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Structural stability of the supporting tower for an elevated Braithwaite pressed steel tank

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***ABSTRACT** : This paper calculates the load of the water tank full with water and wind load and compressive force of stanchions and bracing to withstand water load and wind forces of 15meter elevated steel tank of capacity 163,656 liters (164m3) of water and computer results of the compressive forces were determined using quick basic programming and pce software. Computer results attached from the compressive force, the members were designed for suitability of the sections. The steel elevated tank has 33 modes and 70 elements with fixed supports at Nodes 1,2 and 3 with nodal loads of 277.63KN, 228.65KN and 277.44KN at Nodes 31,32 and 33 respectively with wind load of 11.58KN at node 33. The maximum compressive stress calculated was found to be 395KN at member 24 under a running time of 1.15 minutes.*

***KEYWORDS:** Compressive stress, Braithwaite pressed steel tank, quick basic programming, pce software, wind and dead loads*

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I. INTRODUCTION

An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to provide sufficient pressure in the water distribution system. Without water survival is impossible. Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. A water tank is used to store water for daily requirements like drinking, washing, cooking etc. Tejaswini and Mamatha (2020). The water tanks are majorily classified into water tank resting on ground, under the ground and above the ground. Based on the shape, water tanks are major circular, rectangular and triangular shape both in concrete and steel. Tegawini Koramutta and AnushaSapatla (2019). Various Engineers and researchers have dealt extensively on elevated steel or concrete tanks like VaseemAkhtar, shaik Rehmen and Zubeeruddin (2021), Amit Verma and Purusharth Mishra (2019), Ritu Markum, Valdy, and Satone (2022), and Sagarchinchghare and Rahul Hinger (2022).

II. MATERIALS AND METHOD

The model considered here is steel rectangular elevated water tank of 163,656 liters (164m3) capacity supported on twelve 12 Stanchions, staging of height 15m and spaced 2440mm.

The loads and wind loads were analyzed and placed on the 15m Stanchion. Pce software was used on the beam from secondary to primary beams and loaded on the Stanchions while visual basic 6 (quick basic programming) was used to evaluate the compressive stress on the Stanchions. Thereafter, steel designers manual was used to select the appropriate sections in Beams, Stanchions and bracing.

A. WINDLOAD

Characteristics wind speed = 150KN/hr, from the geometry of the towers = 42m/s, the two forces are not the same which implies that the wind forces in the two discretions will not be the same.

From Table 5 of Engr. Design guide (An introduction of wind effects on structures by C. senator, the drag coefficients for the two directions are given below.

Where

$$CP = \text{wind force} = \frac{1}{2} ev^2A$$

e = density of Air
A = area of the structure normal to the wind direction.

From table A(3) of Engr. Design guide Heart Transfer by James R. Wetty the density of air at 70°C, e = 1.26kg/m3 was used for wind force on wider force fig (1).

Wind force = CD x ½ eva2A

= 2.2 x ½ x 1.26 (42)2 x 6 panels x 3 panels
= 65.5KN

$$\text{Force per point} = \frac{65.5}{3} = 21.83KN$$

Wind force in smaller force Fig (2)
Wind force = CD x ½ ev2A
= 1.4 x ½ x 1.26 x 422 x 5 panels x 3 panels
= 34.74KN

$$\text{Force per unit} = \frac{3474}{3} = 11.58KN$$

B. DEAD LOAD AND IMPOSED LOAD

Weight of empty tank = 9957kg=9957 (9.81) = 97.65KN

Weight of latwork = (0.4 of wt. of empty tank)

= 39.07KN

Sub-total = 136.75KN

Imposed load (wt. of water) 163.656m3 of water

Total design load = (136.75 + 1605.47)KN
= 1742.22KN

Plan area covered by the secondary beams = 6 panels x 5

panels = (1.22 x 6) x (1.22x5)
= 7.32 x 6.1m = 44.6522m

Pressure in secondary beams due to the design load = $\frac{1742.22KN}{44.652m^2}$

C. UNIFORMLY LOAD ON MAIN BEAMS (GIRDER)

Uniform distributed load on the girder is only due to its self weight. Uniform distributed load due to self weight = 0.36KN/M

NB: Loads on the girders ware the reaction from the secondary beam.

D. DESIGN OF STANCHION

1. Check for gravity forces + wind forces

Stanchion element 38 (254 x 102 x 25kg/m)

Maximum compressive force = f = 382.631N

Radius of gyration along yy = ryy = 21.1mm

Length of member = L = 1500mm

Effective length = le = 0.85L

= 0.85 x 1500

= 1275m

Slenderness ratio $\frac{le}{ryy}$

From T.17a BS5950, the permissible compressive

Stress = pc = 120N/mm2

Actual compressive stress, Fe = $\frac{F}{A}$

$= \frac{382.641 \text{ X } 10m^2N}{3210MM} = 119.190$

$\therefore \frac{Fc}{Pc} = \frac{119.19}{120} = 0.994.0$

The section is adequate in analysis of and design of the main beam

E. DESIGN OF EXTERNAL SECONDARY BEAM

A) Estimation of design load

Uniform distributed load to pressure (udL)

$= 39.02 \times ^{1.22}/_2 = 23.80KN$

Total udL – udL due to pressure x udL due to self wt.

= 23.08 x 0.17 = 23.97KN/m say 24KN/m

Design with 203 x 133 x 30kg/m

Ryy=3.17cm

Area = 38.2cm2

From computer result maximum moment is 36.7KN at point 6.10m

$$Zcal = \frac{\text{Max KNm}}{\text{permissble stree N/mm}^2}$$

$$= \frac{36.7 \text{ X } 10^3 \text{ X10 X Nm}^2(\text{Cm}^3)}{165\text{N}}$$

= 222.42CM3

 Elastic modulus =280cm>223cm,P.1173 steel designers manual : Recommended safe section for secondary beam

Both (internal and external) 203 x 133 x 30kg/m is adequate

III. RESULTS AND DISCUSSION

The results are presented in this section as follows with Table 1 to 3 and Figs. 1 to 3. Fig. 1 shows the plan for the supporting tower for an existing elevated Braithwaite Prestressed Steel Tank. Fig.2 shows shear force, binding moment and deflection of primary beam using Pce Software. The computer analysis result of 15meter tower with 163,656 litres (164m3) capacity took 1.15 minutes with high precision and without fear or bias. See discretization of 15m tower in Fig.3.

The maximum compressive force of 382.62KN was checked with the permissible stress of 165N/mm2 and found satisfactory with deal load and wind load so the section 254 x 146 x 43kg/m is satisfactory for the main beam with computer result of maximum bending moment of 76.2KN/m at point 4.8m.

Also the secondary beam was checked from the computer result of maximum bending moment of 36.6KN/m at point 6.18m was found satisfactory from the calculation sheet as 203 x 133 x 30kg/m, grade 43 used.

Table 1 shows Computer results of elevated water tank. Table 2 shows computer results of elevated water tank. Table 3 shows Computer results of elevated water tank.

1) **Specification**

1. CodeNo 653(6 platesx5platesx3plates)

2. ApproxemptywtNKGI. = 9957
3. Normalcapacity inlitres = 163,656(30,000gallon) (164m3)
4. Ht.ofthesupportingtower= 15m
5. Noofsecondarybeams = 6
6. Noofmainbeams(girders) = 3
7. No of Stanchions (I-beams) = 9

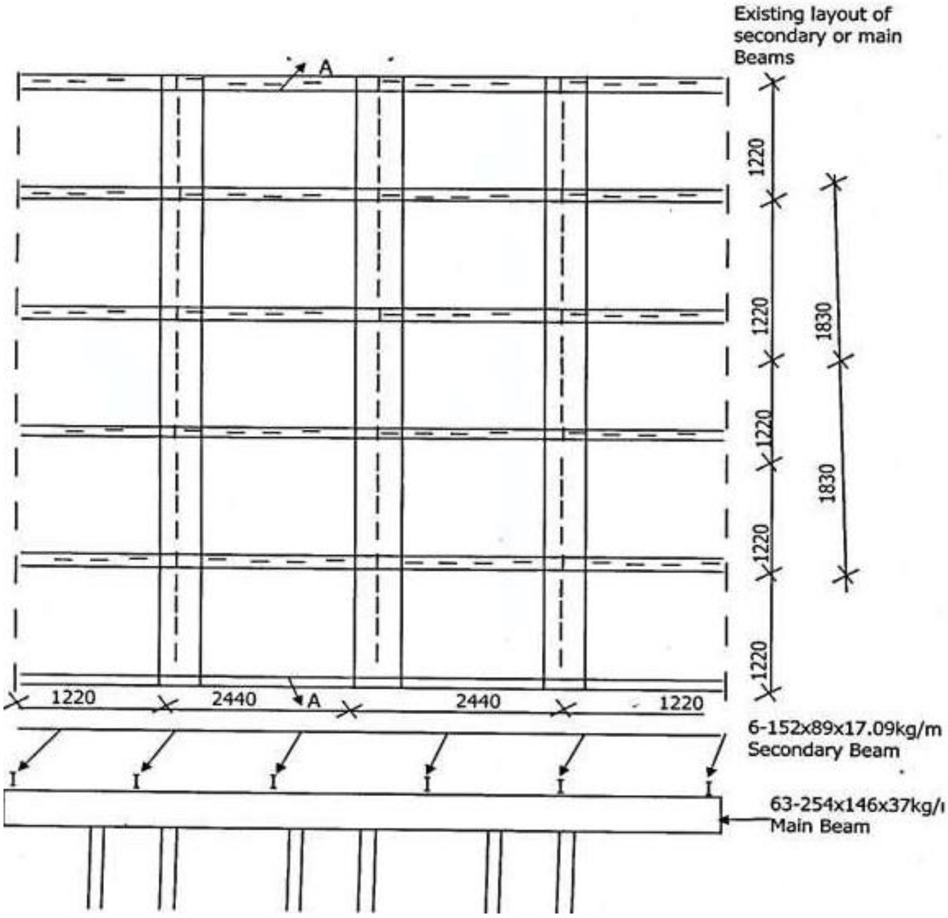

Fig. 1: Showing the plan for the supporting tower for an existing elevated Braithwaite Prestressed Steel Tank.

Table 1: Computer results of elevated water tank

COMPUTER RESULTS FOR 2-D PIN-JOINTED PLANE TRUSS
PROGRAMMER:AKIGWE IFEANYI MICHAEL

INTERNAL DATA

NUMBER OF ELEMENTS OR BARS	: 70
NUMBER OF JOINTS OR NODES	: 33
NUMBER OF SUPPORT OR BOUNDARY NODES	: 3
NUMBER OF LOADED NODE	: 3
MODULUS OF ELASTICITY IN KN/MM2	: 2.1E+08

NODAL COORDINATES

NODE	X (MM)	Y (MM)
1	0	0
2	2.44	0
3	4.88	0
4	0	1.5
5	2.44	1.5
6	4.88	1.5
7	0	3
8	2.44	3
9	4.88	3
10	0	4.5
11	2.44	4.5
12	4.88	4.5
13	0	6
14	2.44	6
15	4.88	6
16	0	7.5
17	2.44	7.5
18	4.88	7.5
19	0	9
20	2.44	9
21	4.88	9
22	0	10.5
23	2.44	10.5
24	4.88	10.5
25	0	12
26	2.44	12
27	4.88	12
28	0	13.5
29	2.44	13.5
30	4.88	13.5
31	0	15
32	2.44	15
33	4.88	15

ELEMENT CONNECTIVITY AND PROPERTIES

ELEMENT	END 1	END 2	AREA (MM2)
1	1	4	.00321
2	2	4	.000912
3	2	5	.00321
4	2	6	.000912
5	3	6	.00321
6	4	5	.000912
7	5	6	.000912
8	4	7	.00321
9	4	8	.000912
10	5	8	.00321

Table 2: Computer results of elevated water tank

6	-2.374331E-06	0
7	0	0
8	6.707036E-06	-1.159741E-04
9	2.284412E-06	-1.525879E-05
10	-1.053441E-05	4.851147E-05
11	0	-2.746582E-04
12	-2.260976E-06	-6.103516E-05
13	0	1.525879E-05
14	2.914094E-06	7.701025E-05
15	-1.370647E-05	-6.103516E-05
16	-3.089299E-06	1.759802E-04
17	-1.907349E-05	0
18	-6.198667E-05	1.373291E-04
19	0	2.13623E-04
20	1.7002E-05	-3.534668E-04
21	1.82753E-05	2.13623E-04
22	1.982055E-05	-1.229645E-04
23	-1.716614E-05	-2.13623E-04
24	4.622035E-05	-6.866455E-04
25	0	-4.119873E-04
26	-1.809228E-04	6.289311E-04
27	0	-2.13623E-04
28	2.861023E-05	2.441406E-04
29	-3.09624E-05	2.643813E-04
30	-3.814697E-06	4.882813E-04
31	-2.861023E-05	-277.4374
32	0	-228.6435
33	-11.57997	-277.4378

ELEMENT AXIAL FORCES
SIGN CONVENTION:COMPRESSION(-);TENSION(+)

ELEMENT	AXIAL FORCE(KN)
1	-252.3866
2	4.893387
3	-347.9407
4	-8.700037
5	-181.1979
6	20.65487
7	20.65487
8	-234.5635
9	-29.13909
10	-347.9407
11	-15.54567
12	-177.6128
13	0
14	2.284412E-06
15	-234.5635
16	29.01124
17	-394.6102
18	15.41781
19	-177.6128
20	23.42531
21	23.42531
22	-189.776
23	-56.50902
24	-394.6099
25	-42.9156
26	-147.0631
27	0
28	-1.370647E-05

Table 3: Computer results of elevated water tank

29	-189.776
30	-54.36892
31	-382.6136
32	-67.96232
33	-147.063
34	22.71314
35	22.71316
36	-232.76
37	27.70711
38	-382.6136
39	41.30042
40	-204.2849
41	0
42	1.82753E-05
43	-232.7602
44	-32.10843
45	-305.7237
46	-45.70177
47	-204.2851
48	18.14872
49	18.14874
50	-255.2339
51	10.80453
52	-305.7234
53	24.39793
54	-240.9962
55	0
56	0
57	-255.2335
58	-19.83595
59	-259.3929
60	-33.42914
61	-240.996
62	16.89818
63	28.47821
64	-265.622
65	-22.56112
66	-228.6435
67	-36.1543
68	-258.5035
69	19.2198

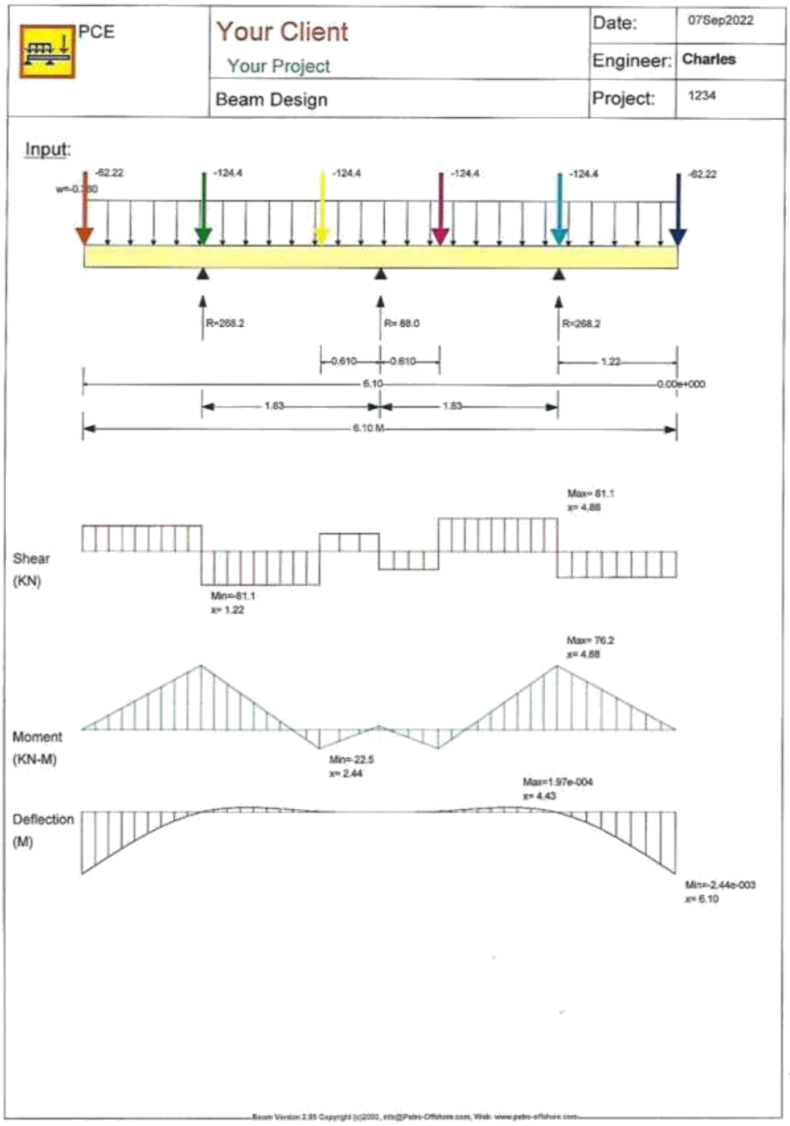

Fig 2: Figure shows shear force, binding moment and deflection of primary beam using Pce Software

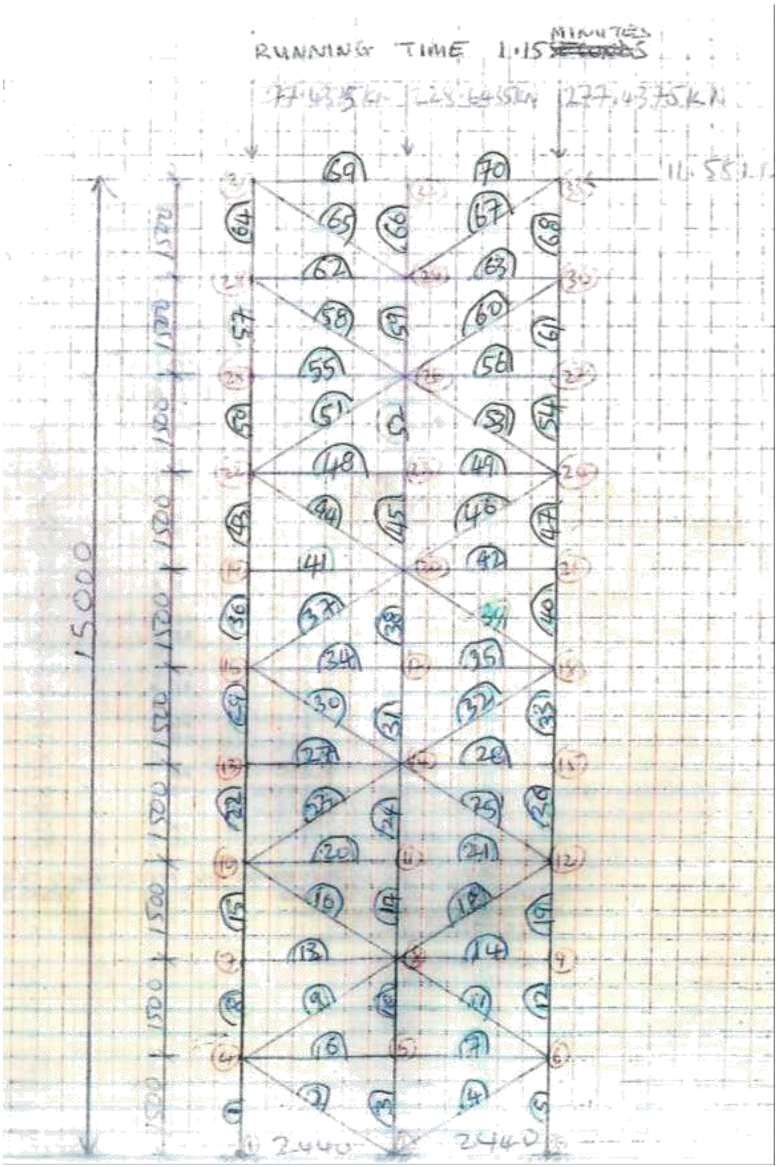

Fig.3: Discretization of 15m elevated tower with wind and dead loads

IV. CONCLUSION

Storage of water in the form of tanks for drinking and washing purposes, swimming pools for exercise and enjoyment and sewage sedimentation tanks are gaining increasing importance in the present-day life. For small capacities we go for rectangular water tanks while for bigger capacities we provide circular water tanks. Design of water is a very tedious method. Particularly design of under-ground tank involves lots of mathematical formular and calculation. It is also time consuming. Hence, program gives a solution to the above problems.

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