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ANALYSIS AND DESIGN OF JACKWELL STRUCTURE

[1]Vaishnavi S. Sarode,[2]Prof. Ms. A. A. Yadav,[3]Er. Minal V. Dehadrai,[4]Alpesh A. Adekar

[1]M.Tech. student Department of Civil Eng. Yeshwantrao Chavan College of Engineering Nagpur Maharashtra India,[2]Asst. Professor Department of Civil Eng. Yeshwantrao Chavan College of Engineering Nagpur *Maharashtra India,[3]Director of Aquades Structural consultants (P) Ltd. Nagpur Maharashtra India,[4]Lecturer, Civil Engineering Department, Shri. Datta Meghe Polytechnic, Nagpur, Maharashtra India*

[1] *Department of Civil Enginerring,*

[1] *Yeshwantrao Chav*an College of Engineering Nagpur, India

Abstract: Intake structure's are used for collecting water from the sources like river, lake, and reservoir and transfer it further to the water treatment plant. The paper highlights the work administered on construction of Jackwell with Overhead Pump House. The main reason for that is rising in demand for water and poor distribution of water. The Paper includes the provision of Design of a water treatment scheme for the area in order to supply the treated water to the houses. Jackwell and Pump House has been analyzed by using STAAD PRO vi8 software under seismic condition.

Index Terms **- Analysis and Design of Jackwell Structure, Pump House, Intake Well, Staad Pro Vi8, Seismic Condition.**

I. INTRODUCTION

Intake structures are hydraulic structures used for collecting water from the sources like river, lake and reservoir and transfer it further to the water treatment plant. Intake structures are masonary or concrete structures and it provides relatively clean water, free from pollution, sand and objectionable floating material. There are two kinds of intake structure a) Wet intake structure b) Dry intake structure. Jackwell Structure or Intake Structure is underwater structure, proper design is essential. Re-construction of the structure become un-economical.

1.1Wet Intake Structure:

It is a type of intake tower within which the water level is practically similar to the level of the sources of supply. It is known as Jackwell and is most commonly used. Jackwell structures are used for accumulating water from the surface sources like a river, lake, and reservoir. It is then further transferred to the water treatment plant. These Jackwell Designs and Constructions are masonry or concrete structures. It provides clean water.

1.2Dry Intake Structure:

In case of dry intake, there is no water within the reservoir. Water enters through the entry port directly into the transferring pipes. It's simply used for the operation of valves etc.

Intakes are hydraulic structures used to extract water from the surface sources like rivers, man-made reservoirs or lakes. Intake structures on channels are intended to divert a particular amount of water from the channel for diverse purposes of use like irrigation, industrial plant cooling, potable water supply and hydroelectric power. It must be possible for both the diverted water and therefore the remaining supply to be evacuated without damage being caused to the environment or the Intake system.

In this present study, jackwell and pump house for Jhagarpur and adjoining villages (Mining Affected) under Rajgangpur, Dist-Sundargarh, Odisha is considered. Jackwell having a height of 13.2 m with concrete masonary of 300 mm thick and height of pump house is 6.5 m with brick masonary of 230 mm thick. Roof slab of 150 mm is proposed to accommodate two pumps and gantry. Load of each pump is 25 kN and load of gantry 81.25 kN (with 25 % of impact). And is analyzed in standard software Staad pro Vi8 using various conditions.

Objective of Study:

The objectives of this project study are often shortening as follows:

- To study the various forces acting on Jackwell Structure.
- To study Traditional analysis of the Jackwell Structure.
- 3D analysis of Jackwell Structure by using standard software Staad Pro Vi8
- Design of Jackwell Structure.
- To Study Criteria for Earthquake Resistant Design of Structures. (Liquid Retaining Tanks –Part 2) IS 1893 -2014 (Part- 2).
- To study the Data for Analysis & Design of Circular Shell Structures: I using Arya's Paper.

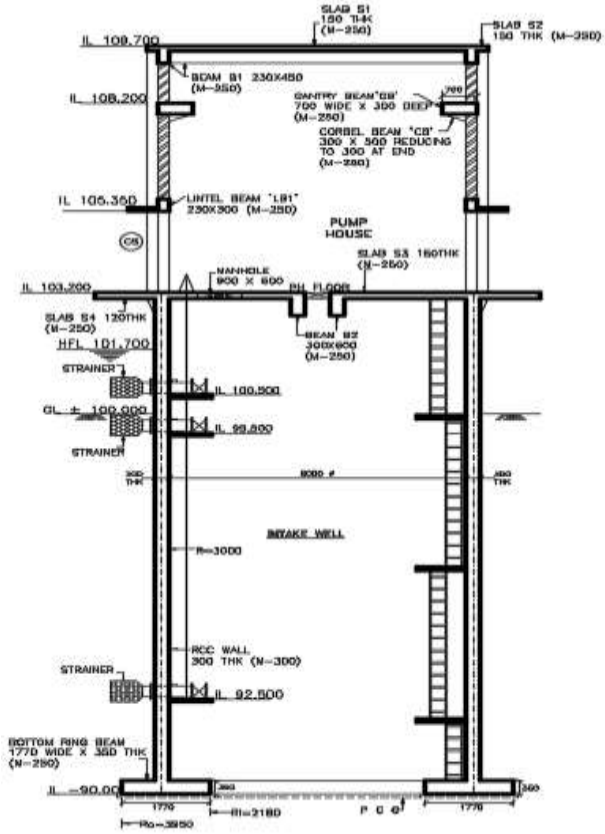


Figure 1: Detailing of Jackwell & Pump House

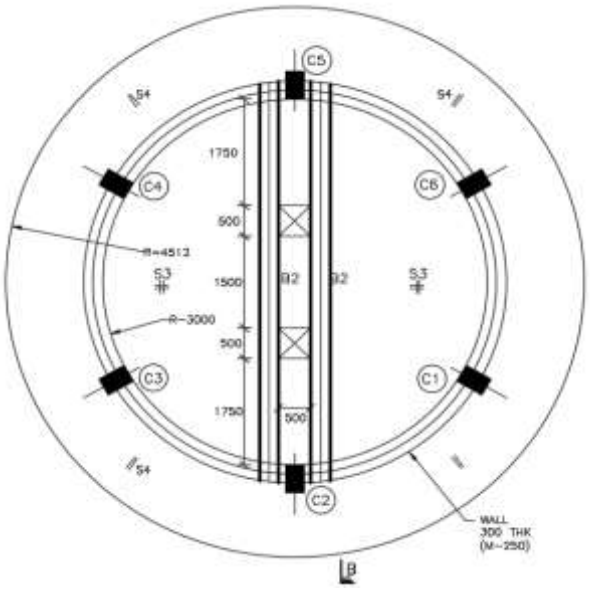


Figure 2: Plan at Pump House Floor Level

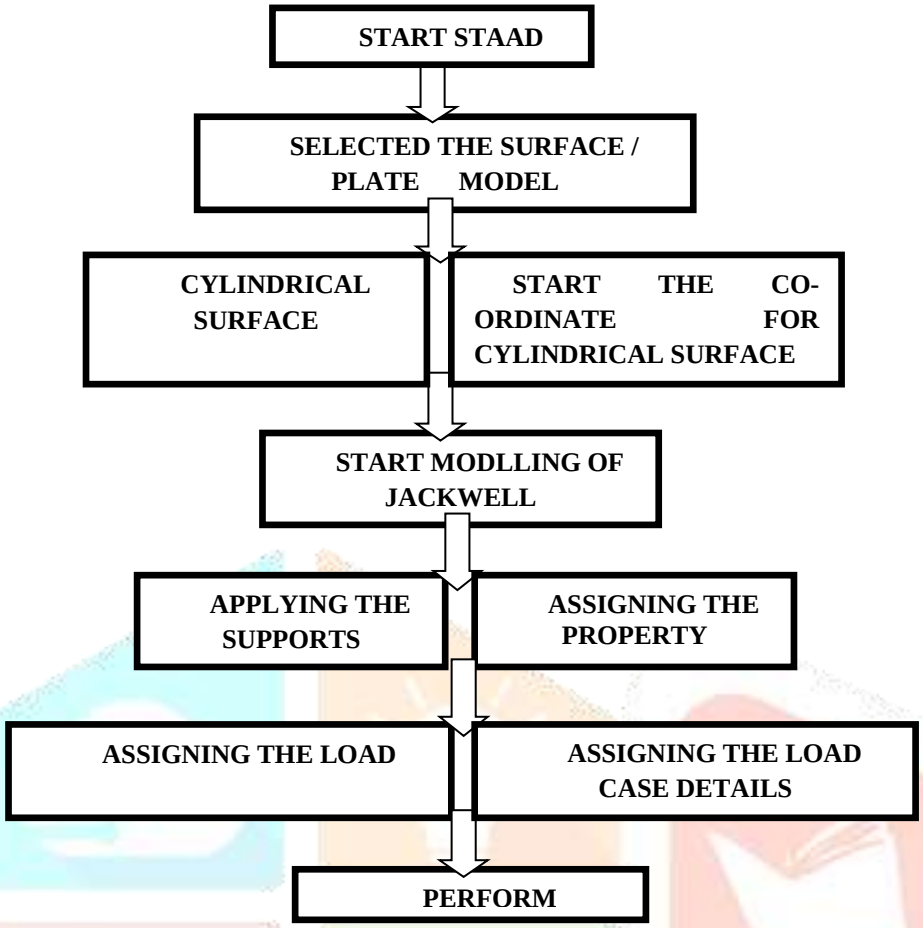
II. METHODOLOGY

Generally working stress method (WSM) is employed for hydraulic design. For designing of Jackwell structure and pump house working stress method is used.

In working stress method design is based on elastic theory. Under the design loads material concrete and steel are assumed to be stressed below their elastic limits. Working stresses (permissible stresses) for the materials are determined by dividing the ultimate or yield stress by a suitable factor of safety values.

Various types of loads are acted on Jackwell Structure which includes Water pressure, Earth pressure, Surcharge and Saturated soil pressure.

Flowchart showing procedure of modeling of Jackwell:



III. STRUCTURAL COMPONENTS

Scheme aspects of structural design are as follows:

- Floor Beams and Floor Slab
- Roof Beams and Roof Slab
- Deign of column, Gantry and Lintel Beams
- Circular beams at lintel level and Roof level

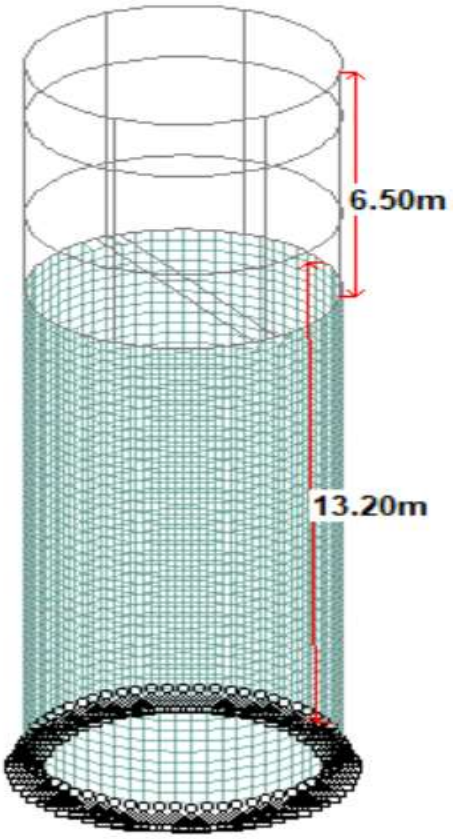


Figure 3: Jackwell & Pump House Model

IV. DESIGN CONSIDERATIONS

Table 4.1: Preliminary Data considered for the Analysis:

Sr. No	Parameters	Data	Sr. No	Parameters	Data
1.	Jackwell	6 m Dia	13.	Roof Beam	230 x 450 mm
2.	Jackwell	13.2 m Ht	14.	Gantry Beam	700 x 300 mm
3.	Wall	300 mm thick	15.	Corbel Beam	300 x 500/300 mm
4.	Pump House	6 m Dia	16.	Lintel Beam	230 x 300 mm
5.	Pump House	6.5 m Ht	17.	Floor Beam	300 x 600 mm
6.	Bottom IL	90.0	18.	Column	300 x 450 mm
7.	Bed Level	92.88/100	19.	Roof Slab	150 mm thick
8.	HFL/FSL	101.70	20.	Cant. Roof Slab	150 mm thick
9.	Roof slab level	109.7	21.	Floor Slab	150 mm thick
10.	Floor Level	103.2	22.	Cant. Floor Slab	120 mm thick
11.	SBC	30 t/m^2	23.	Steel	Fe 415
12.	Seismic Zone	III	24.	Concrete	M 25

Loading Consideration:

Jackwell structure subjected to many types of loads like water pressure, earth pressure, surcharge, saturated soil pressure. These loads are classified as dead load and live load. The two primary design load combinations tank full condition and tank empty condition are considered.

- In tank full condition combination generally water pressure is considered and
- In tank empty condition combination generally earth pressure, surcharge and saturated soil pressure are considered.

V. PREPARATION FOR ANALYSIS AND DESIGN CALCULATION

Table 5.1: Calculation for Pump House:

1.	Roof Slab S1	Level = 109.7	150 mm thick d = 120 mm	M 25	Fe 415
	DL = 3.75 kN/m^2	LL = 0.75 kN/m^2	FF = 1 kN/m^2	Total = 5.5 kN/m^2	
	BM = 6.67 kNm	A = 268.51 mm^2	Spacing = 175 mm	Provide 8 tor @ 175 c/c in square mesh all bras to be brought back upto L/4. Provide near support 2 x 10 tor at top & bottom hoop bars.	
2.	Slab S2 (cantilever = 220 mm)	Level = 190.7	150 mm thick d = 120 mm	M 25	Fe 415
			Spacing = 175 mm	Provide at top & bottom 8 tor @ 175 c/c straight bars by continuing steel of slab S1. Provide 2 x 10 tor at top & bottom as distribution steel.	
3.	Roof Beam B1	Level = 109.7	230 x 450 mm d = 410 mm	M 25	Fe 415
	Slab = 10.51 kN/m	Self wt = 1.73 kN/m	Total = 12.24 kN/m	$WR^2(2a)$ = 124.35 kNm	
	-Ve BM = 11.07 kNm	+ Ve BM = 5.60 kNm	Twisting moment = 1.12 kNm		
	SF at Support = 19.96 kN	SF at contraflexure = 11.49 kN	Torsional SF = 19.28 kN	A = 130.41 mm^2	
				Provide 3 x 12 tor straight at top & bottom.	
				Stirrups: Support to 900, 8 tor @ 100 mm c/c. 900 to centre 8 tor @ 150 mm c/c.	
	τ_v = 0.211 N/mm^2	Pt % = 0.359	τ_c = 0.264 N/mm^2	OK	
4.	Gantry Level (curved span = 3.246 m)	Level = 108.20	700 x 300 mm d = 260 mm	M 25	Fe 415
	Lifted wt = 50 kN	Wt. of gantry = 15 kN	Total = 65 kN	With 25 % impact = 81.25 kN	
	Nearest dist from wall = 1 m	Dist between wheel = 1.5 m	Max reaction = 61.45 kN	Load on 1 wheel = 30.75 kNm	
	Max SF = 47.29 kN	SF = 23.36 kN	Total SF = 70.65 kN	Self wt = 5.25 kN/m	
	Brick wall = 8.91 kN/m	BM = 32.25 kNm	A = 590.43 mm^2	Provide 8 x 12 tor straight at top & bottom.	
	τ_v = 0.285 N/mm^2	Pt % = 0.497	τ_c = 0.310 N/mm^2	OK	
	Net SF = 14.23 kN			Stirrups : 8 tor @ 120 mm c/c.	
5.	Corbel Beam	Level = 108.20	300 x 500 mm d = 460 mm	Reducing to 300 mm at end	
	Cantilever span = 0.5 m	Load at 0.4 m	Max Load = 30.75 kN conc at end	UDL =46.72 kN	

	SF = 77.47 kN	BM = 23.98 kNm	A = 251.83 mm^2	Provide 3 x 16 tor straight at top & bottom.	
	τ_v = 0.561N/mm^2	Pt % = 0.437	τ_c = 0.3026 N/mm^2		
	Net SF = 35.711 kN			Provide 2 L 8 tor @ 100 mm c/c str.	
				Provide 1 x 12 tor horizontal link.	
6.	Lintel Level	Level = 105.34	230 x 300 mm d = 260 mm	M 25	Fe 415
	Circular beam on 6 column R = 3.115 m				
	Brick Load = 14.67 kN/m	Self wt = 1.73 kN/m	Chajja = 1.95 kN/m	Total = 18.35 kN/m	
	$WR^2(2a)$ = 186.37 kNm	-Ve BM = 16.59 kNm	+ Ve BM = 8.39 kNm	Twisting moment = 1.68 kNm	
	SF = 29.92 kN	A = 308.435 mm^2		Provide 4 x 12 tor straight at top & bottom.	
				Stirrups: Support to 600, 8 tor @ 100 mm c/c. 600 to centre, 8 tor @ 150 mm c/c.	
7.	Floor Slab S3	Level = 103.30	150 mm thick d = 120 mm	M 25	Fe 415
	DL = 3.75 kN/m^2	LL = 10 kN/m^2	FF = 0.50 kN/m^2	Total = 14.25 kN/m^2	
	BM = 7.13 kN.m	A = 346.97 mm^2	Spacing = 200 mm	Provide at top & bottom 10 tor @ 200 mm c/c bothways in square mesh.	
8.	Slab S4 (cantilever span = 1.2 m)	Level = 103.30	120 mm thick d = 90 mm	M 25	Fe 415
	DL = 3 kN/m^2	LL = 3 kN/m^2	FF = 0.50 kN/m^2	Total = 6.5 kN/m^2	
	BM = 4.68 kN.m	A = 251.20 mm^2	Spacing = 200 mm	Provide at top 10 tor @ 200 mm c/c radial bars every 4^{th} rod chimta. Dist: 8 tor @ 200 mm c/c str.	
9.	Floor Beam	Level = 103.30	300 x 600 mm d = 555 mm	Span = 6.3 m	
	Slab = 53.86 kN (Triangular load)	Load of Pump = 40 kN	Conc load of each Pump = 25 kN	Self wt = 4.5 kN/m	
	SF = 66.42 kN	BM due to pumps = 34.378 kNm	BM = 44.25 kNm	Total BM = 78.628 kNm	
	A = 836.02 mm^2			Provide 4 x 20 tor straight at top & bottom.	
	τ_v = 0.402 N/mm^2	Pt % = 0.761	τ_c = 0.361 N/mm^2		
	Net SF = 6.855 kN			Stirrups: Support to 1200, 8 tor @ 150 mm c/c. 1200 to center, 8 tor @ 200 mm c/c.	

Table 5.2: Design of Column:

1.	C1 to C6	300 x 450 mm	Starting IL = 521.0	Last IL = 527.5	M 25
	Axial Load = 177.23 kN	L/d = 13.44 > 12, Long Column	Design Load = 182.71 kN	A = 281.95 mm^2	Provide 8 x 12 tor main bars. 8 tor @ 150 c/c.
	Ash = 0.49 S				Hence 8 tor links @ 50.3/0.49 = 100 mm c/c near joint for height of 6500-450/6 =1008 mm.

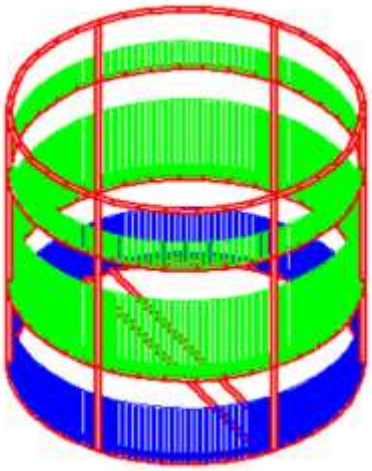


Figure 4: Brick load on Pump House

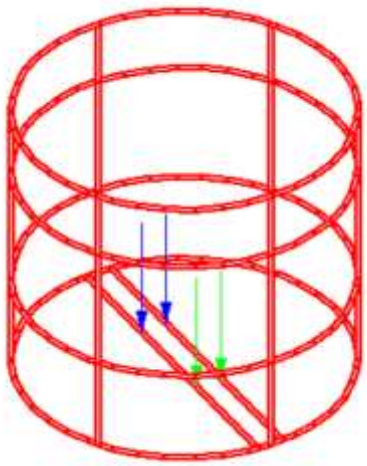
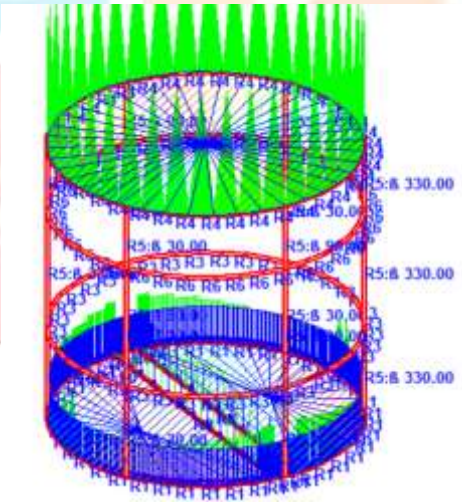


Figure 5: Pump load on Pump House



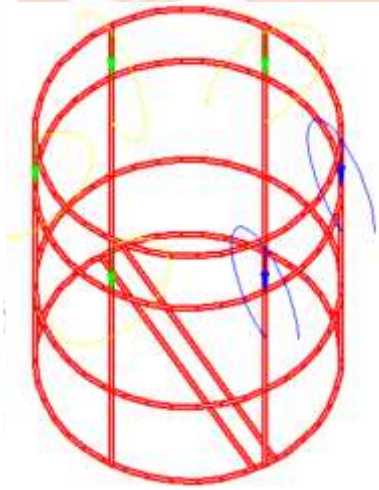


Figure 6: Slab load on Pump House Figure 7: SF and BM on gantry beam of Pump House

VI. RESULTS:

Design of Jackwell:

- Wall thickness = 300 mm
- Grade of Concrete = M 25
- Grade of Steel = Fe 415
- Top Level = 103.20
- Bottom Level = 90.00
- Bed Level = 92.88/100.00
- MWL = 101.70
- Cover = 50 mm

- It is designed for water pressure from inside

Height of water = 101.70 – 90.00 = 11.7 m

For water inside condition Maximum hoop tension = 10 x 11.7 x 3 = 351 kN/m

σ_0 = 351/300 = 1.17 << 1.3 N/mm^2 OK

- The wall is designed for critical Saturated earth pressure from outside, no water inside,

Height of Earth = 100.00 – 90.00 = 10 m

P at base = 10 x 20.8/ 3 = 69.33 kN/m^2

By using Dr. Arya's paper "Data for Analysed & Design of circular shell structures – I" ICJ Aug 69

Total Weight on Structure

BM in Wall	= 19.31 kN.m	
Total Weight of Pump	= 40 x 2 x 1.25	= 100 kN
Top Slab	= π x 3.45^2 x 5.5	= 205.66 kN
Roof Beam	= 0.23 x 0.3 x 2 x π x 3.115 x 25	= 33.76 kN
Brick Wall	= 2 x π x 3.115 x 6.05 x 5.76	= 682.04 kN
PH Floor	= π x 3^2 x 14.25	= 402.90 kN
Gallery	= π x (4.5^2 - 3.3^2) x 6.5	= 191.13 kN
Column	= 0.3 x 0.45 x 6.5 x 6 x 25	= 131.625 kN
Total		= 1747.115 kN
Load/m Length	= 1747.115/ 2 x π x 3.15	= 88.27 kN/m
Self Weight of wall	= 0.3 x 13.2 x 25	= 99 kN/m
Total		= 187.27 kN/m
σ_0	= 187.27/300	= 0.624 N/mm^2 << 6 N/mm^2
σ_b	= (19.31 x 10^3 x 6 /300^2)	= 1.287 N/mm^2 << 8.5 N/mm^2
(0.624/6) + (1.287/8.5)	= 0.255 < 1.0 OK	

Vertical Steel:

As = 19.31 x 10^6 / 0.9 x 130 x 250 = 660.170

Min As = 0.35 x 300 = 105 mm^2 = 52.5 on each face

Provide 10 tor @ 140 c/c vertical on each face

10 tor @ 140 c/c extra at bottom upto IL 3.350 height on each face.

Horizontal Steel:

Maximum HC = 185.34 kN

σ_0 = 185.34 /300 = 0.617 N/mm^2 << 6 N/mm^2

Min As = 0.35 x 300 = 105 mm^2 = 52.5 on each face

Provide hoop steel at Base to top, 10 tor @ 140 c/c vertical on each face.

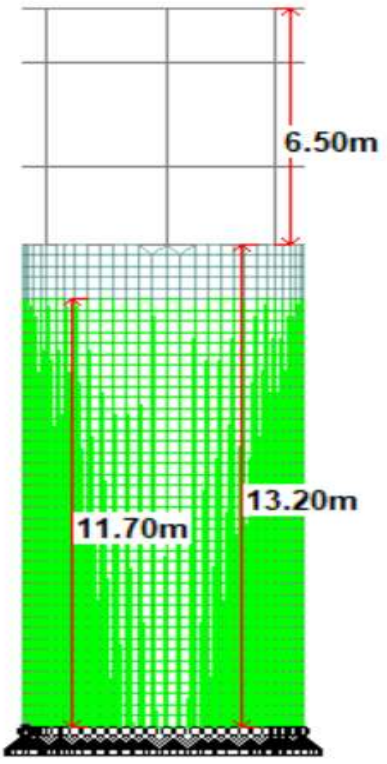


Figure 7: Water pressure inside the Jackwell

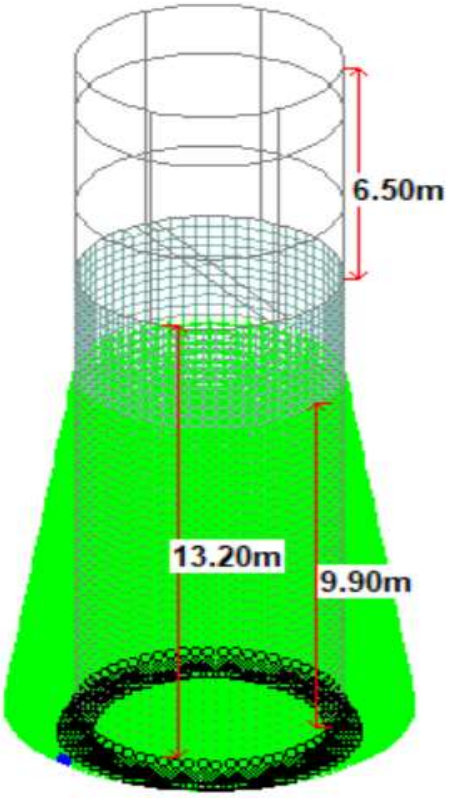


Figure 8: Earth pressure from outside of Jackwell

VII. CONCLUSION

- Jackwell Structure is underground / under –water structure, hence it is necessary to design accurately.
- As Jackwell is underground /under-water structure, reconstruction of the structure become uneconomical.
- Design of economical and efficient water supply scheme of Jhagarpur and adjoining villages (Mining Affected) under Rajgangpur Dist- Sundargarh, Odisha .
- Improvement in supply of potable water to various sections of villages in accordance with their demand and requirement.
- Fulfill the all water demand of domestic, industrial and commercial area of Jhagarpur and adjoining villages (Mining Affected) under Rajgangpur Dist- Sundargarh, Odisha.

VIII. ACKNOWLEDGMENT

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