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DESIGN OF THE SUPPORT STRUCTURE FOR THE PIPE LINE SYSTEM

DOREDLA NAGARAJU [1], BHUKYA PRATHIMA BAI [2], CHILUKURI TRIPURA REDDY [3], TADIKAMALLA NARENDRA [4], K.SIVA REDDY[5]

[1] ASSISTANT PROFESSOR, DEPARTMENT OF CIVIL ENGINEERING, NARASARAOPETA ENGINEERING COLLEGE, NARASARAOPET, INDIA
[2,3,4] UG STUDENT, DEPARTMENT OF CIVIL ENGINEERING, NARASARAOPETA ENGINEERING COLLEGE, NARASARAOPET, INDIA

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Abstract: *This study has been undertaken to investigate the determinants of Design of Support structure in Santhi Nagar near Narasaraopeta using IS 456:2000. The design code for the manufacturing of DI K7 pipes which are to be used for the design of the proposed support structure by using IS 456:200 and Working stress method. To design the support structure, the design requirements to be considered from the existing site conditions and the parameters that are required to be followed for the design water flow and to make the structure to withstand the loads & forces carried by the supports and the footings .the design was undergone with manual calculations by using standard design practices and this was under the AMRUT scheme prestigiously carried out by the Government of INDIA.*

Key Words: *water demand, pedestal, footing, working stress method, limit state method, Support structure.*

1. Introduction

1.1.Pipes for Water Supply System

Pipes which are commonly used in water supply system are given below.

1. Galvanized Iron (GI) Pipes
2. Concrete Pipes

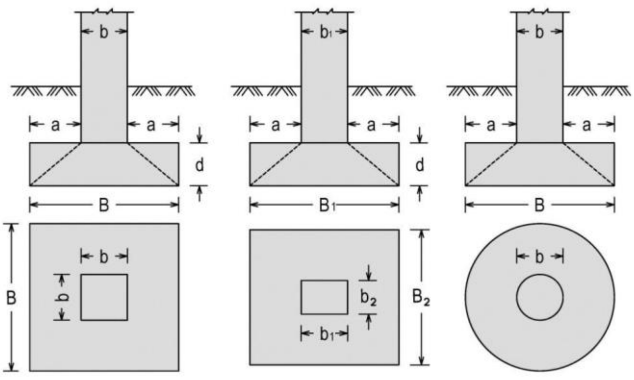
Galvanized Iron (GI) Pipes:

This type of pipe is used for water supply work inside the building. These pipes are wrought steel pipes provided with zinc coating. They are available in light, medium and heavy grades depending on the thickness of the metal. For a 15 mm GI pipe, the thicknesses are 2.0, 2.65 & 3.25 for the light, medium and heavy grades, respectively. Generally the medium grade pipes are used for internal plumbing in building. Mostly screw and socket joints are used for G.I. pipes.

Concrete Pipes:

Unreinforced pipes of small diameters as well as reinforced and prestressed concrete pipes of large diameters are available for water supply and other uses. Small unreinforced concrete pipes are very much used for drainage of rain water. Large diameter pipes are generally used for major water supply works.

Isolated footings can have different shapes in plan; generally, it depends upon the shape of cross section of the column.



2. OBJECTIVES FOR THE STUDY

1) To prepare a design of a new water pipe line system by using design standards.
2) To select pipe material and pipe size according to design standards.

3. RESEARCH METHODOLOGY

Data:

Inner dia of pipe ID 600 mm
Thickness of inlining t_1 12 mm
Thickness of pipe shell t_s 6 mm
Thickness of gunniting t_g 12 mm
Outer dia of the pipe OD 660 mm
As per IS 2062-2006,
min.yield stress for welded pipe, fy 2500 ksc
Unit weight of steel g_s 7850 kg/m3
Unit weight for internal cement mortar lining
g_m 2200 kg/m3

Unit weight of water
g_w 1000 kg/m3
Maximum internal pressure
p_w 0.17 Mpa

Spacing of supports, pedestal
L 5.00 m

Angle of bedding
β 120 deg

Weight calculation (pipe with water in it)

Weight of inlining = π*(0.6+0.012)*0.012*2200
= 50.758 kg/m

Weight of the pipe shell = π*(0.6+2*0.012+0.006)*0.006*7850
= 93.22 kg/m

Weight of gunniting = π*(0.6+2*(0.012+0.006)+0.012)*0.012*220)
= 53.744 kg/m

Weight of water running in the pipe = π*0.6^2/4*1000
= 280.743 kg/m

Total load due to the pipe and water in it = 50.758+93.22+53.744+282.743
= 480.5 kg/m

(a) Maximum value of localized stress in pipe (saddle stress)

FI = K * p/t^2 * log(r/t)

Where,
k a factor obtained from expression (0.02-0.00012(β-90))
B angle of support
K = 0.0164
P saddle reaction including 10% for continuity
= 2642.60 kg
t_s Shell thickness = 6 mm
R radius of pipe, (D/2) = 300 mm
F_l = 470.949 ksc

(b)Bending stress

F_b = bending moment / modulus of shell plate

Where, bending moment, M = WL^2/8
= 480.465*5^2/8
= 1501.5 kg-m

Sectional n π*R^2*t =(22/7)*300^2*6/1000
= 1696 cm^4

f_b =1501.5*100/1696
= 88.53ksc

(c)Hoop stress

F_h = P*d/2/t 1.7*(60/2)(0.6) = 85 ksc

(d) Rim stress

F_r=F_h/4 = 85/4 = 21.25 ksc

LONGITUDINAL STRESS

Maximum permissible longitudinal stress

F' = fy *0.6*efficiency of circumferential joint = 2500*0.6*0.8

F' = 1200 ksc

Total actual longitudinal stress, F' = saddle stress +bending stress +rim stress
= fI + fb + fr
= 470.949+88.53+21.25
F' = 580.7
ksc < 1200 SAFE

CIRCUMFERENTIAL STRESS

Maximum permissible circumferential stress

F"= Fy* 6*efficiency of longitudinal joint
= 2500*0.6*0.9

F" = 1350 ksc

Total circumferential stress, F" = saddle stress +hoop stress= fI + fh
= 470.949+85

F" = 555.9 ksc <1350 SAFE

Hence, c/c distance between the supports, (i.e, pedestal), 5m is sufficient for angle of support being 120 deg.

DESIGN OF SUPPORT STRUCTURE, PEDESTAL 'P'

Grade of concrete M20
Grade of steel Fe 500

Permissible stress in compression, bending, σcbc
= 7 N/mm^2

Permissible stress in compression, direct, σcc
= 5 N/mm^2

Permissible tensile stress in steel
= 230 N/mm^2

Design constants

m	=	280/(3 σcbc)	=	13.3333
k	=	m σcbc / (m σcbc)=		0.2887
j	=	1- k/3	=	0.9038
Q	=	½ kj σcbc	=	0.9132
θ		$= \tan^{-1}(\frac{H}{L})$	=	27 deg

Hoop force in pipeline,σ_t = PD/2
= 51 KN

Longitudinal force in the pipeline = 0.303* σt
= 15.45 KN

Vertical component = 7.01 KN

15.45*SIN (27*PI ()/180)

Horizontal component = 13.77 KN

15.45*COS (27*PI ()/180)

Reaction due to pipe and water on support = 26.89 KN

Self-weight of the pedestal = 29.9 KN

Total load coming on to the support = 63.8 KN

Pedestal design

Dimensions of pedestal

Either side offset lengthwise = 0.200 m

The distance between the offsets = 0.600 m

Length (0.6+2*0.2) = 1.000 m

Width = 0.230 m

Height of the support

Above ground level = 4.00 m (upto the base of pipe)

Below ground level = 1.100 m (upto the base of pedestal)

Total height = 5.100 m

Stress on concrete support = load/area

63.793/(1*0.23) = 277.361 KN/m^2

Permissible stress on concrete = 5000 KN/m^2

277.361< 5000 KN/m^2

(The size of the pedestal, (1m*0.23m), is provided based on the structural requirement of pi and ring girder. The actual stress on concrete is 277.36 kN/Sq.m, which is very meager.)

Design for pedestal

Reinforcement

To determine the gross area of the pedestal

P = $\sigma cc.Ac$ +σsc.Asc

σcc = 5 N/mm^2 (permissible stress in concrete)

σsc = 230 N/mm^2 (permissible stress in steel)

Ac = net area of the concrete section (mm^2)

Asc = c/s area of the longitudinal bar R/F (mm^2)

Dia of bar Φ = 10 mm

A_{sc} π*(10)^2/4 = 78.54 mm^2

A_g = $\frac{p}{\sigma cc(1-p)+p\sigma sc}$

P = percentage of steel assumed = 1% (minimum 0.8% to resist direct stress)

A_g = $\frac{63.793*1000}{5*(1-0.01)+0.01*230}$

= 8799.034 mm^2

Area of steel required = 1% of Ag

0.01*8799.034 = 88 mm^2

Spacing of the bars required = 1230 mm

Provided say 200 mm

Number of longitudinal bars provided = perimeter of the pedestal/spacing

2*(1000+230)/200 = 12.3

Say 14 no's

Area of steel provided = area of bar*number of bars

78.54*14 = 1099.56 mm^2

Area of steel provided area of steel required

1099.56 > 87.99 mm^2 SAFE

Minimum area steel required = 0.12% of BD

0.23*1*0.12/100 = 276 mm^2 SAFE

However provide reinforcement of 10 mm dia bars @ 2

DESIGN OF FOUNDATION FOR SUPPORT [P]

DATA

Unit weight of concrete = 25 KN/m^3

Unit weight of soil = 21 KN/m^3

Grade of concrete M20

Details for footing design

Maximum load of pipe @ support R_B & R_D =63.793 KN

Weight of the pedestal = L*B*H *unit weight

[5.265*1*0.23*25] = 30.274KN

Deduction for the portion OAXB

Area of OAXB = Θ /360*(πr^2) = 0.443 m

= 120/360 * (π * 0.33) ^2

= 0.114 m^2 = 0.1329 m

OX' = (d/2) * sin (30)

= 0.165 m

X'X = (D/2) - ox'

= 0.165 M

AB = (0.66/2) * sin (120)/sin(30)

= 0.600 M

Area of OAB = 0.05 m^2 = 0.5*0.165*0.6

Area of AXB = area of OAXB –area of OAB
= 0.114-0.05
Area of AXB = 0.064 m^3
Vol. = 0.015 m^3

Total weight of the portion to be deducted
= 0.375 KN
0.015*25

Actual weight of the pedestal 30.274 -0.375
= 29.899

= 29.899 KN

Pedestal dimension
Lenth = 1 m
Width = 0.23 m
Base area = ` 0.23 m^2

Load at the base portion = 93.692 KN
Stress = 93.692/0.23 = 407.357 KN/m^2

Footing dimension

Projection on either side of width of pedestal W = 0.45m
Projection on either side of length of pedestal L = 0.45m
Depth of foundation excluding pedestal = 0.6 m
Width of foundation 0.23+2*0.45 = 1.13 m
Length of foundation 1+2*0.45 = 1.9 m
Depth of foundation = 0.6 m
Base area of foundation 1.13*1.9 = 2.147 m^2

Load at the base portion = 93.692+ (2.147*0.6*25) = 125.897 KN

Moment due to the horizontal component of longitudinal force of water in pipe

Horizontal component = 13.77 KN
Moment = 83.03 KN-m
= 83030000 N-mm

Moment due to frictional force, M_1

M_1 = 77923000 N-mm

Moment due to passive pressure of soil, M_2

Height of soil up to footing base = 1.7 m
Angle of internal friction of soil = 30 deg
Passive earth pressure $k_p\gamma H$ = 107.1 KN-m^2
Passive force $(k_p\gamma H)\ H/2*L_f$ = 172.967 kn
Lever arm for soil portion from base of footing
= 0.567 m

Moment due to passive force of soil, M_2
= 172.967*0.567
= 98.072 KN-m
M_2 = 98072000 N-mm

Moment due to active pressure of soil, M_3

Active earth pressure $k_a\gamma H$ = 11.9 KN/m^2
Active force $(k_a\gamma H)\ H/2*L_f$ = 19.219 KN
Lever arm for soil portion from base of footing
0.567 m

Moment due to active force of soil, M_3
= 19.219*0.567
= 10.897 KN-m
= 10897000 N-mm

Design of section

M_4 = $P_0L/8*(B-b)^2$
B = 1.13 m L = 1.9 m
b = 0.23 m I = 1 m
area of the footing at the base A = BL
= 2.147 m^2

Weight coming on the footing W = 93.692 KN
Net uupward pressure at the footing,
p_0 = W/A = 93.692/2.147 = 43.639 KN/m^2
M_4 = (43.639*1.9)/8*(1.13-0.23)^2 = 8.395 KN-m
= 8.395*10^6 N-mm

Total moment acting on footing,M =[M1-M2+M3]+M4
=17.647*10^6 N-mm

d = $\sqrt{\{\frac{M}{(QL)}\}}$
= {(17.647*10^6)/(0.9132*1900)}^(1/2)
= 100.85 mm required
= 544.00 mm provided
Hence safe

Check for shear (width wise)

One way shear

Shear force, "F" = ½*[B-b]-d
V = p_0 F
V = 43.639*(0.5*(1.13-0.23)-0.544)*1
= -4.102 KN
τv = v/bd
= -4102/(1000*544)
= -0.008 N/mm^2
Permissible shear stress = kτc

K = 1

τc = 0.174 N/mm²

k τc = 0.174 N/mm²

As, τv < k τc safe

Two way shear

Shear force, "F" = $P_0[B^2-b_0^2]$

= $p_0[B^2-(b+d)^2]$

F = 43.64*[1.13^2-(0.23+0.544)^2]

= 29.6 KN

τv = $F/(4b_0d)$

= (29.6*1000)/[4*(230+544)*544]

= 0.018 N/mm²

Permissible shear stress

K = (0.15+β)

β = shorter/longer side of the column (or) pedestal

= 0.23

K = 0.73

Kτc = $k*0.16\sqrt{fck}$

= 0.73*0.16*(20)^(1/2)

= 0.522 N/mm²

τc = 1.8 N/mm² M20

(table 24, IS 456:2000)

As, τv < Kτc < τc max SAFE

Check for shear (length wise)

One way shear

Shear force,"F" = ½[L-I]-d

V = p_0F = -4.102 KN

τv = V/bd =-0.008 N/mm²

Permissible shear stress

K = 1

τc = 0.174 N/mm²

Kτc = 0.174 N/mm²

As, τv < Kτc safe

Two way shear

Shear force, "F" =$P_0[L^2-I_0^2]$ =$P_0[L^2-(I+d)^2)$

= 53.5 KN

τv = $F/4I_0d$ = 0.009 N/mm²

Permissible shear stress = Kτc

K = (0.15+β)

β = shorter/longer side of the column(or)pedestal

= 0.23

K

Kτc = $k*0.16\sqrt{fck}$

= 0.73*0.16*(20)^(1/2)

= 0.522 N/mm²

τc = 1.8 N/mm² M20

(table 24, IS 456:2000)

As, τv < Kτc < τc max SAFE

Check for stability

Frictional force = 13.44 KN

Active force = 19.22 KN

Passive force = 172.97 KN

Force from pipeline = 125.90 KN

Safety against sliding:

Coefficient of friction, μ = 0.75

Fs = 8.187 > 1 SAFE

Check for stresses in soil:

P = 125.897 KN

M = 17.647 KN-m

A = 2.147 m²

z = 0.404 m³

P max P/A+M/Z= (125.897/2.147) + (17.647/0.404) =102.319 KN/m²

P min P/A-M/Z= (125.897/2.147)-(17.647/0.404) =14.958 KN/m²

For no tension condition, minimum stress allowed

Reinforcement calculation

Main reinforcement

Area of steel required = $M/(\sigma st\ j\ d)$

17.647*10^6/(230*0.9038*544) = 156.053 mm²

Dia of the bar = 12 mm

Area of a single bar = 113.097 mm²

Min.Ast required = 0.12% (bD)

0.12*1000*600/100 = 720 mm²

Spacing required = Ab*1000/Ast

113.097*1000/720 = 157.079 mm

Say 150 mm

Area of steel provided = 753.98 mm²

Hence okay

Percentage of reinforcement provided = 0.139 %

Therefore, provided 12 mm dia bars @150 mm c/c spacing along width direction

Distribution reinforcement

Min. area of steel required = 0.12%

(bD)

0.12/100*1000*600	=	720 mm^2
Dia of the bar	=	12 mm
Area of a single bar	=	113.097 mm^2
Spacing required	=	
A_b*1000/Ast		
113.097*1000/720	=	157.079 mm
Say 150 mm		
Area of steel provided	=	753.98 mm^2

Hence okay

Therefore, provided 12 mm dia bars @ 150 mm c/c along length direction

3. CONCLUSIONS

As we had encountered canal as obstruction while laying the pipeline system, so we had divided the total obstruction length into 4 bays & 3 support structures are proposed for total length. For each individual support structure, force of gravity, pipe load (with water) and water pressure on the walls of the support structure are considered to transfer the forces through the pedestal to the proposed footings of the support structure. Under the maximum operating pressure designed according to IS 8329: 2000 (ANNEX "E" Table -I), IS 456:2000 and working stress methods are adopted. From the methodology we need to provide a pedestal of Length 1.000 m, Width 0.230 m, Total height 5.100 m & footing with width of foundation 1.13 m, Length of foundation 1.9 m, Depth of foundation 0.6 m is to be provided for the design considerations.

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BIOGRAPHIES

DOREDLANAGARAJU M.Tech [SE],MBA, LMISTE, AMIE,J r. AM.ASCE, Assistant Professor,
Department of Civil Engineering, Narasaraopeta Engineering College [Autonomous], Narasaraopet, Andhra Pradesh, India.

BHUKYA PRATHIMA BAI,
UG STUDENT,
Department of Civil Engineering, Narasaraopeta Engineering College [Autonomous], Narasaraopet, Andhra Pradesh, India.

CHILUKURI TRIPURA REDDY,
UG STUDENT
Department of Civil Engineering, Narasaraopeta Engineering College[Autonomous], Narasaraopet, Andhra Pradesh,India.

TADIKAMALLA NARENDRA,
UG STUDENT
Department of Civil Engineering, Narasaraopeta Engineering College [Autonomous], Narasaraopet, Andhra Pradesh,India.

K.SIVA REDDY
UG STUDENT
Department of Civil Engineering, Narasaraopeta Engineering College,[Autonomous], Narasaraopet, Andhra Pradesh, India.