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DESIGN, ANALYSIS AND OPTIMIZATION OF INTZE TYPE WATER TANK FOR DIFFERENT PARAMETERS AS PER INDIAN CODES

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ABSTRACT

Storage reservoirs and overhead tanks are used to store water. All tanks are designed as crack free structures to eliminate any leakage. In this project, working stress method is used to design an INTZE tank and Elements of the INTZE tank are designed by limit state method. In general, for a given capacity, circular shape is preferred because stresses are uniform and lower compared to other shapes. Lesser stresses imply, lower quantities of material required for construction which brings down the construction cost of water tanks. This project gives in brief, theory, design and analysis of the INTZE type water tank. The main objective of this paper is to give best estimates of the required quantity of concrete and steel for a given water holding capacity. Preparing the design, estimation, costing, analysis of designs and cost comparison of output graphs for various inputs is included in this report.

Keywords: Capacity of Water Tank, Cost Analysis, IS Codes, Safe Bearing Capacity of Soil and Wind Speed Etc.,

I. INTRODUCTION

Water tanks are used to store water. Cost, shape, size and building materials used for constructing water tanks are influenced by the capacity of water tank. Shape of the water tank is an important design parameter because nature and intensity of stresses are based on the shape of the water tank. In general, for a given capacity, circular shape is preferred because stresses are uniform and lower compared to other shapes. Lesser stresses imply, lower quantities of material required for construction which brings down the construction cost of water tanks.

INTZ type water tank is one such water tank which has circular shape with a spherical top and conical slab with spherical dome at the bottom. In this type of water tank, the inward forces coming from the conical slab counteract the outward forces coming from the bottom dome which result less stress on the concrete bottom slab of the water tank. Due to lesser stresses, the thickness of the concrete bottom slab reduces and reducing the amount of concrete required which has direct influence on the cost of the water tank.

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II. CLASSIFICATIONS OF WATER TANKS

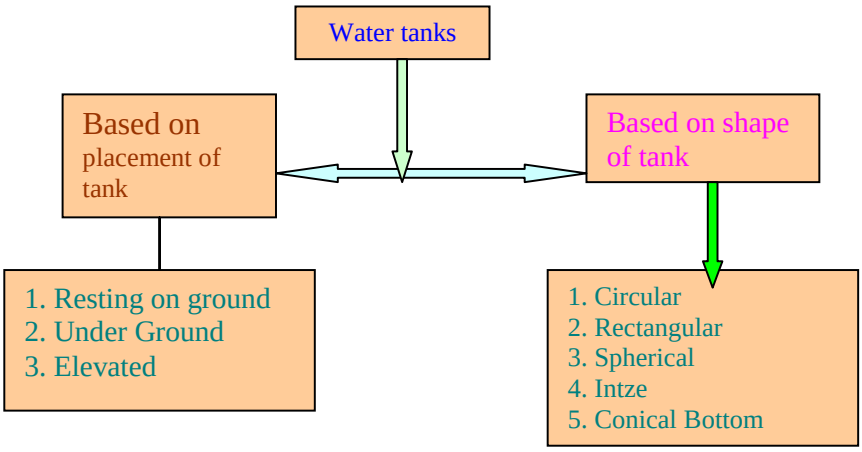

Fig -1

III. DESIGN REQUIREMENTS OF INTZE TYPE WATER TANK

Fig -2

3.1. Top Dome: The dome at the top usually 100mm to 150mm thick with reinforcement along the meridians and latitudes, the rise is usually l/5th of the diameter

3.2. Top Ring Beam: The ring beam is necessary to resist the horizontal component of the thrust of the dome. The ring beam will be designed for the hoop tension induced.

3.3. Cylindrical Wall: This has to be designed for hoop tension caused due to horizontal water pressure. Thickness of the wall should be kept minimum 150mm

3.4. Bottom Ring Beam: This ring beam is provided to resist the horizontal component of the reaction of the conical wall on the cylindrical wall. The ring beam will be designed for the induced hoop tension.

3.5. Conical Slab: This will be designed for hoop tension due to water pressure. The slab will also be designed as a slab spanning between the ring beam at top and the ring girder at bottom.

3.6. Bottom Spherical Dome: The floor may be circular or domed. This slab is supported on the ring girder. The rise of the bottom dome should be 0.2 times diameter of the bottom dome. The diameter of bottom spherical dome should be 0.6D

3.7. Design of Circular Girder: This will be designed to support the tank and its contents. The girder will be supported on columns and should be designed for resulting bending moment and Torsion

3.8. Column Section: These are to be designed for the total load transferred to them. The columns will be braced at intervals and have to be designed for wind pressure whichever govern

3.9. Braces: These are used to reduce the buckling of the columns. These are placed at regular intervals along the length of the columns

3.10. Foundations: These are used to support the columns. These are used the transfer the load from columns to Soil through bottom ring girder

IV. ECONOMICAL PROPORTION OF STRUCTURAL ELEMENTS

- Rise of top dome h_1= (1/7) D
- Height of cylindrical tank proper, h2=0.4 D
- Height of conical dome h_3=0.2D
- Rise of bottom spherical dome h_4=(1/7)D
- Diameter of bottom circular girder,D_1=0.6D

V. DESIGN SPECIFICATIONS

Grade of concrete =M20

Grade of steel = Fe 415

Capacity of tank, Safe bearing capacity of soil and Wind Pressure are varying parameters

VI. ANALYSIS AND COMPARISON OF RESULTS OF INTZE TYPE TANK:

For each case, different results are obtained by changing various parameters like Capacity of tank, Safe bearing capacity of soil and Wind Pressure. From the obtained results, graphs have been prepared and compared for cost analysis.

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Case 1 SBC Vs Cost Vs Different Capacity

Table 1- S.B.C Vs Cost Vs 5 lack Capacity

Capacity (Lt)	Bearing capacity (kN/m^2)	Wind speed (m/s)	Overall cost (Rs)
500000	75	50	1373486
500000	100	50	1266836
500000	125	50	1180536
500000	150	50	1149586
500000	175	50	1149586
500000	200	50	1121986
500000	225	50	1121986
500000	250	50	1100286

Table 2- S.B.C Vs Cost Vs 10 lack Capacity

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	75	50	3425232
1000000	100	50	2879332
1000000	125	50	2627832
1000000	150	50	2487732
1000000	175	50	2429932
1000000	200	50	2377732
1000000	225	50	2330032
1000000	250	50	2291232

Table 3- S.B.C Vs Cost Vs 15 lack Capacity

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1500000	75	1500	6198903
1500000	100	1500	5061153
1500000	125	1500	4553053
1500000	150	1500	4238003
1500000	175	1500	4060903
1500000	200	1500	3907303
1500000	225	1500	3838253
1500000	250	1500	3780453

Table 4- S.B.C Vs Cost Vs 20 lack Capacity

Capacity (Lt)	Bearing Capacity (kN/m^2)	Wind Speed (M/S)	Overall Cost (Rs)
2000000	75	50	9613630
2000000	100	50	7657480
2000000	125	50	6651380
2000000	150	50	6109930
2000000	175	50	5879280
2000000	200	50	5668830
2000000	225	50	5491680
2000000	250	50	5409180

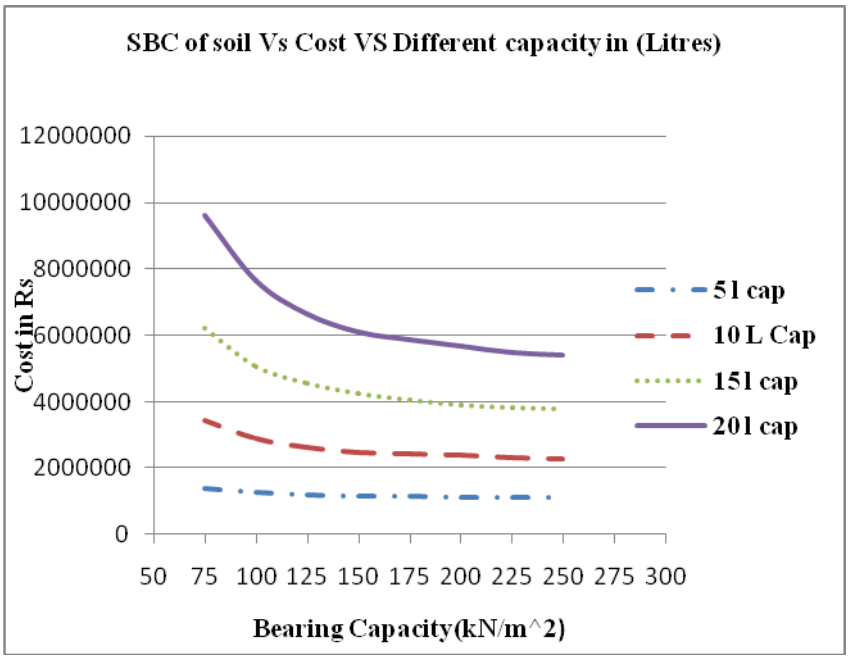

Chart – 1

Discussion from Chart-1

1. Cost will reduces when bearing capacity of soil increases.
2. From 150 Kn/$m^2$to 250 (kN/m^2**)** SBC there is not much variation in cost. But from 75 **(**kN/m^2)to125 (kN/m^2)there is a considerable variation in cost
3. At 100 KN/m^2SBC,for 10 lack litre capacity, cost is Rs 26,41,564; for 20 lack litre capacity, cost is Rs 69,50,741. Therefore, two tanks of 10 lack litre capacity instead of one 20 lack litre capacity tank should be preferred.

CASE -2 Capacity Vs Cost Vs Different SBC

Table 5- Capacity Vs Cost Vs 75 kN/m^2 SBC

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	75	50	1373486
1000000	75	50	3425232
1500000	75	50	6198903
2000000	75	50	9613630
2500000	75	50	13919283

Table 6 - Capacity Vs Cost Vs 100 kN/m^2SBC

Capacity in (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	100	50	1266836
1000000	100	50	2879332
1500000	100	50	5061153
2000000	100	50	7657480
2500000	100	50	10618083

Table 7 - Capacity Vs Cost Vs 150 kN/m²SBC

Capacity in (Lt)	Bearing capacity (kN/m²)	wind speed (m/s)	Overall cost (Rs)
500000	150	50	1149586
1000000	150	50	2487732
1500000	150	50	4238003
2000000	150	50	6109930
2500000	150	50	8265583

Table 8 - Capacity Vs Cost Vs 200 kN/m²SBC

Capacity (Lt)	Bearing capacity (kN/m²)	wind speed (m/s)	Overall cost (Rs)
500000	200	50	1121986
1000000	200	50	2377732
1500000	200	50	3907303
2000000	200	50	5668830
2500000	200	50	7441833

Table 9 - Capacity Vs Cost Vs 250 (kN/m²) SBC

Capacity in (Lt)	Bearing capacity ((kN/m²)	wind speed (m/s)	Overall cost (Rs)
500000	250	50	1100286.1
1000000	250	50	2291232
1500000	250	50	3780453.96
2000000	250	50	5409180
2500000	250	50	7116883.42

Discussion from Chart- 2:

1. Prefer to construct water tank between 150 to 250 kN/m^2 SBC

2. Between 5 lack to 10lack capacity there is no so much of cost variation, in this region cost not so much dependent upon soil bearing capacity

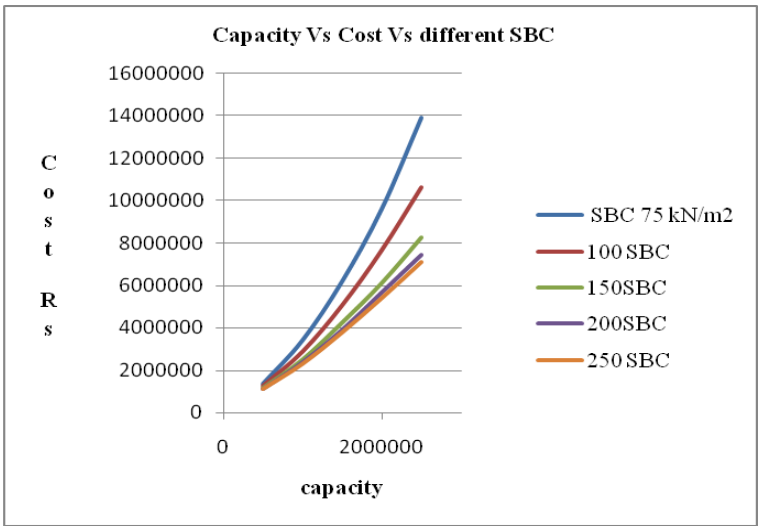

Chart-2

CASE – 3 Cost Vs Different Wind speed Vs Capacity

Table 10 - Cost Vs Wind speed Vs 5lakh Capacity

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	33	1042202.99
500000	125	39	1072636.26
500000	125	44	1106369.54
500000	125	47	1143452.84
500000	125	50	1180536.11
500000	125	55	1271202.65

Table 11 - Cost Vs Wind speed Vs 10lakh Capacity

Capacity in (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	125	33	2297331.09
1000000	125	39	2390014.91
1000000	125	44	2499098.74
1000000	125	47	2561365.66
1000000	125	50	2627832.57
1000000	125	55	2848233.32

Table 12 - Cost Vs Wind speed Capacity Vs 15 lacks

Capacity in (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1500000	125	33	3888992.37
1500000	125	39	4069779.57
1500000	125	44	4211221.03
1500000	125	47	4374512.5
1500000	125	50	4553053.96
1500000	125	55	4858891.15

Table 13 - Cost Vs Wind speed Capacity Vs 20lack

Capacity in (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
2000000	125	33	5714847.06
2000000	125	39	5944591.91
2000000	125	44	6216586.76
2000000	125	47	6425483.33
2000000	125	50	6451379.89
2000000	125	55	7167173.02

Discussion from Chart – 3:

From above graph it can be concluded that for 5 lack litre capacity of water tank, for the wind speed between 33 to 41 m/s, cost is constant. If capacity of water tank increases, then cost also increases.

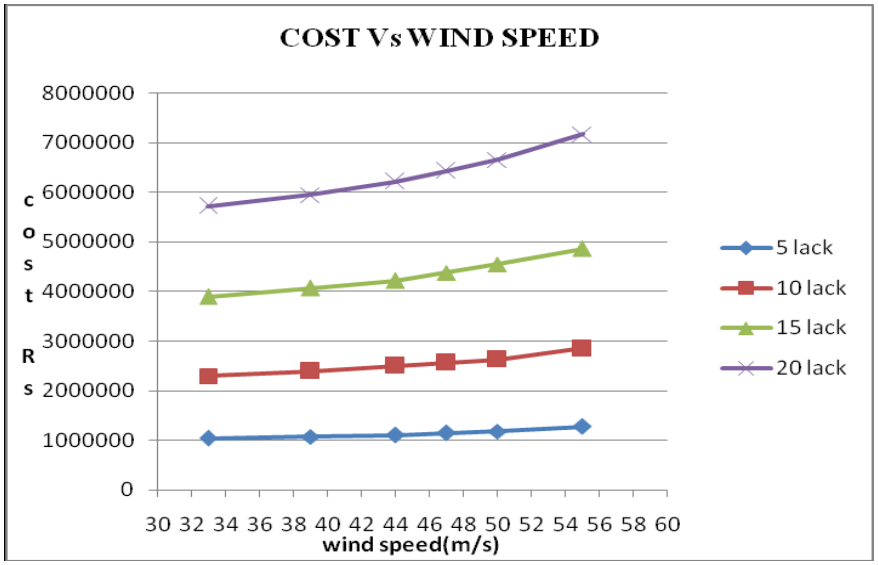

Chart - 3

CASE – 4 Cost Vs Different Capacity Vs Wind speed

Table 14 - Cost Vs Capacity Vs 33m/s wind Speed

Capacity (Lt)	Bearig capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	33	1042202
1000000	125	33	2297331
1500000	125	33	3888992
2000000	125	33	5714847
2500000	125	33	7791814

Table 15 - Cost Vs Capacity Vs 39m/s wind Speed

Capacity (Lt)	Bearing capacity ((kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	39	1072636
1000000	125	39	2390014
1500000	125	39	4069779
2000000	125	39	5944591
2500000	125	39	8053419

Table 15 - Cost Vs Capacity Vs 44m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	44	1106369
1000000	125	44	2499098
1500000	125	44	4211221
2000000	125	44	6216586
2500000	125	44	8477259

Table 16 - Cost Vs Capacity Vs 33m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	47	1143452
1000000	125	47	2561365
1500000	125	47	4374512
2000000	125	47	6425483
2500000	125	47	8720128

Table 17 - Cost Vs Capacity Vs 44m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	50	1180536
1000000	125	50	2627832
1500000	125	50	455305
2000000	125	50	6451379
2500000	125	50	9128483

Table 18 - Cost Vs Capacity Vs 44m/s wind Speed

Capacity (Lt)	Bearing capacity ((kN/m^2)	wind speed (m/s)	Overall cost (Rs)
500000	125	55	1271202
1000000	125	55	2848233
1500000	125	55	4858891
2000000	125	55	7167173
2500000	125	55	9744572

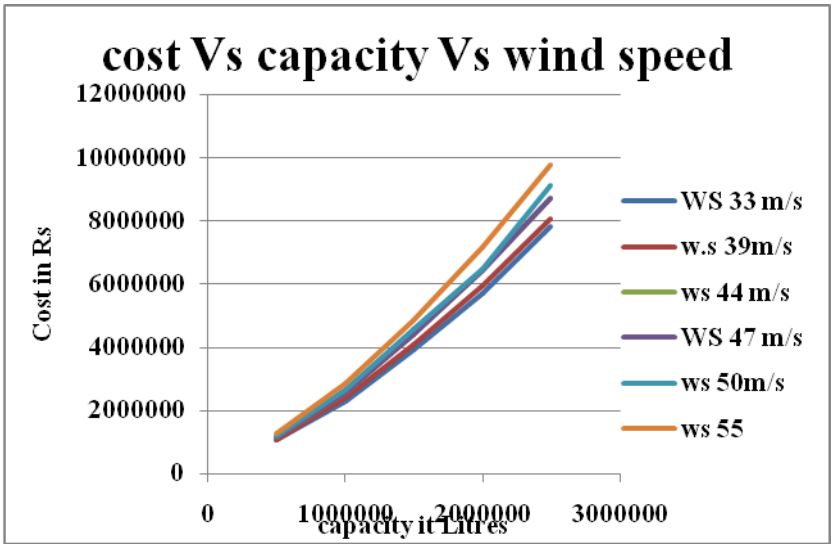

Chart-4

Discussion from chart-4:

Between 5 to 10 lack litres, there is not much of cost variation with respect to wind speeds

CASE – 5 Cost Vs Wind Speed Vs Different SBC

Table 19 - Cost Vs Wind Speed Vs 100 kN/m^2 SBC

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	100	33	2548881
1000000	100	39	2641564
1000000	100	44	2750598
1000000	100	47	2812915
1000000	100	50	2879332
1000000	100	55	3099783

Table 20 - Cost Vs Wind Speed Vs 150 kN/m^2 SBC

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	150	33	2157231
1000000	150	39	2253214
1000000	150	44	2362248
1000000	150	47	2421265
1000000	150	50	2487732
1000000	150	55	2708133

Table 21 - Cost Vs Wind Speed Vs 150 kN/m² SBC

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	200	33	2047231
1000000	200	39	2143214
1000000	200	44	2252248
1000000	200	47	2311265
1000000	200	50	2377732
1000000	200	55	2598133

Table 22 - Cost Vs Wind Speed Vs 150 kN/m² SBC

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	250	33	1960731
1000000	250	39	2053464
1000000	250	44	2162498
1000000	250	47	2224815
1000000	250	50	2291232
1000000	250	55	2511633

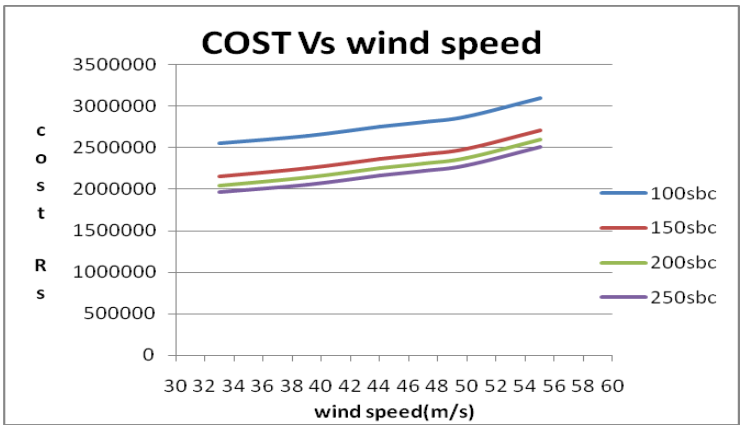

Chart – 5

Discussion from chart – 5:

If wind speed increases then cost increases. So prefer to locate the water tank where wind speed is less and SBC is high.

CASE – 6 Cost Vs SBC Vs 33m/s Different wind Speed

Table 23 - Cost Vs SBC Vs 33m/s wind Speed

Capacity (Lt)	Bearing capacity kN/m^2	wind speed (m/s)	Overall cost (Rs)
1000000	75	33	3094731
1000000	100	33	2548881
1000000	125	33	2297331
1000000	150	33	2157231
1000000	200	33	2047231
1000000	250	33	1960731

Table 24 - Cost Vs SBC Vs 39m/s wind Speed

Capacity (Lt)	Bearing capacity kN/m^2	wind speed (m/s)	Overall cost (Rs)
1000000	75	39	3190714
1000000	100	39	2641564
1000000	125	39	2390014
1000000	150	39	2253214
1000000	200	39	2143214
1000000	250	39	2053464

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Table 24 - Cost Vs SBC Vs 44m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	75	44	3299748
1000000	100	44	2750598
1000000	125	44	2499098
1000000	150	44	2362248
1000000	200	44	2252248
1000000	250	44	2162498

Table 24 - Cost Vs SBC Vs 47m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	75	47	3358765
1000000	100	47	2812915
1000000	125	47	2561365
1000000	150	47	2421265
1000000	200	47	2311265
1000000	250	47	2224815

Table 25 - Cost Vs SBC Vs 47m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	75	50	3425232
1000000	100	50	2879332
1000000	125	50	2627832
1000000	150	50	2487732
1000000	200	50	2377732
1000000	250	50	2291232

Table 26 - Cost Vs SBC Vs 47m/s wind Speed

Capacity (Lt)	Bearing capacity (kN/m^2)	wind speed (m/s)	Overall cost (Rs)
1000000	75	55	3645633
1000000	100	55	3099783
1000000	125	55	2848233
1000000	150	55	2708133
1000000	200	55	2598133
1000000	250	55	2511633

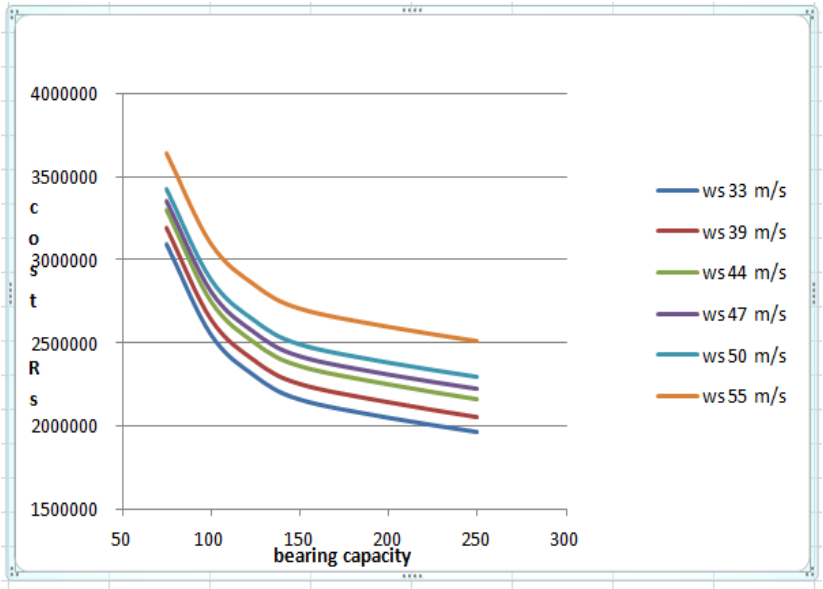

Chart -6

Discussion from chart – 6:

Here, SBC dominates the wind speed, the change of wind speed not so much effect on cost when we prefer high SBC

VII. CONCLUSIONS

- From chart 1, we concluded that the cost will reduce when bearing capacity of soil increases.
- From chart 1, we analyzed that at 100 kN/m^2 SBC, for 10 lack litre capacity, cost is Rs 26, 41,564; for 20 lack litre capacity, cost is Rs 69,50,741. Therefore, two tanks of 10 lack litre capacity instead of one 20 lack litre capacity tank should be preferred.
- From chart 1, we concluded that between 150 kN/m^2 to250 kN/m^2 SBC there is not so much variation in cost. But from 75 kN/m^2 to125 kN/m^2 there is a considerable variation in cost.
- From chart 2, we concluded that between 5 lacks to 10 lacks capacity there is no so much of cost variation, in this region cost not so much dependent upon soil bearing capacity. In the same way (from chart 4) between 5 to 10 lack litres, there is not much of cost variation with respect to wind speeds.
- From chart 2, it can be concluded that there is a considerable variation in cost for 75kN/m^2 to 100 kN/m^2 SBC, So Prefer to construct water tank between 150 kN/m^2 SBC to 250 kN/m^2 SBC.
- From chart 3, it can be concluded that for 5 lack litre capacity of water tank, for the wind speed between 33 to 41 m/s, cost is approximately constant. But in the same region for 10 lacks to above capacity, cost will varies.
- From chart 5, we analyzed that the cost will increase when wind speed increases, so prefer to locate the water tank where wind speed is less and SBC is high.
- From chart 6, we analyzed that the change of wind speed not so much effect on cost when we prefer high SBC.

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