of 1.45, the overall design is considered safe and economical.

CONCLUSION

- The underwater tunnel sets a new trend in transportation engineering using advanced technology.
- It reduces travel time and makes transportation more efficient.
- Helps in reducing energy consumption, air pollution, and noise emission.
- Supports sustainable development and national growth.
- The submerged floating tunnel remains stable due to buoyancy and hydrostatic forces.
- However, it is not sufficiently resistant to wave and current forces.
- Structural failure occurs at the center of the tunnel under wave impact.
- Stronger reinforcement and rigid shell materials are required.
- Further research can make it a safe, economical, and sustainable future transport system.

FUTURE SCOPE

Submerge floating tunnel (SFT) is an innovative structure that has never been existed. It is much more complex than bridge and tunnel due to its unique structure form and complicated working Environment. Although SFT has a lot of advantages and great development potential, there are still some problems and challenges need further research.

- Seismic and disaster analysis
- Use of smart materials
- Real monitoring system

- Hybrid tunnel system
- Advanced waterproofing techniques
- Automation in construction

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