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A STUDY ON ADVANCED UNDERWATER CONSTRUCTION AND IT'S CHALLENGES

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Abstract – *This article is focused on the advanced underwater construction and it's challenges. Underwater buildings are structures which are built under the water and each constructing built has a specific motive related to it in keeping with the type of its construction. The caissons and cofferdams are the techniques used for the construction of underwater structures. Mainly there are four types of underwater construction methods. They are tremie method, pump method, toggle bags method and bag works method. Different case studies of underwater construction will be analysed in this article. The major challenges of underwater construction and remedies are also discussed.*

Key Words: Underwater construction, Caissons, Cofferdams, Tremie method, Pump method

1. INTRODUCTION

Population in India is increasing rapidly and reached approximately 138 crores with average growth of 1.2% every year. Traffic Congestion is one of the major problems that India is facing and it has a massive impact on the quality of air, time of travelling, trade and cost. It has been noted that the government are trying their best in order to come up to this problem by creating structures such as Tunnels, Subways, Flyovers and Bridges. But unfortunately it fails as does not match up with the increase of population and due to less amount of land available for the construction. So the scope of underwater construction is increased day by day.

Underwater construction will have great benefits to the people living in India. There will be a decrease in the populated places present on the surface of land. There will be a progress and enhancement in technology used for its construction. It will promote tourism as all the people from all over the world would come for the astonishing experience of numerous fishes and coral and it will be provide as a source of entertainment for them.

There are many materials to be had for the building but our selection should be such that the material fulfils our requirement and to be had with a minimal price. Whilst choosing the materials to be used inside the manufacturing, it is critical to make sure that the burden restriction is not exceeded.

The principle fabric used for construction underwater changed into a unique kind of steel and acrylic. The acrylic fabric is used specifically for visibility, on the same time because the steel is used for reinforcements (enables). Excessive energy steel is used as it is in particular reasonably-priced, and has its immoderate yield electricity. It isn't always additionally a terrific conductor of power and warmth. It's far an excessive corrosion resistance. Acrylic fabric is used in preference to glass; it is better than glass due to being much less dense, and it's also has higher effect electricity than the glass. Acrylic gives the herbal duration and colourings of the encompassing materials than glass. It's also proper insulator of strength which is good in searching out the fitness and safety of clients and underwater creatures.

1.1 Objectives

- To find the materials which can be used for the construction of underwater building.
- To study about the different methods of underwater constructions.
- To study about the challenges of underwater construction and its remedies.

2. LITERATURE REVIEW

2.1 Hemant Kumar Sain, Mayank Mehandiratta, Vikas Yadav, Priyanka Mandal(2019)

The underwater construction is mainly required where the transportation & field area is no available for required living than make a underwater Construction. There are many difficulties has to be faced in the underwater construction. We first see the place of construction right or wrong and there is no damage to be aquatic life. It provides better transportation path or public transportation and consumes less time or transportation, the disadvantage is that it consumes more time in construction. To make this type of construction only good materials are used stable life long time. So to make this type of effective construction we must follow this processer.

2.2 Jitesh Mehta, Jayeshkumar Pitroda , J.J.Bhavsar (2015)

Caissons are permanent structures and becomes economical in cases where the plan area of foundation is small, large depth of water and for loose soils. 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 high quality underwater concrete for major structures, although they may find application in special cases. High quality concrete can be placed underwater in drilled shafts. However, proper concrete mix and proper placement techniques are essential as well as performing effective nondestructive testing to confirm sound concrete. Open caissons are small cofferdam that are placed and then pumped dry and filled with concrete. These are generally used in the formation of a pier.

2.3 N.Mohamed Nizar , Bavabahurudeen , N.Sriram (2016)

The design of underwater theatre is to facilitate the luxurious massive structure under the water. From this project we come to the conclusion that, designing these type of structures the tourism in India by this the revenue of the country can also be increased. In Singapore underwater theatre is made completely of concrete but in our theatre we had included fiber glasses along with concrete so the scenic beauty of the aquarium is visible to us. The effective Design of underwater theatre has been created by using the following Indian standard code books IS: 4090-1967, IS: 456-2000.

2.4 Kiran Dabral, R Selvaraj , Simon J (2016)

The methods which are used to place concrete underwater are the pre-packed concrete method, the tremie method, and the concrete pump method . Use of the tremie is currently the most often utilized technique for placing concrete under water. To meet all the requirements of properties of underwater concrete, researchers have been extensively working on construction material to develop admixtures for use in concrete that permit the concrete to be placed underwater without the use of tremie. These materials are referred to as anti-washout concrete. The admixture is used to prevent washout of cementitious material and dispersion of aggregate during underwater placement of concrete.

2.5 Gopal murty, Kumar umang, Satyam barle, Bhumika das (2018)

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2.6 Chiranjit Samanta, Rabi Das, Kousik Sabui (2018)

The procedure of formulating the concrete mixtures should be in such a way that they are easy to place and also withstand even in the adverse underwater conditions. The required properties are ability of concrete to flow, retention of workability over a reasonable time, self-compacting, adequate cohesion to avoid segregation, low heat of hydration, low bleeding, controlled set times, development of adequate compressive strength, adequate bond strength, low creep and shrinkage, resistance to washout by flowing water, abrasion resistance, and some more according to the condition in which the structure is to be built. Out of all the mixes, the material which gives the best performance as an anti-washout admixture and optimization of the dosage of that material for specific volume of concrete will be carried out.

2.7 Zaran D. Patel , Dr. Jayeshkumar Pitroda (2017)

This record analyzed a present day generation of construction of structures beneath the water. Constructing building under the water is the future establishment that has a superb effect on the environment. This document has shown up what underwater buildings are. It has mentioned the impact of underwater constructions on environment and social existence. It has tested the materials which can be utilized in underwater constructing. It additionally has described the problems that are faced during the construction of structures below the water. It has described the air flow structures which are used. It has higher the reader with a few examples of underwater constructions that have been built or under manufacturing, in order to mesmerize him with the appealing view and the magnificence of buildings.

3. TECHNIQUES OF UNDERWATER CONSTRUCTION

3.1 Caissons

The term caisson is derived from Latin, which means box or case. Caissons are hollow inside and usually constructed at site and sunk in place into a hard bearing stratum. It's a prefabricated hollow box or cylinder. It is sunk into the water to some desired depth and then filled with concrete thus forming a foundation. There are different types of caissons

box caisson, open caisson, suction caisson, pneumatic caisson etc.

3.2 Cofferdam

A cofferdam, also called a coffer is an enclosure built within, or in pairs across, a body of water to allow the enclosed area to be pumped out. This pumping creates a dry working environment so that the work can be carried out safely. Enclosed coffers are commonly used for construction or repair of permanent dams, oil platforms, bridge piers etc., built within or over water. These cofferdams are usually welded steel structures, with components consisting of sheet, piles, wales and cross braces. Such structures are usually dismantled after the construction work is completed. There are different types of cofferdams earthen cofferdam, rockfill cofferdam, single-walled cofferdam, double-walled cofferdam, Cellular cofferdam, braced cofferdam etc.

4. METHODOLOGY

4.1 Tremie method

Tremie method is one of the most common methods that is used for concreting under water. In this method, a long steel pipe (named as tremie) having a diameter of 15 to 30 cm is inserted vertically into the water. The pipe should be long enough that it reaches to the bed of water keeping its one end above the water level. The tremie is then fitted with a hopper at the upper end for pouring concrete inside the pipe. The lower end of the tremie pipe must be closed with a check valve before inserting it into the water. After that, freshly mixed concrete is poured with the help of hopper. When the concrete is poured, it displaces the air and water present in the pipe and finally reaches to the bed.

4.2 Pump method

Underwater concreting using pumping technique is a developed version of Tremie pipe and it is quicker method for concreting in areas that is difficult to access such as under piers. Pumping provide several advantages that Tremie pipe is lacking for example, pouring concrete from mixer to formworks directly, solve blockages in the pipe because concreting is through pumping instead of using gravitational force, and risk of segregation is decreased.

4.3 Toggle bags method

Toggle Bags method is useful when small amount of concrete is required. A reusable canvas bag is sealed at the top with chain and secured with toggles is filled with concrete and dropped carefully into the determined location then through opening at the bottom of the bag the concrete is discharged. Used for repair work. It is one of the oldest and simplest techniques of placing concrete underwater. The bags are malleable in nature so that they can be interlocks each other easily. Once the bags are placed. they are spiked together with reinforcement bars of small size.

4.4 Bag work method

Bag work concrete method used for renew ballast or to seal holes temporarily. The bags are produced from considerably strong fabric with capacity of 10 -20 liters and it carried by divers to the selected position. The concrete slump is between 19- 50 mm and 40 mm is the maximum aggregate size that can be used. The installation of the bags is similar to bricks in order to create bonds.

5. CASE STUDIES

5.1 Kolkata underwater tunnel

East West Metro Tunnel is an under-construction underwater river tunnel of Kolkata Metro West Bengal. The river tunnel is constructed underneath Hooghly River. Tunnel length is 10.8 km (6.7 mi) and width is 5.5 metres. A 520m stretch of the tracks will go through a tunnel under the Hooghly River. The roof of the tunnel would be about 30 metres from the ground level. The tunnel will be expected to be completed in march 2022.The tunnel will be the first underwater river tunnel in India. The tunnel is used by East West Metro Line for metro rail service and constructed by Kolkata Metro Rail Corporation.

For tunnelling below the river, the water tightness, waterproofing, and the design of gaskets were the major challenges. Because the tunnel is being constructed for a service of 120 years so it cannot afford any water leakage during service.

Boring the underwater tunnels, which are predominantly composed of soft and stiff clay, has been one of the complex challenges of the project. Two German-made tunnel boring machines (TBMs), named Prerna and Rachna, were deployed for the process. Equipped with earth pressure balancing (EPB) capabilities, the machines are suitable for projects on unstable terrain or under structures that are sensitive to ground disturbances. They can withstand three times more atmospheric pressure during the boring process.

Fig -1: Kolkata underwater tunnel

5.2 Ithaa undersea restaurant

The Ithaa Undersea Restaurant, located in the island nation of Maldives, is a breathtaking acrylic structure located 16 feet below sea level. Constructed almost entirely of transparent acrylic, the restaurant offers its patrons panoramic views of the marine life surrounding the restaurant. The restaurant, which is roughly 500 square feet, was built using the float and lower method. After being assembled in Singapore, Ithaa was transported on a barge, then lowered with the help of sandbags onto steel-driven piles that form its foundation. The estimated life span of the restaurant is 20 years. Once constructed, Ithaa would be winched into the water. Technical challenges, limited resources, and quality control problems in building a structure of 175 tonnes in the Maldives were foreseen. Hence, a decision was made to build Ithaa in Singapore instead.

Fig -2: Ithaa undersea restaurant

5.3 Atlantis hotel

The Atlantis Hotel in Dubai is located on The Palm, a human-made island in the shape of a palm frond. Though most of the structure is above ground, the hotel features several underwater suites 20 feet below sea level. After descending an elevator into the suites, guests are greeted by massive floor-to-ceiling windows with views of sea animals—even from the bed and bathtub. While details are scant about the construction of the underwater suites, above-ground construction involved modular units, which may have been used for the undersea portion as well. Additionally, since the Atlantis Hotel is situated on a human-created island, it is likely that cofferdams were used throughout construction. Instead of concrete slabs, the foundations of The Palm were created from 7 million tons of rock blasted from the nearby Hajar Mountains.

Fig -3: Atlantis hotel

5.4 The transbay tube

The Transbay Tube is an underwater railroad tunnel that spans 3.6 miles, connecting Downtown San Francisco to West Oakland, carrying nearly 30,000 passengers an hour during the morning and evening commutes. Originally built in 1974, the Tube is an astounding feat of undersea construction, particularly due to concerns about earthquakes in California's Bay Area. Consisting of 57 individual components, the Transbay Tube was built off-site, then lowered into place after being towed into the middle of the Bay by barges. Divers worked at a depth of 135 feet below sea level to connect individual pieces that were set on a trench in a precise, seismically-sound path.

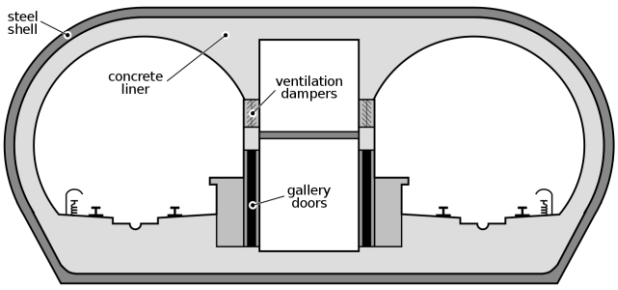

Fig -4: Crosssection of transbay tube

6. CHALLENGES OF CONSTRUCTION

6.1 Budget

Building beneath water is a very costly way because of using heavy machinery, devices and professional employees. Building below water also includes some of welfare and it

desires to large price range. One of the major challenge in Kolkata underwater metro is doubled cost.

6.2 Corrosion and erosion

Undersea projects in coastal environments must take into account the corrosive effects of saltwater. Erosion is the method of weathering and delivery of solids (sediment, soil, rock and different rock particles) in the natural surroundings or their source and deposits them someplace else. It normally takes place because of transport with the resource of wind, water, or ice so engineers ought to pick out appropriate materials for beneath water building.

6.3 Water pressure

Both during construction and over the life of a structure, the effects of water pressure play a pivotal role. Stress performs a large characteristic in persuading the guidelines of the constructing additionally people comes to problems one or the other at some stage in the development system or at some point of the protection procedure.

6.4 Finding suitable material

When building in water, materials must be used that can withstand a variety of complications, including water pressure, corrosion, and erosion. The most common materials used in underwater construction include concrete, steel and acrylic glass.

6.5 Location of fuel

Any coincidence may also be possible when the driller machines and other machinery are trying to find out oil or to any ship also can damage the outlook and structure of the building it's far out of manage.

6.6 The hassle of warmth of the water

The temperature varies reasonably over the surface of water, it is heated from the ground from the below by the usage of daylight hours, but at depth maximum of the water may be very cold.

6.7 Environmental building elements

No doubt that the primary problem that is to be had in our mind at the equal time as talking approximately the development of underwater systems is the problem of aeration. There need to be a supply of renewable air that helps in respiratory, and removing unwanted gases. Permits discover a solution, for the air flow hassle, that changed into implemented at the same time as the development of the underwater Holland tunnel.

7. REMEDIES

By the proper design of underwater structures using experienced engineers and architects can reduce the cost of construction. Construction safety also considered because it also increase the cost of construction. Proper schedule of work is maintained by construction management s it will reduce the cost and time during work.By using materials like concrete and acrylic glass most corrosion due to sea water can be controlled. Erosion is the another challenge due to wind, water, ice etc in water so it can be reduced using breakwaters coverd with geotextiles. It does not make any water pollution also.

To overcome water pressure shape of structure is important. By analysis we can say that spherical shape is most suitable to with stand water pressure. But this sphere shape is often overturned by a combination of other factors. To identify these factors three materials often used for underwater structures; steel, concrete and glass/acrylic glass were analysed. The fabrication processes, construction methods and material properties all influence the design possibilities of each material. While theoretically each material can take any shape, some shapes proved easier to construct and thus are cheaper.

There are many materials used in land construction but as we come underwater construction the material is limited because of pressure, corrosion etc. so we mainly use common materials in underwater construction like steel, concrete and acrylic glass. Location of fuel is out of manage but before starting the work small investigation conducted related to fuel location may be helpful.

Temperature is the another issue in underwater construction. By using the acrylic glass it may be reduced. Environmental elements are considered mainly for safety of before and after construction. Proper ventilations are provided on structures. Supply of air using pump is also important. There are many modern techniques for this aeration.

8. CONCLUSIONS

Underwater construction is a most social relevant and also a intresting topic in this modern world. The main part of this article are literature review and case studies. The conclusions are arrived from this. After studying literatures related to underwater construction we can understand the underwater construction is a complicated and costly work. The caissons and cofferdams are the techniques used for the construction of underwater structures. Caissons are hollow inside and usually constructed at site and sunk in place into a hard bearing stratum. A cofferdam, also called a coffer is an enclosure built within, or in pairs across, a body of water to allow the enclosed area to be pumped out.

There are several methods to carry out underwater concreting such as termie method, pumping methods, toggle bag method and bag work method. 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 high-quality 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. There are many challenges that affect the underwater construction. Its remedies are also explained in this article.

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