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Analysis and Design of Marine Structures in LTTD Plant at ANDROTH Island of UT Lakshadweep

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Abstract

LTTD Technology is a proven, environmentally friendly desalination plant. LTTD is a desalination technique that takes advantage of the fact that at low pressures water evaporates at lower temperatures, even at the low ambient temperature. The system uses vacuum pumps to create a low pressure, the low-temperature atmosphere in which water evaporates between two volumes of water, even at a temperature gradient of 8 ° C. Cooling water is supplied up to 600 meters (2000 ft) from deep sea depths. To condense the evaporated water vapour, this cold water is pumped into coils. The condensate arising from this is purified water.

Setting up of LTTD project in UT Lakshadweep involves significant challenges. The islands are characterized by coral reef and low availability of heavy machinery and skilled men. The islands people are suffering with low availability of fresh water so the LTTD is the desalination plant which can provide fresh water which does not require pre and post-treatment of seawater.

Keywords: *LTTD, Post-treatment, Desalination.*

1.Introduction

NIOT developed LTTD Technology for conversion of sea water into fresh water. This technology is simple and it works with the principle of thermal gradient available in ocean. Three such LTTD plants were installed at Kavaratti in 2005, Minicoy in 2011, Agatti in2011 and are functioning continuously till date. Subsequently, UT administration requested NIOT to establish similar plants in six more islands.

On behalf of Union Territory of Lakshadweep, NIOT awarded a contract to HITECH CIVIL ENGINEERS PRIVATE LIMITED.,PORT BLAIR for 'Setting up of low temperature thermal desalination plant with components of process plant, submarine HDPE pipe and marine structures in Androth Island of UT Lakshadweep with the capacity of 150m3/day'. This report provides the design basis of marine structures for implementation of project.

2. Literature review

R. Venkatesan has written a paper on the comparison of the seawater desalination cycle between LTTD and RO: an integrated fiscal, financial, and environmental system. This study primarily carries out the technical analysis of the Low Temperature Thermal Desalination (LTTD) method established by Chennai NIOT, which has a technology development mandate**.** The primary desalination technologies can be categorized into thermal and membrane desalination techniques that contribute to the separation mechanism. Thermal desalination removes salt from water by evaporation and condensation, where semi-permeable membranes and forces such as pressure to isolate salt are used as membrane processes.

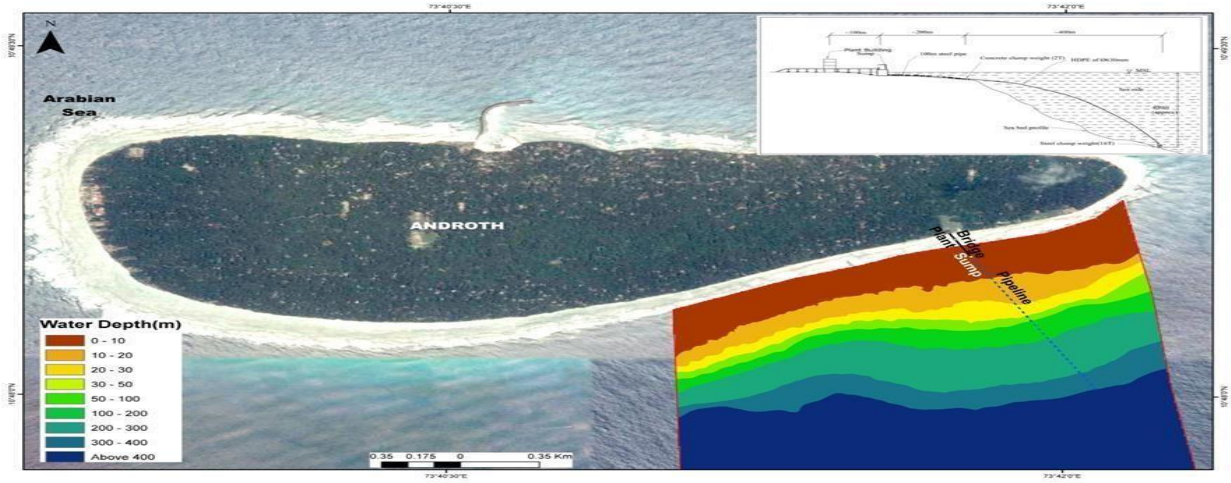
3. Working - LTTD

Operating with this LTTD technology involves evaporating warm surface seawater (about 28oC) in a vacuum-preserved Flash Chamber (about 27 mbar) and thereby liquefying the resulting vapor in a condenser. The condenser's coolant water is drawn using the thermal gradient available in the ocean, namely by using the ocean water temperature control feature with a rise in depth. A long pipe is installed in the ocean from a distance of about 1000 m from a depth of about 350-400 m to draw the cold water (at about 12oC).

4. Project location

Androth Island is located about 300 km from Kochi and it extends between 11°28' to 11° 29.9' N and 72° 59.8' to 73° 0.7' E. The island is about 4.7 km long with an area of 5 sq Km with and a maximum breadth of

1.4 Km. A harbour is located on the east side of Androth Island. The sea bed is uneven and trenches of about 60m are present in most of the area. The proposed desalination plant is located on the South east side of island and its location is shown in Figure1.



5. General configuration

The LTTD plant consists of 3 parts of Civil/Marine structures. They are Plant building, Sump and Bridge.

6. Design philosophies

A philosophy of design is a set of assumptions and procedures that are used to fulfill the structure's conditions of serviceability, sustainability, efficiency and functionality. The theory of design used for constructing RCC systems is described below;

Limit state method (IS 456: 2000 & IS 4651 part 4 -2014)
Limit states are the appropriate limits for the structure's stability and serviceability specifications before failure occurs. Therefore, the design of structures by this approach should ensure that they do not exceed limit states and do not become inappropriate for the use they are intended for.
There are two main limit states:

(i) limit state of collapse and
(ii) limit state of serviceability

7. Design and Analysis

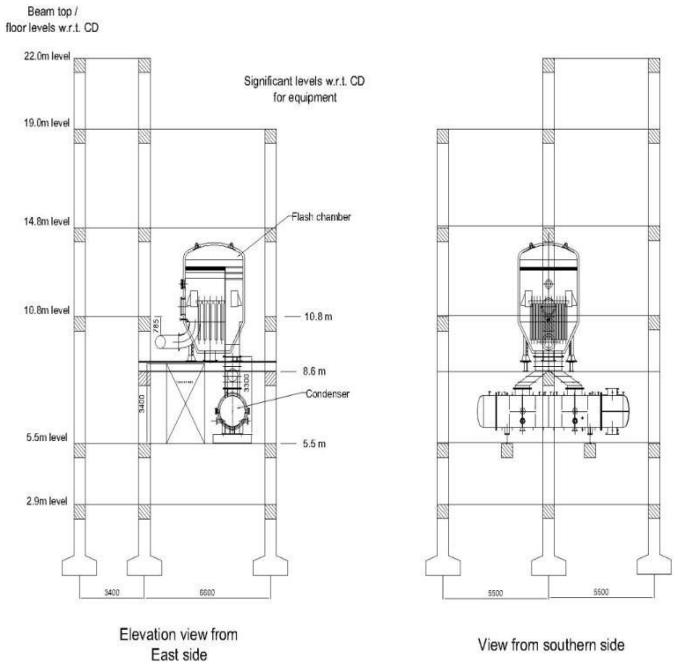
In these paper we are design the 3 parts of marine structures in LTTD plant. The design and analysis of the civil/marine structures are made in STAAD pro. The interface confederate is simple and the analytical values of RC systems are great and we get economical Etabs steel data compared to STAAD pro data. STAAD pro is useful for examining RC structure frames over Etabs, as the codes are better integrated into STAAD pro.

Plant building:

They are total 6 levels in plant building. Each and every level has its purpose. The total height of building is 22m.

Floor Levels and their Purpose

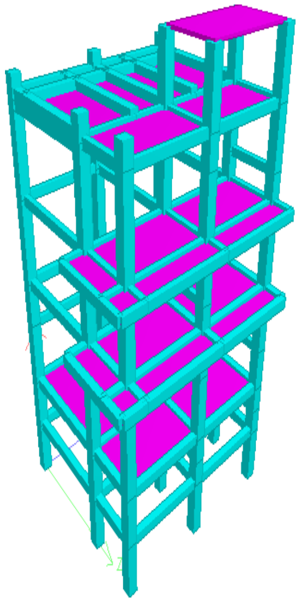
No	Levels	Total Height of Floor (m)	Purpose
1	+2.9m	2.9	Base level Floor
2	+5.5m	2.6	Condenser level
3	8m	5.2	Flash chamber
4	+10.8m	-	Control panels
5	+14.8m	3.8	Extra rooms
6	+19.0m	4.2	Supporting Instruments
7	22.0m	3	Head room



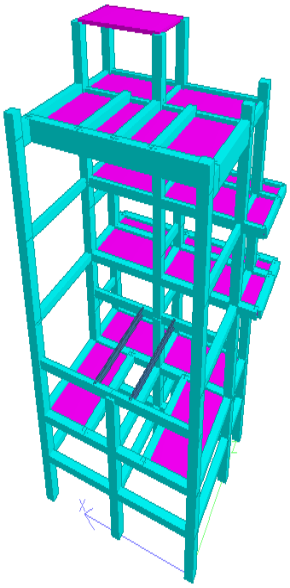
Elevation view from East side

View from southern side

Elevation of Plant Building



Before Installation



Post Installation

Statements of the plant :

1 Characteristic Compressive strength of concrete = 40 N/mm^2
2 Steel (Grade) = 500 N/mm^2
3 Unit Weight of Plain cement concrete = 24 kN/m^3
4 Unit Weight of Reinforced cement concrete = 25 kN/m^3
5 Unit weight of Sea water = 1.025 kN/m^3
6 Acceleration due to gravity = 9.81 m/s^2
7 Total height of plant building = 22 M
8 Width of plant building in X direction = 13 M
9 Width of plant building in Z direction = 10 M
10 Total plan area of building = 130 m^2
11 Characteristic strength of steel for steel beams = 250 N/mm^2
12 Unconfined Compressive strength,qu = 500 kN/m^2
13 Cohesion = qu/2
= 250 kN/m^2

Loads :

The concrete reinforced structures are designed to withstand the following loading modes

Dead load

The Dead Loads are the structural loads self-weight such as beams, columns, slabs, walls, paints, plastering, etc. All the wall loads are given as uniformly distributed load over concerned beams. The dead load distribution is shown in fig 2.

Live load

These are loads of nature that are shifting or dynamic and does or doesn't present on structure through planned structural use. With different types of structures, live loads are common, and vary with occupancy level. Live loads to be considered for configuration are obtained from Part-2 of IS875. It is referred to as 'LL' in this report. The details of Live Load on Plant Building are detailed below. The live load distribution is shown in fig 3.

Areas with plant equipment	5	KN/m^2	Refer IS 875 part 2
On floors and corridors	3	KN/m^2	

Equipment Load

It is the load from machinery / equipment on the structure which is a permanent part of structure. In the current civil structures, plant building houses for heavy mechanical equipment's such as flash chamber, condenser, vacuum system, control panels at required levels. It is referred to as 'LL' in this report. The weight of each equipment's are as follows: The distribution is shown in fig 4.

Empty Weight			
1	Flash chamber	10	MT
2	Condenser	11	MT
3	Vacuum system	2	MT
4	Control panel	5	MT

Operational Weight			
1	Flash chamber	21.5	MT
2	Condenser	16.5	MT
Flooded Weight			
1	Flash chamber	42	MT
2	Condenser	24	MT

Wind Load

Wind impacts are horizontal loads applied to the wind-facing side of the structure surface area. The wind loads are considered along the four directions with suction and pressure inside rooms as per IS 875 Part 3. The details of is shown in fig 5.

Earth Quake / Seismic Load:

During an earthquake the seismic loads on the structure result from inertia forces produced by ground accelerations. The magnitude of these loads is a function of the many variables that include building mass, seismic zone, building dynamic properties, soil-structure interaction, strength, length and frequency content of the ground motion. In current plant building is subjected to earthquake load calculated as per IS 1893 (part 1) 2016. The seismic load details is shown in fig 6.

Seismic zone = III Refer IS 1893 (part 1) 2016
Zone factor, Z = 0.16
Importance factor, I = 1.5
Response reduction factor = 3 (OMRF)

Horizontal Seismic Coefficient, Ah = ((Z*I)/(2*R)) * (Sa/g)

Spectral acceleration coefficient, Sa/g = 1 response spectra graph from IS 1893-1 (2002)

Ah = 0.04

Wave Load:

The Plant building columns are located in intertidal and breaker zones. Wave loads are critical in such an environment where breaking of waves is highly likely. Hence they are designed for breaking wave loads. For finding breaking wave loads on Columns, the formula provided in ASCE standard “Minimum design loads for buildings and other structures”, The details of Wave Load on Bridge priers at various Locations is given in Table.

Tide	=	1.6	m
Seabed level wrt CD	=	-0.5	M
Highest water level or DWL (m)	=	2.1	M
Diameter (D)of column	=	0.7	M
Breaking wave height Hb	=	0.78 x DWL	
	=	1.638	M
Wave force	=	0.5 ρ g Cd D Hb^2	KN
	=	16.52	KN

Load Combination:

Load combinations are assigned as per IS 456 – 2000 and IS 4651 (Part 4) 2014 is adapted for concrete structures in plant building

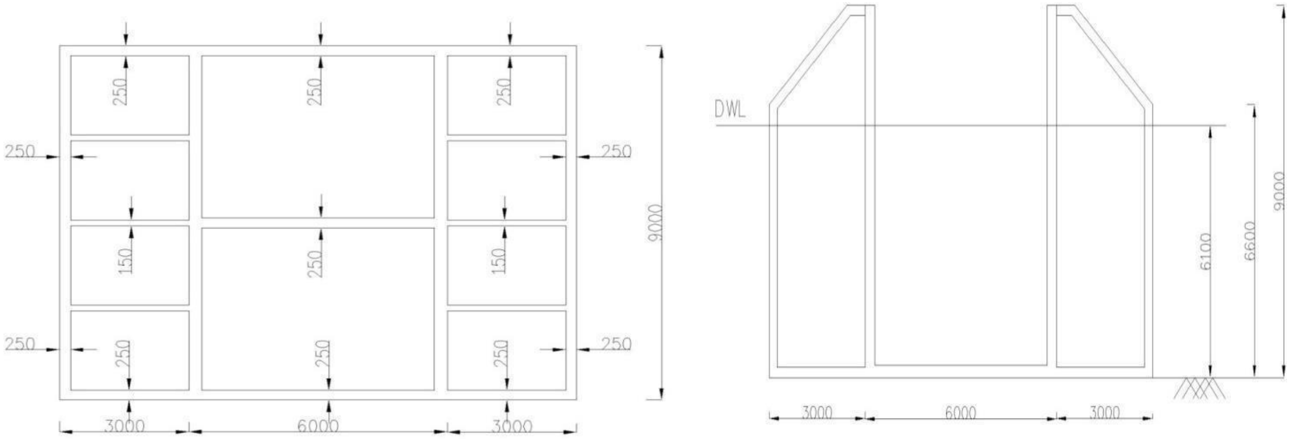
Sump :

The sump is located at 4.5 m water depth with respect to charted datum and consists of two chambers; one for warm surface water being drawn directly from sea through an inlet and pumped to the plant; other for deep sea cold water drawn from 400m depth into cold water portion of sump and pumped to the plant. The sump also consists of pumps for pumping water to plant building. In order to achieve an additional water plane area during towing and also to increase the dead weight for in place stability after installation, a wing portion is provided around the main sump filled with sand.

Dimensions of Sump Elements

Overall Configuration				
S.No	Description		Value	Units
1	Length of Inner Sump	=	6	m
2	Length of Land Side Wing Wall	=	3	m
3	Length of Sea Side Wing Wall	=	3	m
4	Width of Sump	=	9	m
5	Height of Wing Wall	=	6.6	m
6	Total Height of Sump	=	9.1	m
7	Angle of Inclination of Wall	=	45	Deg

Thickness of Elements				
1	Main Base	=	0.3	m
2	Wing base	=	0.25	m
3	Centre Main Wall	=	0.25	m
4	Centre Intermediate wall	=	0.25	m
5	Wing Main wall	=	0.25	m
6	Wing Partition wall	=	0.15	m
7	Clear cover for all walls	=	75	mm



Plan and Elevation of Sump

7.2.2 Loads

Dead load

Dead loads are static or stationary loads which are moved over structure until the end of life span. Dead loads are the structural members self-weight loads such as beams, columns, slabs, walls, wrapping, plastering, etc. The dead load or the self-weight of this structural elements is calculated by using unit weight of materials as per design basis report.

Hydrostatic Force:

The water store in cold water and warm water chambers causes down ward force on base slab and lateral hydrostatic force on walls.The maximum water level inside the sump is considered as design water line. In addition to this the hydrostatic forces will be acting on outer wall of sump due to static sea level. An static uplift force also acts on the base of the sump. The Forces applied in STAAD model.

Design water height	=	6.1	M
Lateral force at bottom of wall due to water inside sump	=	62.525	kPa
Weight of water downwards	=	62.525	kPa

Earth Pressure:

The soil used for increasing stability of sump in wing wall causes down ward force on base slab and lateral earth pressure on walls.. The detail calculations are given below:

Height of soil infill on main sump wall	=	9	M
Height of soil infill on outer wing wall	=	6.1	M
Height of soil infill on wing side wall	=	7.55	M
Angle of internal friction	=	30	Degrees
Coefficient of active earth pressure, ka	=	0.33	
Lateral force due to soil on main sump wall	=	54	kPa
Lateral force due to soil on outer wing wall	=	36.6	kPa
Lateral force due to soil on wing side wall	=	45.3	kPa
Weight of soil downwards	=	135.9	kPa

Extreme Wave Loads

The wave pressures due to extreme events are estimated using Goda's method. The detail method for estimation are given in In-place stability sub-section..

Load Combination

Load Combinations are given as per Table-1 of IS 4651-2009. For this analysis of sump Normal, Extreme and Reversal cases are considered.

Bridge

Bridge connects sump from offshore to plant building in intertidal zone and then to shore. The purpose of the bridge is to support the two HDPE pipelines which carry the warm and cold water from the sump to the plant and to provide access for the installation, operation and maintenance of the submersible pumps at sump.

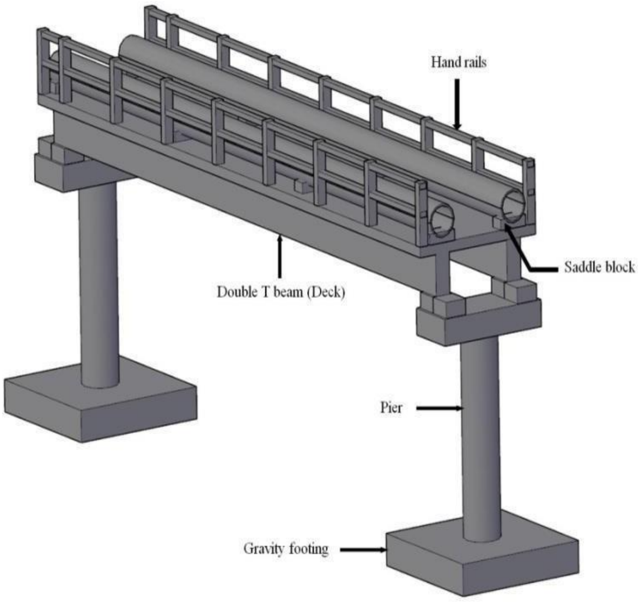
The bridge consists of two segments,

1) Intertidal Zone (from shore to wave breaking area)

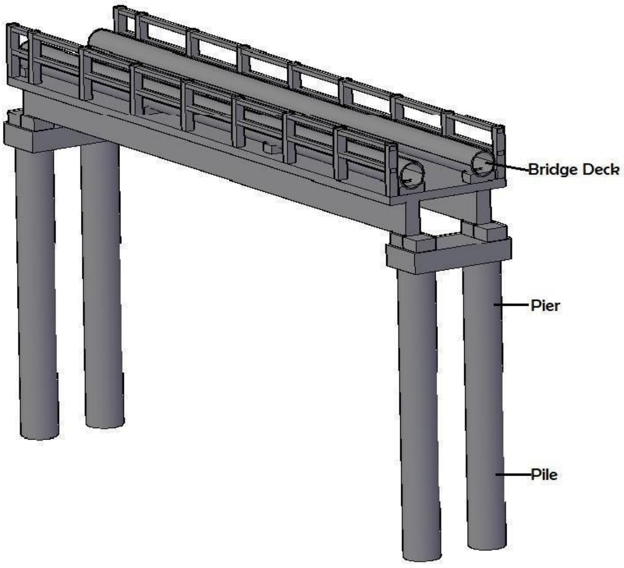
2) Breaker Zone and beyond breaker zone (beyond wave breaking area till sump).

Dimensions of Bridge Elements

S.No	Description		Value
1	Span of Bridge	=	15 m
2	Width of Bridge Deck Slab	=	3 m
3	Thickness of Bridge Deck Slab	=	0.2 m
4	Size of Beams supporting Bridge Deck	=	0.4 x 1m
5	Size of Pedestals to support Bridge Deck	=	0.5 x 0.5 m
6	Diameter of Bridge Pier in Intertidal Zone	=	0.8 m
7	Size of Square Footing in Intertidal Zone	=	3 m
8	Diameter of Bridge Pier in Breaking Zone	=	1.2 m
9	Size of Square Footing in Breaking Zone	=	4 m



Bridge and it's components in Intertidal zone



Bridge and it's components in breaker zone

Loads :

Dead Load :

The total dead load on the bridge can be calculated as,

<u>Double T Beam Deck</u>

Span of beam = 15M

Width of slab = 3M

Depth of slab = 0.2M

Beam Width = 0.4M

Overall depth of beam = 1.2M

Overhanging length of slab	=	0.4 M
Thickness of Floor finishes	=	0.075 M
Dead Load due to double T beam deck	=	39.125 kN/m

Live Load:

Live loads are to be checked out for design purpose which are taken from IS875 Part-2. In current structures live loads of 3 KN/m^2 were considered.

Live load (3 kN/m2)	=	9	kN/m
Live load on each beam supporting deck slab	=	4.50	kN/m
Factored Live load on each beam (1.5)	=	6.75	kN/m
Total Live Load acting on Pier from one bridge span	=	67.50	kN

Wind load:

The wind loads are considered along the bridge and across the bridge as per IS 875 Part 3.

Wind speed	Vb	39	m/s
Risk coefficient factor	k1	1.06	
Terrain category	1		
Class	A		
Factor	k2	1.08	
Topography factor	k3	1	
Cyclone importance factor	k4	1.15	
Design wind speed	Vz	Vb * k1 * k2 * k3 * k4	
		51.34	m/s
Design wind pressure	Pz	$0.6 * Vz^2$	
		1.58	kN/m2

Wind force on deck along X	3.16	kN	Acting at the top of pier
Wind force on deck along Z	22.78	kN	Acting at the top of pier
Wind force on pier P6 & P7 along X & Z	1.90	kN/m	Acting at the top of pier
Wind force on pier P1 to P5 along X & Z	1.27	kN/m	Acting at the top of pier

Wave Load:

The bridge piers are located in intertidal and breaker zones. Wave loads are critical in such an environment where breaking of waves is highly likely. The piers of the bridge and the sump will be designed for breaking wave loads. For finding breaking wave loads on piers, the formula provided in ASCE standard "Minimum design loads for buildings and other structures", clause 5.4.4.1 – Breaking Wave Loads on Vertical Pilings and Columns are used as detailed. details of Wave Load on Bridge priers at various Locations is given in below Table .

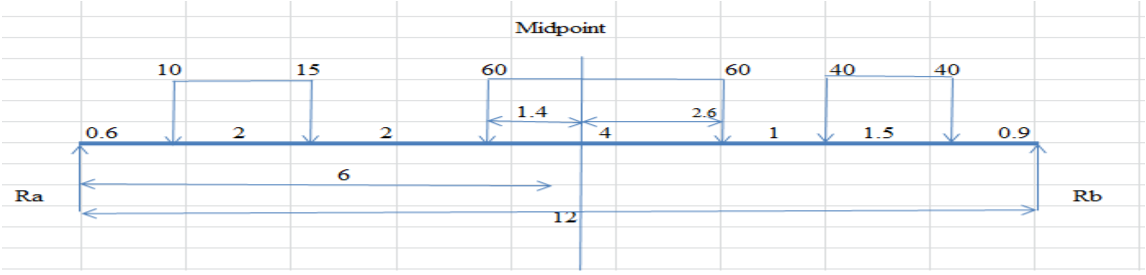
Wave Loads on Piers and Pier Lengths

Marking	Seabed level wrt CD (m)	Highest water level or DWL (m)	Diameter (D) in m	Breaking wave height Hb(m) = 0.78 x DWL	Wave force (kN) = $0.5\ \rho\ g\ C_d\ DH_b^2$	Provided Deck top level in (m)	Critical Length of pier/pile (m)
Intertidal Zone	-0.5	2.1	0.8	1.638	18.89	6	5.00
Breaker Zone	-5	6.6	1	5.148	233.17	8.02	11.52

Vehicular Load

The condenser has to be transferred from shore to the plant building through bridge which is located in the intertidal zone. The condenser is supported on a frame with two axels spaced at 4m apart. This setup which weighs about 12 tons is pulled using a tractor and guided by a Fork Lift behind the condenser. This setup is placed on deck such that the midpoint of the line joining center of gravity of all loads and largest load is at the center of deck to get maximum force.

Loading on bridge deck during installation of Condenser.



<u>Vehicle loads</u>

Resultant Load	=	225.0	kN
Ra	=	86.3	kN
Rb	=	138.8	kN
Maximum Moment	=	328.5	kNm
Impact factor for sudden application of breaks	=	4.5/(6+L)	
	=	0.25	
Moment due to impact	=	82.1	kNm
Shear due to impact	=	34.7	kN
Total Moment	=	410.6	kNm
Total shear force	=	173.4	kN
Factored moment due to vehicle loads	=	615.9	kNm
Factored Shear due to vehicle loads	=	260.2	kN

8. Load Combinations:

Load combinations as per IS 4651 (Part 4) 2014 is adapted for components of Bridge.

9. Conclusion:

- LTTD plant has also many benefits, like aqua culture if it used in the circumstances of the ocean thermal gradient and depletion of thermal pollution if it used in the circumstances of power plant exude.
- While coming to the cost of the LTTD plant it would depend on the technology used and may vary from place to place, the technology used in this plant provides water at just 61paise per litre for island based plant.
- The technology used is environment friendly completely indigenous with low operational and maintenance issues and with long term sustainability.
- The design marine construction was prepared considering site-specific conditions of respective islands.
- These type of plants, is useful in the pacific islands and found to be the best technology for remote islands, as there is no maintenance.

References

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