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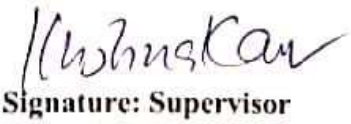

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Department of Civil Engineering
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Supervisor

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12.07.2024

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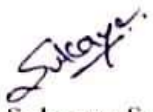

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*"With profound gratitude, I dedicate this thesis to my cherished **Parents**, whose steadfast support has been my cornerstone, and to **Professor Krishna Kant Pathak**, whose mentorship and guidance have fueled my perseverance and dedication".*

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List of notations and abbreviations used in software programs

Symbol or Notation	Description
w	Self-weight of the member
R	General notation for radius of domes
Θ	Angle subtended to the centre by any member
$T1$	Meridional forces acting at member
$T2$	Hoop forces acting at member
ψ	Slope of any member
E	Modulus of elasticity of member
t	Thickness of the member
x	Horizontal displacement of member
Δ	Lambda parameter for domes
K	General coefficients of member
$M.S.$	Moment stiffnesses of member
$T.S.$	Thrust stiffnesses of member
$CorrM.S$	Corresponding moment stiffnesses of member
$CorrT.S.$	Corresponding thrust stiffnesses of member
R_1	Radius of top Dome
K_{td}	Stiffness coefficient of the top dome
λ_{td} and λ_{bd}	Lemda parameter for top & bottom domes
$\theta_{td,}$ and θ_{bd}	half Angle subtended by top & bottom domes respectively.
γ_w	Specific weight of water
P	Radial pressure at any depth
H	Height of the cylindrical wall
R	Radius of any beam
M	coefficient for the cylindrical wall
Z	Moment of inertia for tank walls for the cylindrical wall
W_z	Load on conical dome
Y	Vertical distance at the at any point from top of CD

x_{cd}	Horizontal displacement at CD
Δ	Delta parameter for CD
ξ *and* ξ'	Eta parameter for CD
L	Slant length of conical dome
t_{cd1} *and* t_{cd2}	Thickness of conical dome at top and bottom respectively
k_1, k_2, k_3 & k_4	Stiffness coefficients of conical dome at top, and bottom
k'_1, k'_2, k'_3 & k'_4	Stiffness coefficients of conical dome at bottom
K *and* K'	Equivalent stiffness coefficient at conical dome
$\theta_{cd1,}$ *and* θ_{cd2}	Angle of conical dome at top & bottom with respect to vertical
x_{td} *and* ψ_{td}	Horizontal displacement and rotation of top dome respectively
h_1 *and* h_2	Height of top and bottom dome
t_1	Thickness of top dome respectively
b_2 *and* d_2	Width and depth of top ring beam respectively
t_{3top} *and* $t_{3bottom}$	Thickness of cylindrical wall at top and bottom respectively
b_4 *and* d_4	Width and depth of middle ring beam respectively
t_{5top} *and* $t_{5bottom}$	Thickness of conical dome at top and bottom respectively
t_6	Thickness of bottom dome respectively
b_7 *and* d_7	Width and depth of bottom ring beam respectively
Dc	Diameter of column
b_9 *and* d_9	Width and depth of braces respectively
b_{10} *and* d_{10}	Width and depth of foundation beam respectively
d_{11}	Depth of raft slab
ψ_{td}, x_{td}	Rotation and horizontal displacement of the top dome
ψ_1, x_1	Rotation and horizontal displacement of the top ring beam or net rotation and net displacement of joint

ψ_{wall}, x_{wall}	Rotation and horizontal displacement of the wall
ψ_2, x_2	Rotation and horizontal displacement of the middle ring beam i.e. net rotation and net displacement of joint
ψ_{cd1} , ψ_{cd2}, x_{cd1}, x_{cd2}	Rotation and horizontal displacement of the conical dome at top and bottom
ψ_{bd}, x_{bd}	Rotation and horizontal displacement of the bottom dome
ψ_3, x_3	Rotation and horizontal displacement of the bottom ring beam i.e. net rotation and net displacement of joint
w_1 -w_7	Self weight and live load acting on members in kN/m^2 of each member of the tanks body
SW1-SW11	Total weight of each member of the tank body in kN
A1-A11	Volume of concrete used in member
Q1-Q11	Quantity of steel in each member of tank
T_1	Meridional forces at top dome
H_1	Horizontal forces at top dome
MS1-MS7	Moment stiffness of any member
CorrMS1 or CorrTS1 and CorrMS7 or CorrMS7	Corresponding stiffness of any member
TS1- TS7	Thrust stiffnesses of any member
WL_{Wall}	Vertical load due to water at cylindrical wall
TL_{MRB}	Total vertical per meter load at level of middle ring beam
$BM\ at\ MRB$	Bending moment at middle ring beam
$HThrust\ at\ MRB$	Horizontal thrust at middle ring beam
WL_{Cd}	Water load at C.D.
TL_{CD}	Total load per meter at bottom of C.D.
$HF_{CDTop}, HF_{CDBottom}$	Horizontal force at top and bottom of conical dome
T_{5Top}, $T_{5Bottom}$	Meridional forces at top and bottom of conical dome
A_{rcd}	Angle of conical dome to the vertical

WL_{BD}	Water load at bottom dome
TL_{BD}	Total load at bottom dome per square meter
$HForce_{BD}$	Horizontal thrust imposed at bottom support
TL_{MGB}	Total load at main girder beam
H_{NET}	Net horizontal force at bottom support
$HTension1 - HTension7$	Actual hoop tension in members of tank body
A_{st}	Area of reinforcement
$A_{st}H1 - AstH7$	Hoop tension Reinforcement in all the members of tank body.
$A_{st}M1 - AstM7$	Moment reinforcement in all the members of tanks body.
f_y, f_{ck}	Steel stresses and characteristic strength of concrete
f_{ct}	Tensile stress in concrete
f_{ct1}-f_{ct7}	Tensile stress in concrete in each member of tank body
M	Modular ratio
H_u	Factored hoop tension in any member
A_{stM}	Reinforcement for moment
NOs	Calculation of number of bars
Φ	Diameter of bar used
$A_{\emptyset}$	Area of bar
τ_{max}	Maximum shear stress
τ_c	Shear stress in concrete
P	Percentage reinforcement
F_S	Stress at any level
e_1	Strain at level of stress
e_2	Strain due stiffening effect of concrete in direct tension
e_m	Average steel strain
w_{cr}, w_{cr1}	Crack width in tension and flexure respectively
a_{cr}	Distance from the point considered to the surface of the nearest longitudinal bar

S_p	Half average spacing between bars
C_{min}	Minimum cover to the longitudinal bar
$x_{n.a.}$	Depth of neutral axis
$(A_{st})_{pro}$	Area of steel provided
H_{stress}	Factored hoop stresses
T_u	Factored meridional thrust
T_{stress}	Meridional stresses
N	Number of columns
$\propto_{centre}$	The angle at the center in radians
$d_{critical}$	Distance of critical section
$\propto_{critical}$	Angle at the critical section in radians
BM_{cr}	Bending moment at the critical Section
M_t	Twisting moment
$BM_{continuity}$	BM by continuity equations
M_{EQ}	Equivalent moment
M_{DM}	Design moment
E	Eccentricity
d_{hf}	Distance of hoop force
La	Depth of neutral axis of main girder beam
F_T	Force of tension
F_C	Force of compression
BM_{mid}	BM at midspan
$d_{shearcr}$	Critical Section for shear
SF_{MGB}	Shear forces
$\propto_{Twist}$	Angle for twisting moment
$H_{staging}$	Height of staging
H_{Total}	Total height of staging
$C.l._{Panel}$	Clear length of each panel above FGL
Cl_{brace}	Clear length of brace
$SWuptobrace$	Total weight per column upto braces

V_{bs}	Basic wind speed
$\boldsymbol{k_1}$	Risk coefficient
$\boldsymbol{k_2}$	Terrain roughness and height
$\boldsymbol{k_3}$	Topography factor
$\boldsymbol{k_4}$	Importance factor for cyclonic regions
V_z	Design wind speed
P_z	Design wind pressure
$WPatTankbody$	Wind load on container
$Htankcg$	Wind load acting at 'x'
N_{Eff}	Effective Number of column
W_{up}	Wind pressure at each panel except lower panel
W_{lp}	Wind pressure at lower panel
W_{brace}	Wind pressure at brace
$SF_{AT\ Panel\ 1} - SF_{AT\ Panel\ 5}$	Shear force at panel I-V
$EWT_1 and\ EWT_2$	Effective weight for full and empty tank conditions
$Def_1\ and\ Def_2$	Deflection for full and empty tank condition
n_2	Number of braces
$T_{Full}\ and\ T_{Empty}$	Time period in full tank and empty tank
$\boldsymbol{Z}$	Zone factor
$\boldsymbol{I}$	Importance factor
$\boldsymbol{R}$	Response reduction factor
Sa/g	Average response acceleration coefficient
A_{HFull}, A_{HEmpty}	Horizontal earthquake acceleration coefficient in F.T. and E.T.
V_{BFull}, V_{BEmpty}	Base shear calculation V_B in full and empty tank
OTM_w, OTM_s	Over turning moment in wind and seismic
$P_u\ and\ N_8$	Axial loads and number of column respectively
$BM_{MaxinCol}$	Max B.M. in one column in lowest panel in full tank
$BMbrace_1, BMbrace_2, Mbrace_F$	Moments in braces
sw	Density of steel in t/m^3 = 7.8 t/m^3

b_{raft}, d_{eff10}	Width of raft, effective depth of F.B.
D_i, $R_i, D_o and\ R_o$	Inner diameter, outer diameter, inner and outer radius of raft
Bc	Net Safe Bearing Capacity of Soil
$MaxUP$	Upward pressure when tank is full.
$MaxP_o$	Max pressure on soil due to Lateral forces at outer egde
$MaxDP$	Max downward pressure, when tank is full
$MaxUP_{ET}$	Upward pressure when tank is empty
$MaxDP_{ET}$	Max downward pressure at empty tank
$MaxUPth$	Maximum upthrust at outer edge,
BM_i	B.M. at the inner face of beam,
BM_o	B.M. at the outer face of beam,
f_m , E_m , V_m	Modulus of elasticity, stress and volume fraction of mortar
f_r , E_r , V_{rL}	Modulus of elasticity, stress and volume fraction of reinforcement in ferrocement
f_{fc} , E_{Fc}	Modulus of elasticity, stress and volume fraction of ferrocement
n_f	Modular ratio of ferrocement
A_{tr}	Transformed area
A_m	Area of mortar
A_{ri}	Area of reinforcement provided in layers
ΔL_{min}	Minimum crack spacing
p_f, τ, σ_{mu}	Perimeter, Shear stress and ultimate mortar stress in ferrocement respectively
ΔL_{max}	Maximum crack spacing
ΔL_{av}	Average crack spacing
W_{av}	Average crack width
N_u	Hoop carrying capacity of lining
ε_{SH}	Shrinkage dtrain in ferrocement

b_f, c	Width if Ferrocement, depth of neutral axis
f'_c	Compressive strength of ferrocement
C_c	Compression force in concrete stress block
C_{ri}	Compression force in concrete stress block due to reinforcement
ε_{ri}	Stain at any point on the section
T_{ri}	Tensile forces at each layer of reinforcement
Ast_f	Reinforcement area required in ferrocement for Hoop
HT_{fl}	Hoop tension in ferrocement
t_f	Thickness of ferrocement lining
V_r	Volume fraction
S_r	Specific surface area reinforcement
σ_r	Service stress in reinforcement
σ	Estimated stress at crack stabilization
W_{max}	Crack width under Hoop in Ferrocement

List of acronyms

Acronyms	Description
BM	Bending moments
B.R.B	Bottom ring beam
C.D.	Conical dome
CWT I	Conventional type I tank
CWT II	Conventional type II tank
E.T.	Empty tank
F.T.	Full tank
HWT	Hybrid water tanks
M.R.B	Middle ring beam
O.M.	Over -turning moment
T.D.	Top dome
T.R.B	Top ring beam