

PERFORMANCE EVALUATION OF COOLING TOWER UNDER WIND LOAD USING COMPUTATIONAL FLUID DYNAMICS

Kinchit Soni¹, Dr. Suhasini Kulkarni²

¹P.G. Student (Structure), Dept. of Civil Engineering, Parul University, kinchithsoni@gmail.com

²HOD, Dept. of Civil Engineering, Parul University, suhasini.kulkarni@paruluniversity.ac.in

Abstract— cooling tower is a heat rejection device, which extract the waste heat of industry to the open atmosphere through cooling of the water stream to a lower temperature. Hyperbolic Cooling towers are mainly subjected to its self-weight and dynamically applied wind loads and earthquake loads. In present study, a cooling tower of 143.50 mt of height has been considered for the dissertation progress. For the purpose of work, wind velocity of 39 m/s, 44 m/s and 47 m/s are applied on tower geometry as per IS: 875 (Part 3)-2015. Where the spacing between two tower as adjusted as per 0.5D, 0.75D and 1.0D as per the minimum criteria of IS: 11504-1985 and angle of wind is adjusted from 0°, 45° and 90°. Support of Ansys Workbatch 18.1 has been adopted and results of pressure variation on surface of shell from 0°, 90° and 180° are recorded. In present study, boundary condition of cooling tower considered are top end free and bottom end fixed. Where, maximum face size of hexahedral mesh is considered as 7000 mm and for tetrahedral 6000 mm respectively.

Keywords— Natural draught cooling tower, Wind tunnel, IS: 875 (Part-3)-2015, IS: 11504-1985, CFD, Inlet, Outlet, Static pressure.

I. INTRODUCTION

Cooling tower is a heat refusal device, which abstracts waste heat to the atmosphere however the cooling of a water stream to a lower temperature. Mutual ideas for cooling towers are providing cooled water for air-conditioning, manufacturing and electrical power generation. R/C cooling towers are exposed to its self-weight and the dynamic load such as an earthquake motion and a wind effects. Exclusively, dynamic analyses of these structures are vital aspect to design R/C cooling tower structures. Specifically, dynamic analyses of these structures are important factor to design R/C cooling tower structures. The structures have huge surfaces of concrete by increasing its constructional height and also, R/C shell structure is typically placed on the supporting columns to yield cold air into it. R/C cooling tower epitomizes the combinations of R/C shell and R/C column structures.

The most mutual sight, particularly in power plants and nuclear plants, is hyperboloid-shaped cooling towers. The hyperboloid shape influences the strength of the intact structure. Since cooling towers are theoretical to cool the employed fluid down to a low temperature, they discharge vapours into the atmosphere over the opening at the top of the tower. Therefore, these towers have to be appropriately tall (they can be as tall as 200 meters), or besides the released vapour may ground fogging or recirculation. To support such a high structure, it is exceptionally important that the base is noticeably consolidated and spread over a large area so that it can support the tall, heavy structure overhead it. This is why cooling towers have a large, circular base.

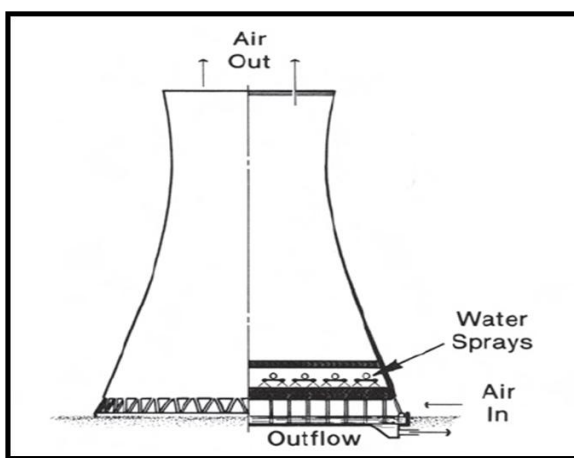


Fig.1 Counter Flow draught cooling Tower

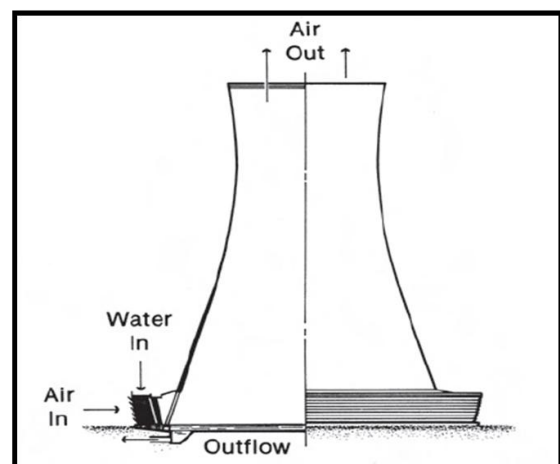


Fig.2 Cross Flow draught cooling Tower

II. METHODOLOGY

Aerodynamic processes are not easily quantifiable during the concept phase. Usually the only way for the engineer to optimize his designs is to conduct physical tests on product prototypes. With the rise of computers and ever-growing computational power, the field of Computational Fluid Dynamics became a commonly applied tool for generating solutions for fluid flows with or without solid interaction. In a CFD analysis, the examination of fluid flow in accordance with its physical properties such as velocity, pressure, temperature, density and viscosity is conducted. To virtually generate a solution for a physical phenomenon associated with fluid flow, without compromise on accuracy, those properties have to be considered simultaneously.

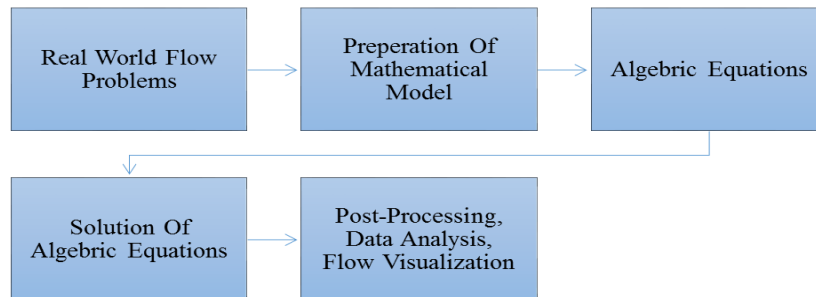


Fig.3 Process of CFD

Tab.1 Geometrical Properties of CT1

Sr. No.	Description	Symbols	Cooling Tower 1 (CT1)
1	Total Height	H	143.50 mt
2	Height of Throat	H_{thr}	107.75 mt
3	Diameter of Top	D_t	63.60 mt
4	Diameter of Bottom	D_b	110.00 mt
5	Diameter at throat level	D_{thr}	61.00 mt
6	Column Height	H_c	6.20 mt
7	Shell Thickness	S_{thk}	0.50 mt

Tab.2 Categorised Models in CFD

Wind speed V_b (m/s)	Angle of Wind (θ)		
	0°	45°	90°
39	0.5D	0.5D	0.5D
	0.75D	0.75D	0.75D
	1.0D	1.0D	1.0D
44	0.5D	0.5D	0.5D
	0.75D	0.75D	0.75D
	1.0D	1.0D	1.0D
47	0.5D	0.5D	0.5D
	0.75D	0.75D	0.75D
	1.0D	1.0D	1.0D

A. Pressure on shell surface of CT1 for different spacings and Wind velocity

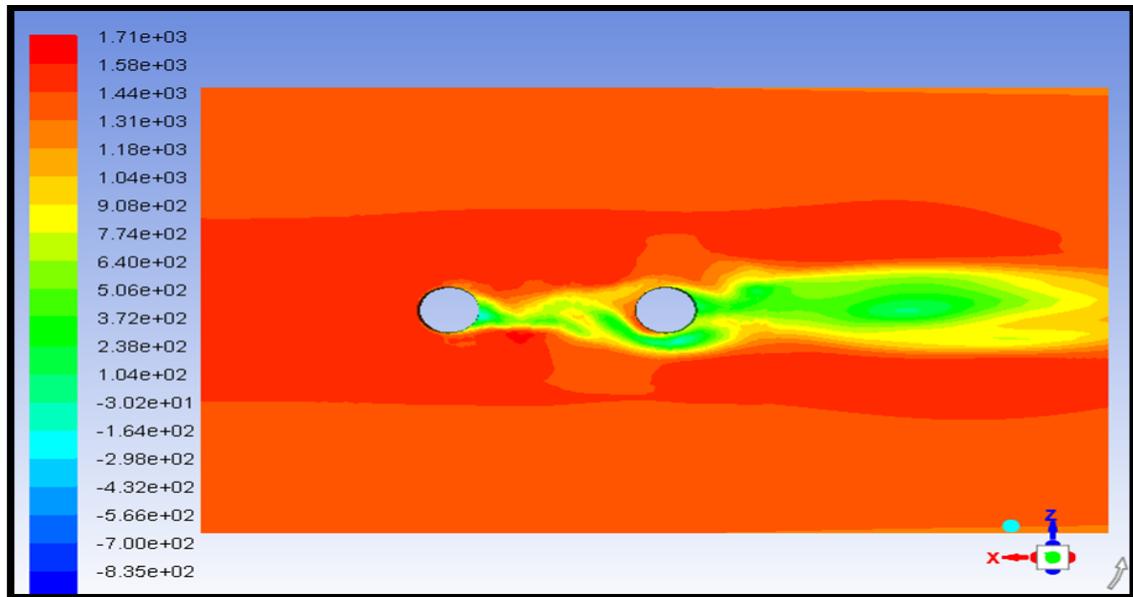


Fig.4 Static Pressure for 0° Wind Angle (39, 44, 47) Top View

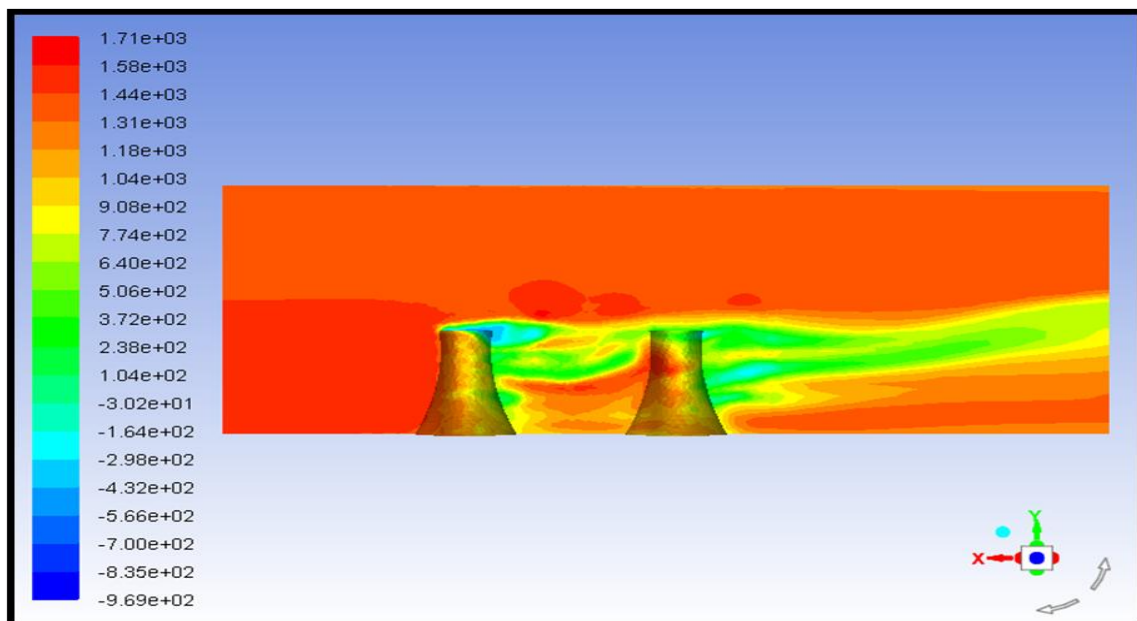


Fig.5 Static Pressure for 0° Wind Angle (39, 44, 47) for 1.0D Spacing

Table 3: Maximum Pressure on CT-1 at 0° Wind for 39, 44, 47 m/s, Spaced at 0.5D

CT1- 0°- 0.5D -39 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1018.4	-1450.5	638.6	638.6	-1450.5	448.6
107.75	1018.4	-1830.3	-310.98	638.59	-1070.7	-880.73
143.5	-121.06	-880.76	-310.98	258.76	-690.8	-690.8

CT1- 0°- 0.5D -44 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1236.4	-1862.9	409.66	1029.45	-1656.3	203.07
107.75	1236.4	-2689.3	254.53	822.85	-2895.9	-210.11
143.5	210.07	-1036.5	-210.11	-416.71	-829.9	-416.71
CT1- 0°- 0.5D -47 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1411.2	-2119.1	469.78	1175.83	-1648.4	469.78
107.75	1411.2	-3060.5	234.43	940.48	-3295.9	-236.27
143.5	234.43	-1177.7	-236.27	234.43	-942.33	-471.62

Table 4: Maximum Pressure on CT-1 at 0° Wind for 39, 44, 47 m/s, Spaced at 0.75D

CT1- 0°- 0.75D -39 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	965.16	-1569.2	603.11	603.11	-1388.17	422.08
107.75	965.16	-1750.23	-483.04	422.08	-1388.17	241.06
143.5	965.16	-1931.25	-302.01	422.08	-1388.17	-120.99
CT1- 0°- 0.75D -44 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1232.62	-1934.79	780.13	780.13	-1934.79	327.64
107.75	1232.62	-3066	-351.085	553.88	-1934.79	-124.84
143.5	553.88	-803.57	-351.085	327.64	-803.57	-351.085
CT1- 0°- 0.75D -47 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1412.17	-2277.27	621.57	1148.64	-2013.74	621.57
107.75	1412.17	-3594.94	-696.08	885.11	-2804.34	-432.55
143.5	-432.5	-1223.14	-432.55	-432.55	-959.61	-169.01

Table 5: Maximum Pressure on CT-1 at 0° Wind for 39, 44, 47 m/s, Spaced at 1.0D

CT1- 0°- 1.0 D -39 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	954.05	-1294.86	391.82	766.64	-1482.27	391.82
107.75	954.05	-2419.32	-357.81	204.41	-1857.09	204.41

143.5	-920.04	-732.63	-357.81	-357.81	-732.63	-170.4
CT1- 0°- 1.0 D -44 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1213.71	-2119.79	499.38	975.6	-1643.58	499.38
107.75	1213.71	-3072.22	-453.04	261.28	-2357.9	-214.93
143.5	-929.25	-929.25	-453.04	-691.14	-691.14	-453.04
CT1- 0°- 1.0 D -47 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	1419.96	-2492.13	861.09	1140.53	-1933.26	581.66
107.75	1419.96	-3609.87	-256.64	581.66	-2771.56	-256.64
143.5	-1094.95	-815.51	-536.08	-536.08	-1374.38	-536.08

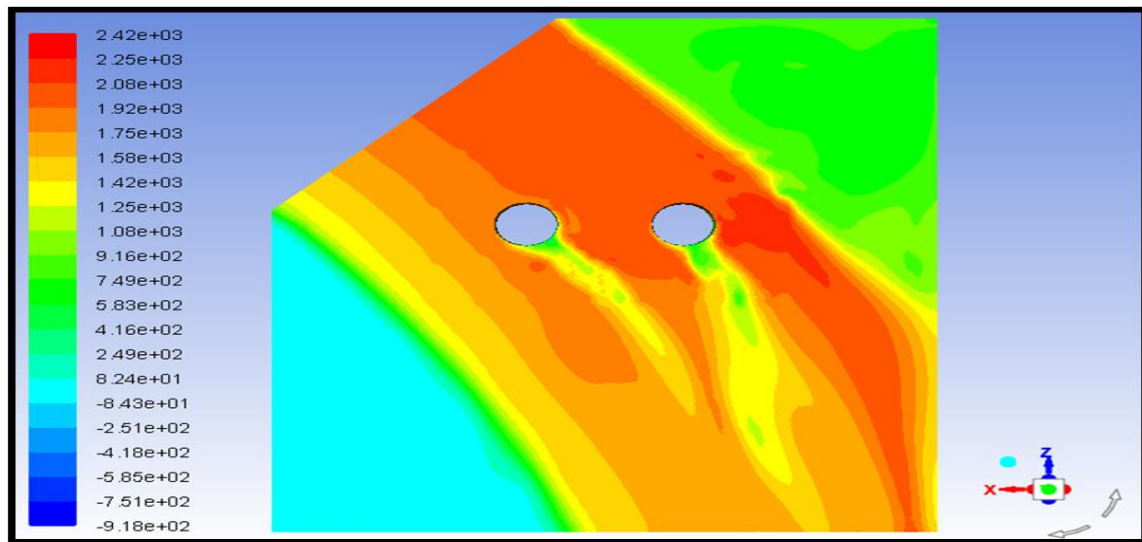


Fig.6 Static Pressure for 45° Wind Angle (39, 44, 47) for 1.0D Spacing

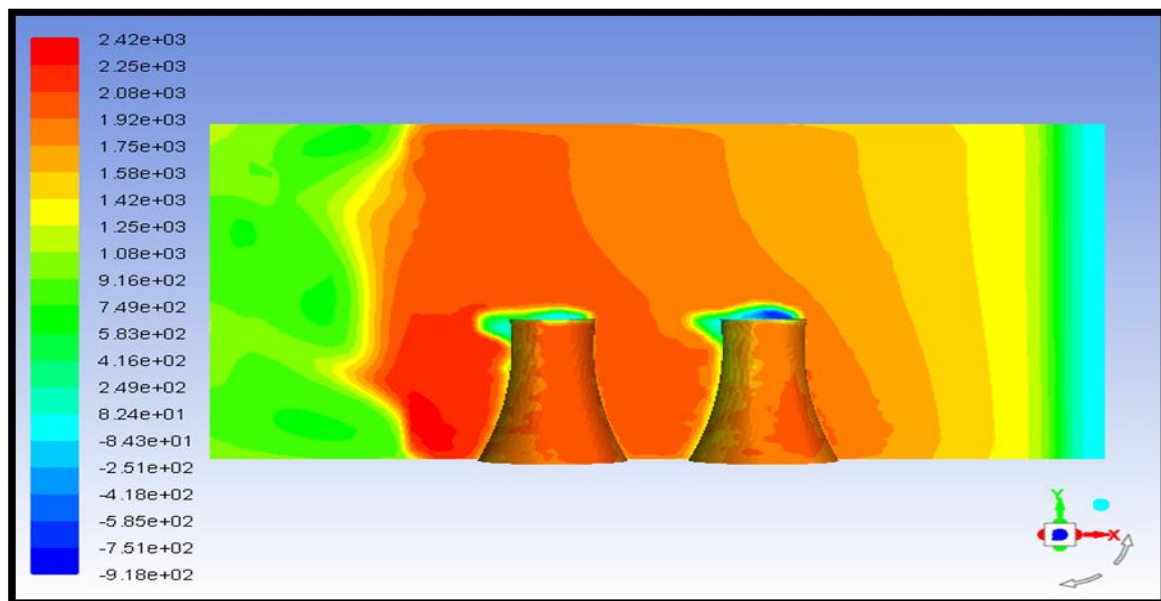


Fig.7 Static Pressure for 45° Wind Angle (39, 44, 47) for 0.5D Spacing

Table 6: Maximum Pressure on CT-1 at 45° Wind for 39, 44, 47 m/s, Spaced at 0.5D

CT1- 45°- 0.5D -39 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-471.5	544.91	-1081.36	-878.07	748.19	-674.79
107.75	-878.07	341.62	-1284.64	-1081.36	951.47	-471.5
143.5	-268.22	138.34	138.34	-268.22	544.91	341.62
CT1- 45°- 0.5D -44 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-838.04	943	-1092.47	-1346.91	943	-583.6
107.75	-1601.34	688.57	-1855.78	-1601.34	943	-1092.47
143.5	-329.16	-838.04	-329.16	179.7	688.57	-329.16
CT1- 45°- 0.5D -47 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-193.78	721.73	-2024.82	-1414.47	1026.9	-498.95
107.75	-1109.3	721.73	-1719.65	-2024.82	1332.07	-1109.3
143.5	-1109.3	416.55	-498.95	-498.95	721.73	-193.78

Table 7: Maximum Pressure on CT-1 at 45° Wind for 39, 44, 47 m/s, Spaced at 0.75D

CT1- 45°- 0.75D -39 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-498.54	974.27	-498.54	-498.54	763.86	-288.14
107.75	-1129.74	553.46	-919.34	-919.34	132.66	-288.14
143.5	-708.94	-919.34	132.66	-498.54	-288.14	553.46
CT1- 45°- 0.75D -44 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-631.02	442.95	-899.51	-631.02	711.44	-362.52
107.75	-899.51	711.44	-1705	-1168.01	979.94	-899.51
143.5	-899.51	-899.51	174.45	-631.02	-362.52	442.95
CT1- 45°- 0.75D -47 m/s (N/m²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-778.45	1091.55	-1090.12	-778.45	1403.22	-466.78
107.75	-1713.46	1403.22	-1401.79	-1401.79	1091.55	-1091.22
143.5	-1090.12	-1090.12	-466.78	-466.78	-466.78	156.55

Table 8: Maximum Pressure on CT-1 at 45° Wind for 39, 44, 47 m/s, Spaced at 1.0D

CT1- 45°- 1.0 D -39 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-550.67	483.64	-550.67	-343.81	690.5	-136.94
107.75	-1171.26	276.78	-964.4	-757.53	897.37	-757.53
143.5	-550.67	-136.94	-136.94	-343.81	276.78	276.78
CT1- 45°- 1.0 D -44 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-795.15	840.79	-795.15	-522.44	840.79	-249.83
107.75	-1613.13	840.79	-795.15	-1067.81	1113.45	-795.15
143.5	-795.15	295.48	-249.83	-522.44	568.13	295.48
CT1- 45°- 1.0 D -47 m/s (N/m ²)						
Height (mt)	Tower1			Tower2		
	0°	90°	180°	0°	90°	180°
6.2	-1090.4	994.67	-1090.4	-792.53	994.67	-196.8
107.75	-1686.14	398.93	-1090.4	-1090.4	1292.53	-494.66
143.5	-792.53	-196.8	-196.8	-494.66	398.93	-196.8

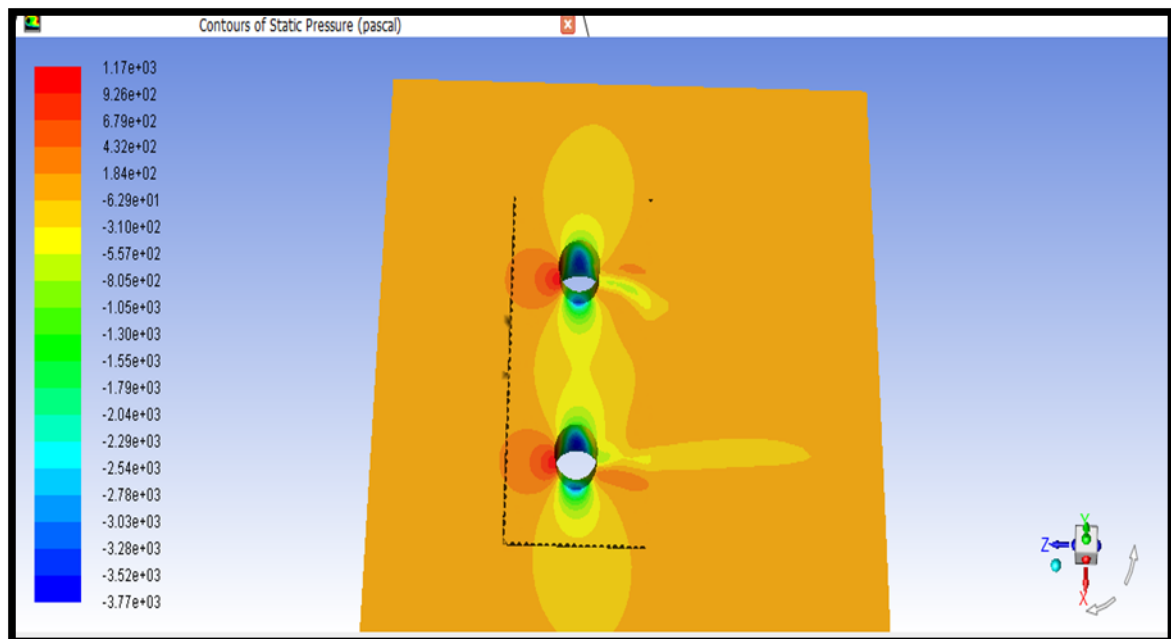


Fig.8 Static Pressure Contours at Throat level of Tower for 90° Wind Angle (39, 44, 47) for 1.0D Spacing

B. Graphical representation of difference of pressure on shell surface of CT1:

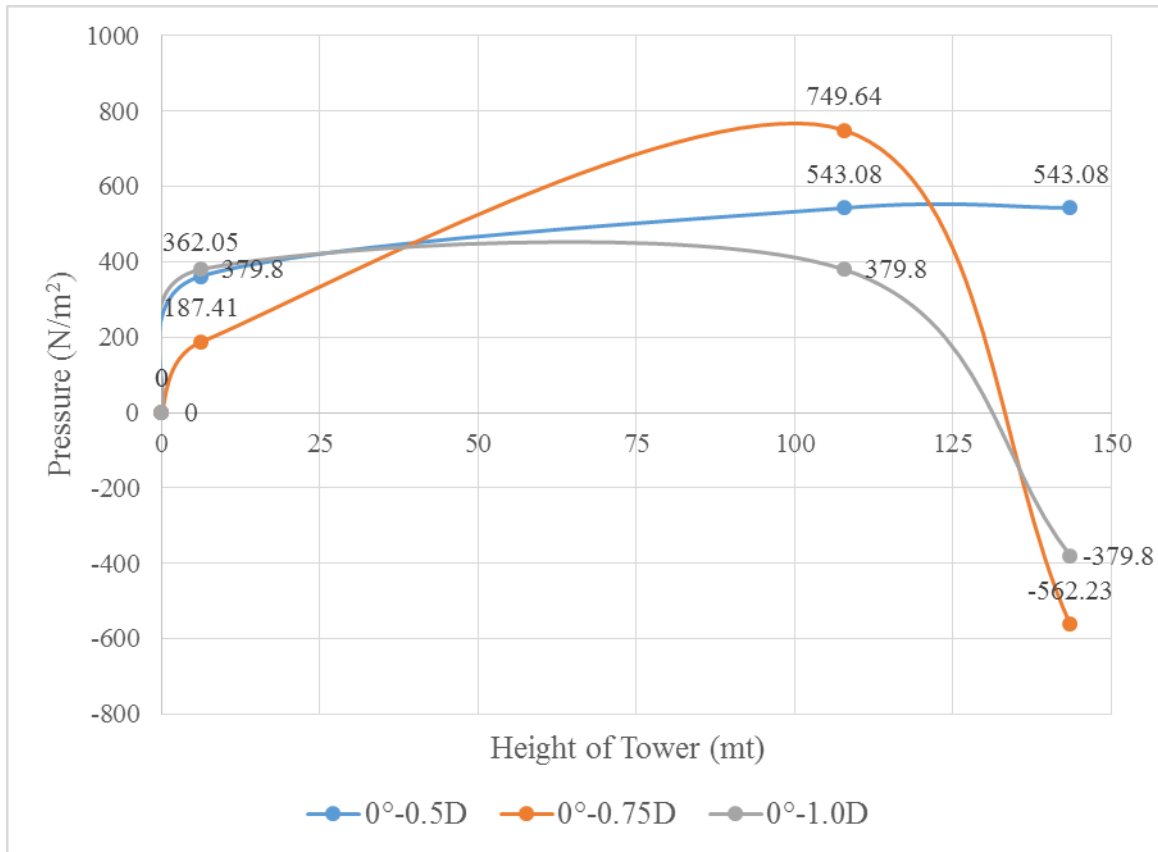


Chart 01: Pressure difference on both towers CT-1 on 0° surface for 0° wind of 39 m/s speed

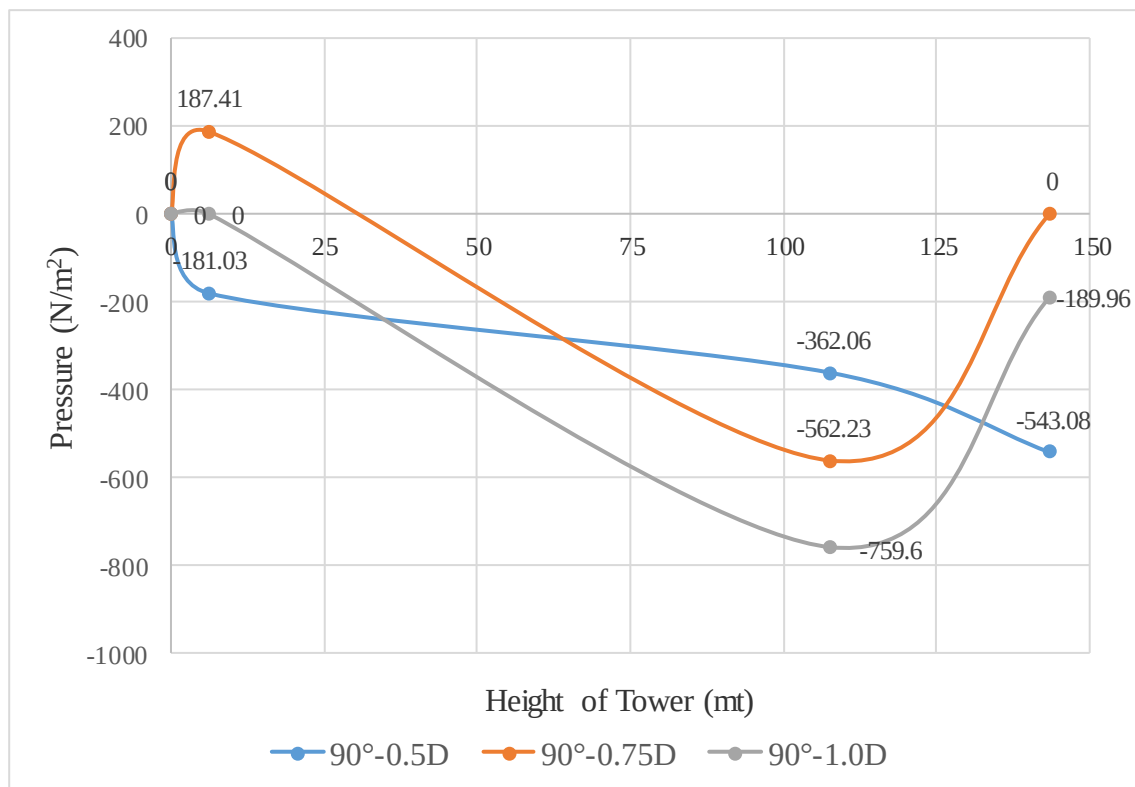


Chart 02: Pressure difference on both towers CT-1 on 90° surface for 0° wind of 39 m/s speed

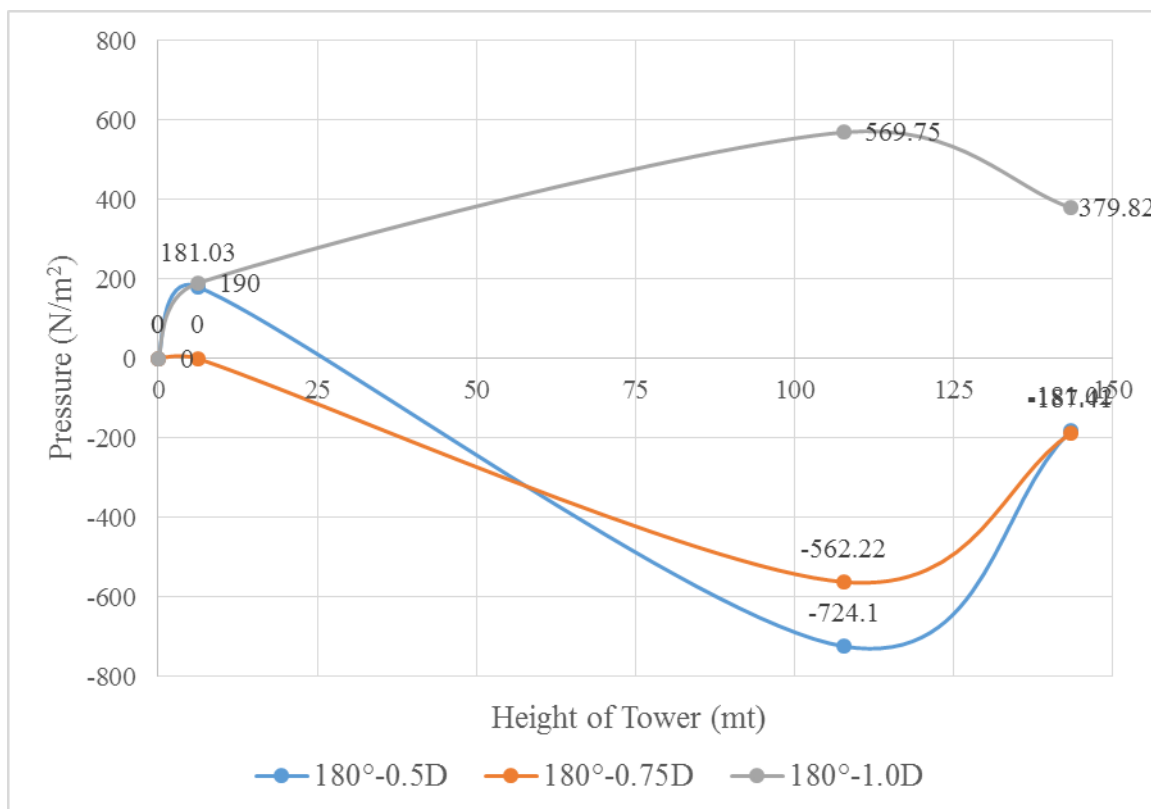


Chart 03: Pressure difference on both towers CT-1 on 180° surface for 0° wind of 39 m/s speed

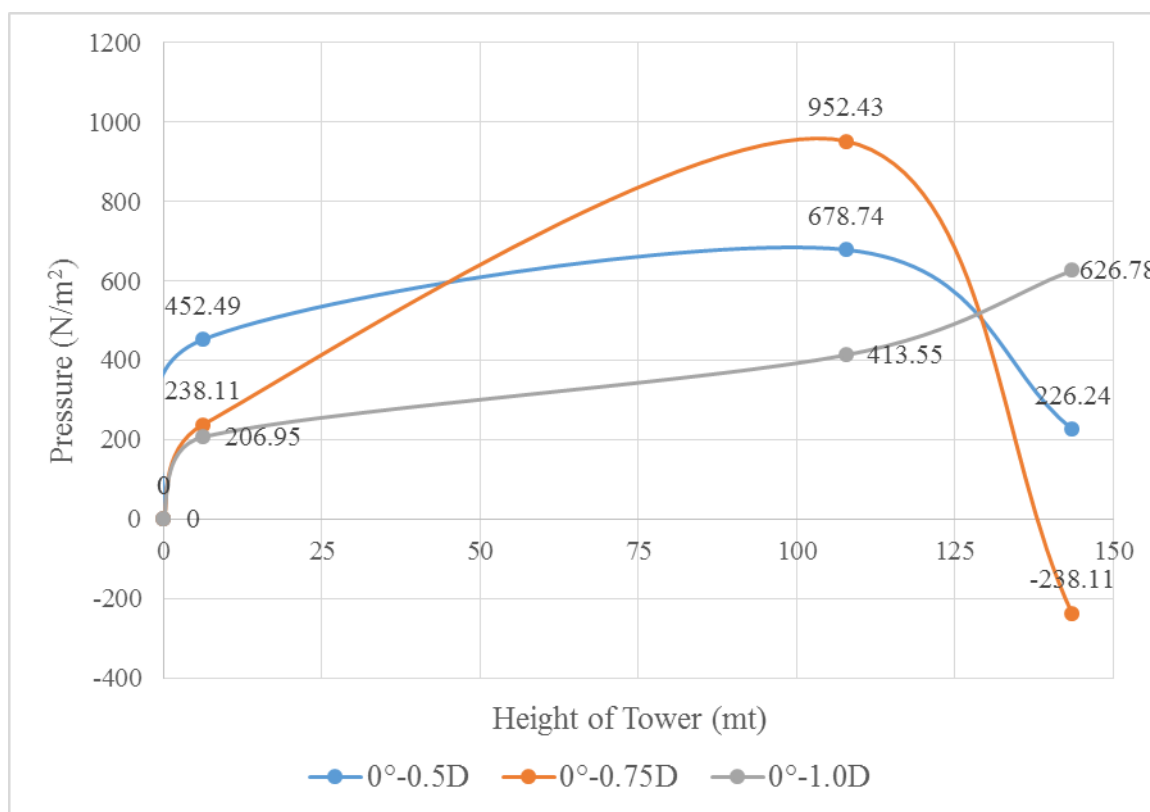


Chart 04: Pressure difference on both towers CT-1 on 0° surface for 0° wind of 44 m/s speed

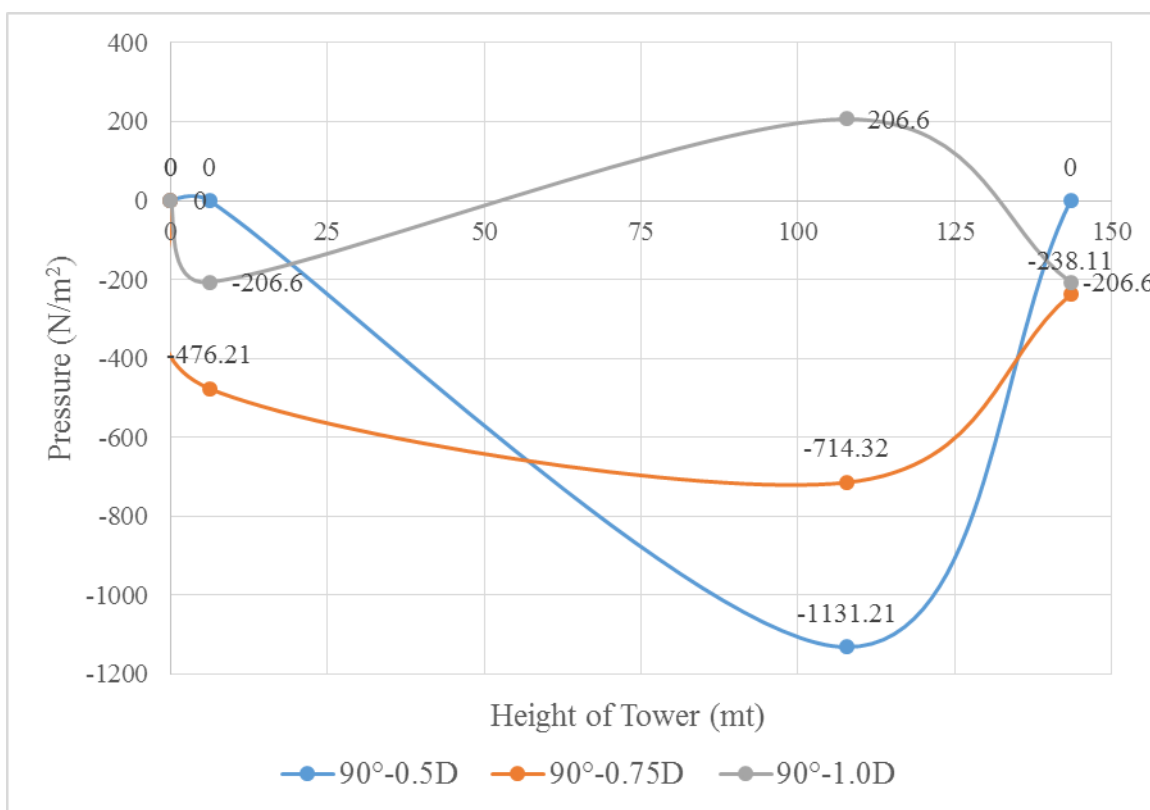


Chart 05: Pressure difference on both towers CT-1 on 90° surface for 0° wind of 44 m/s speed

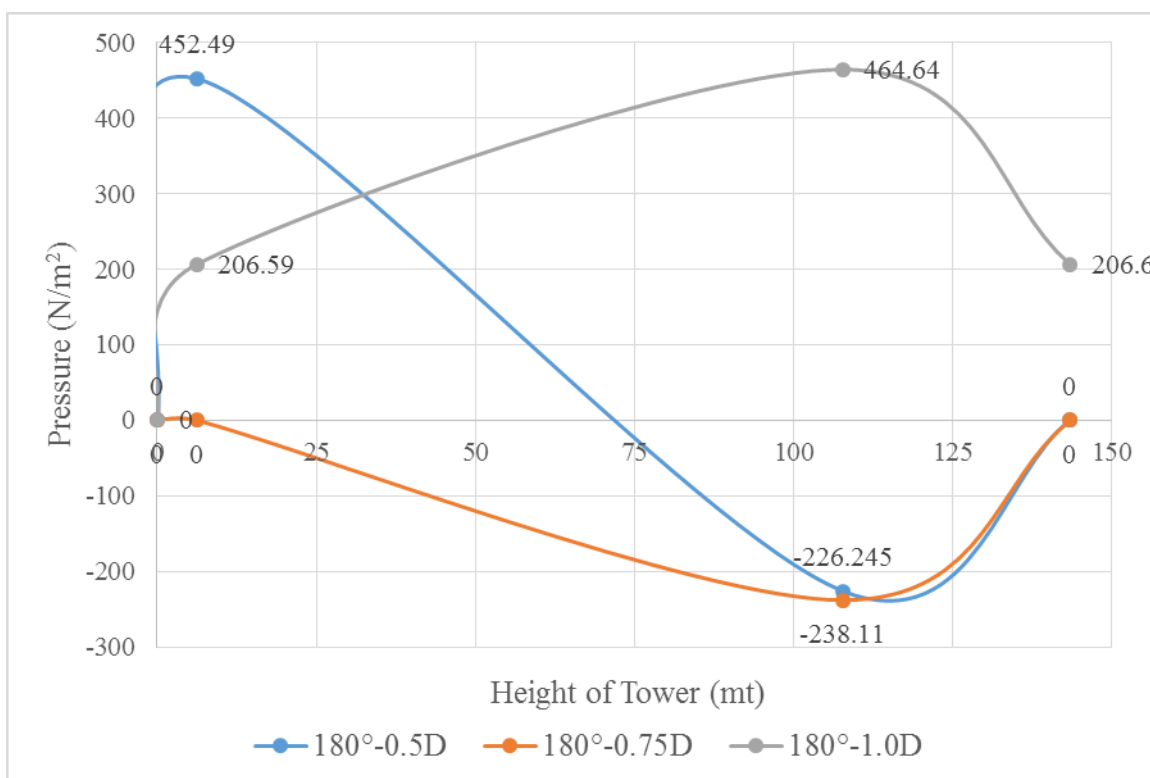


Chart 06: Pressure difference on both towers CT-1 on 180° surface for 0° wind of 44 m/s speed

III. CONCLUSION

As per above pressure values and charts, difference of pressure on the second tower in the group has been observed on the different angular surfaces. From the above study, few conclusions are derived are:

1. Maximum pressure coefficient has been observed on 70° on the shell surface of the wind force application.
2. As the distance between two towers increased from 0.5D to 0.75D, wind pressure on 0° surface is decreased from 5.55% at lintel level, 33.90% at throat level. Whereas it is observed of increase in pressure of 63.11% on the top of tower.
3. As the distance between two towers increased from 0.5D to 0.75D, wind pressure on 90° surface is decreased from 4.40% at lintel level, 22.87% at throat level and 27.48% at the top of tower.
4. As the distance between two towers increased from 0.5D to 0.75D, wind pressure on 180° surface is decreased from 5.90% at lintel level. Whereas it is observed of increase in pressure of 127.37% at throat level and 82.48% on the top of tower.
5. As the distance between two towers increased from 0.75D to 1.0D, wind pressure on 0° surface is increased from 27.11% at lintel level. Whereas it is observed of decrease in pressure of 51.57% at throat level and 184.77% on the top of tower.
6. As the distance between two towers increased from 0.75D to 1.0D, wind pressure on 90° surface is decreased from 6.77% at lintel level and 33.777% at throat level. Whereas 47.22% increment in pressure is observed on the top of tower.
7. As the distance between two towers increased from 0.75D to 1.0D, wind pressure on 180° surface is decreased from 7.16% at lintel level, 15.20% at throat level and 40.83% at the top of tower has been observed.

IV. REFERENCES

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