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Analysis of Structural Dynamics Turbo Generator Load on Foundation Structure for Estimation Stresses during Vertical Excavation Using Finite Element Method

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Abstract

The load over the turbo generator should be visualized .Based on the finite element value and experimental value of soil parameter as such major principal stresses and minor principal stresses, normal stresses, shear stresses, bearing pressure were analyzed for the analysis of foundation structure .The analysis of factor bending moment, intensity of pressure, maximum pressure , main area of steel ,distribution of steel were carried out for a comparative statement of the two dimensional and three dimensional approach .Three dimensional approach became realistic and exact approach over two dimensional approach .

1. Introduction to Structural Dynamics Turbo Generator Foundation Load

Statics load ,Beam weight Q = 9L =1.2X7.9X24 =225.72KN

Machine weight p= 700 KN ,Load due to longitudinal girder N1= 1.2x1.0x.65x24=18.72 kN

$1/3^{rd}$ self weight of the column ,N2=.8x24x9.3/3=59.52Kn

H1= 12.0-1.2-1.5 = 9.3 m ,N=N1+N2 =78.24 KN ,lb=1/12x1x$(1.2)^3$,Effective span and height of the frame Lo =3.4m

Z=.6,h0= 9.9m,Z=.6m,X=.5m ,

h0/l0 = 9.9/3.4=2.917,x/10=.5/3.4=.14,α =.01,Effective span , l=l0- 2x α =3.4-2x.5x.01 =3.39m

Effective height h=h0-z α =9.9 -.6x.01 =9.798 m , K=(Ib/Ic)h/l =5.293

Deflection due to concentrated load P = (Pl /06Ef Ib)*(2k+1)/k+2
=(700*3.39/96*3*10e7*.144)*(2*5.293+1)/(2*5.293+2) =6.063E-5 m

The deflection due to udl at beam center
=(Ql3/384EfIb)x(5k+2)/(k+2)=
225.72*3.39/384*3*10e7*.144(5*5.293+2)/(5.2932+2) =4,2910e-6 m
Deflection at the center of the beam due to shearing forces
= 3/5(L/Ef Ab(P+Q/2) =3/5X(3.39/3X10E+7X1.2)X(700+225.72/2) =39.17X10E-7m
The axial compression of the column
= (h/Ef Ac)*(N+ (P+Q)/2) =(9.8/3*10e7*1.0)*(43.04+(700+225.72)/2) =61.29*10e-7m
Total deflection at center of the beam = Δ1+Δ2+Δ3+Δ4
=147.05*10e-6 m
Vertical natural frequencies of the frame A1 is (fn) A1= 30/(Δ)½
Frame A2 ,**Beam cross section area ,**Ab = 1.4mx1.2m =1.687m2 ,Column cross section area =1.0*1.4 =1.4 m2,Ib= 1/12)*1.4*1.2³ =0.2016 m4,Ic=1/12*1.4*1.0³= .116 m4 ,K= 2.322,l=3.2m,h=4.3 m,static load ,P= 900 KN ,Q= 91= 96.7 KN ,N=(.85+.65) * 1.2 *24 + 1/3(1.4*24*3.8) = 85.76 Kn,Δ1=(900*3.2³/96*3*10e+7*.2016)(2*2.322+1)/4.322 =66.33*10e-6 m,Δ2=(96.76*3.2³/3.84*3*10e7*.2016)(5*2.322+2)/2.322+2 =4.3*10e-6 m ,Δ3 = 3/5(3.2/310e7*1.68(900 + 96.76/2)=36.12*10e-6,Δ4= 4.3/3*10e7*1.68(85.76+(900+96.76)/2), Total deflection at center of the beam = Δ1+Δ2+Δ3+Δ4 =166.55*10e-6 m,(fn)A2= 30/Δ½ = 2324.6 rpm,Frame A3,Ab= 1.44 m2,Ac = 1.2 m2,Ib= 1/12(1.2*1³)= .1 m4,K= 2.322,Loads P= 600KN,Q= ql=1.44*2.4*24=82.94 Kn,N=.85*1.2*1*24+1/3*1.2*24*3.8 =60.96 KN,Δ1= (600*3.2³/96*3*10e7*.1728)(2*2.322+1)/4.322 =51.59*10e-6m,Δ2= 82.94*3.2³/384*3*10e7*1.44(5*2.322+2/2+2.322) =28.5*10e-6m,Δ3= 3/5*3.2/3*10e7*1.44(600+82.94/2) =28.5*10e-6 m,Δ4=4.3/3*10e7*1.2(60.96+682.94/2) =48.06*10e-6 m,Δ=132.44*10e-6 m ,(fn)An= 30/(Δ)½ =2606.82 rpm,Fnh=horizontal natural frequency,Khi = lateral stiffness of cross frame I of in ton /meter,Wi =total weight on the frame I including machine weight ,weight transevers beam and weight transmitted by the longitudinal girder.

IG = ∑wi * Gi ² = WA * GA² + WB * GB²,XGi = Distance of weight Wi from the vertical axis through the center of gravity ,IH = ∑ khi * Hi² = KhA * HA² + KhB * HB² + KhC * HC² + KhD * HD²

XHi= distances of cross frame I from the center of rigidity H ,α0=1/2(e²∑ khi/IG + ∑ khi/∑Wi + I H/IG).

Horizontal frequencies, Wi = Pi + +QI + 2 Ni,WA1 = 700 +69.12+ 2* 43.04 = 855.20 KN

WA2= 900+ 96.76+2*85.76=1168.28 kN,WA3= 600+ 82.94+ 2*60.96=804.86 KN

XG =(1168.28*2.5+804.86*5.5)/ 2828.34,XG =2.6m,K= 2.322m ,XG = Disatance of resultant from the axis of the frame ,(Δh)A1 = h³/12Ef Ic(3k+2)/6k+1 + 6h/5EfAc(1+Ach*18k²/ (Abl(6k+1)²) + h3/Ef Ac l2* (18k²/ (Abl(6k+1)²),=(4.3³/(12*3*10e7*0.0833)*(3*2.322+2)/(6*2.322+1)²)+6*4.3/5*3*10e7

*1(1+1*4.3/12*3.2(18(2.322)²/(6*2.322+1)²)+
4.3³*18*2.322²/3*10e7*1*3.2(6*2.322+1)²(Δh)A1= 19.5710e-7 m/kn

Frame A2,(Δh)A2 = 4.3³* (3* 1.63 +2)/12*3*10e7*.116*6*1.63+1) + 6*4.3/(5*3*10e7*1.4(1+1*1418(2.322) ²/1.68*3.2(6*2.322+1))+ 4.3³*18*2.322²/3*10e7*1.4*3.2²(6*2.322+1)²=11.4*10e7+1.36*10e3+.804*10e-7 =13.57*10-7 m/KN

(Δh)A3 = (4.3³* 3*2.322 +2)/12*3*10E7*.1*6*2.322+1+6*4./5*3*10E7*1.2(1+1*1.4*18*2.322²/1.44*3.2*(6* 2.322+1)²

+4.3²/3*10E7*1.2*3.2²(18*2.322²/(6*2.322+1)²) =15.85*10e-7 m/KN,Rigidity Factor ,KhA1 = 1/(Δh)A1= 510.98*10e3 KN/m,KhA2 = 1/(Δh)A2= 736.9*10e3 KN/m,KhA3 = 1/(Δh)A3= 630.91*10e3 KN/m,∑ Kh = 1878800 KN/m,XH =(756.91*2.5+630.91*5.5)/187800 = 2.827 m,Eccentricity e = XH –HG =2.827-2.6 =.277 M,IG =855.2*2.6 ² + 1168(28(2.6-2.5)²+ 630.9(5.5-2.827)²=8670 KN/m2,IH =510.98*2.827²+ 736.91*(2.827-2.5)²+630(5.5- 2.827)² =8670.3 KN/m2

αe∑α0 = 1/2[e²∑kh/IG + ∑Kh/∑wiG + IH/IC],Where ∑ WAi = ∑w = ∑WA1 + ∑WA2 + ∑w A3

α0 = ½[.227² 1878800/12561.1 +187880/2828.34 + 8670.3/12561.1] = 336.33

Horizontal natural frequency: fnh = 30 [α0 Ŧ {α0² - Kh IH/WiG IG}½]½ = 30 [336.33 Ŧ {336.33² - 1878800X8670.3/2828.34X12561.1}½]½ = 30 [689.05 Ŧ335.64] ½ = 777.6 rpm

Amplitude Calculation: Vertical Amplitude & Magnification factor

Δ = 0.4 for concrete foundation ,fn≤ fm than fm=fn for computation of av,M=7.85 for all frames (fn≤ fm),Static displacement fv ,Rb =Rotating weigh ,(Rb)A1 =35 Kg,(Rb)A2 = 70 Kg,(Rb) A3 = 50 Kg,Rotaing weights on frame column (Rc coming from along frames and crtoss frame A1,A2 and A3 taken together) are given (Rc) A1 = 60/2 =30 kN,(RC) A2 = 60/2 + 40/2 =50 kN,(RC) A3 = 20 KN,Centrifugal forces on cross beam (Cu) and frame column (Cc) given by Cb = 0.2 Rb (fn/fm) ²,Cc = 0.2 Rc (fn/fm) ²,Rb and Rc are the rotating weights respectively on cross beams and frames column respectively (A1, A2 ,A3).

(Cb)A1 =0.2*35*(2473.85/3000) ²:(Cb)A2=0.2*70*(2473.85/3000) ²:(Cb)A3=0.2*50*(2473.85/3000) ²:(Cb)A1= 4.07 kN:Cb)A2=6.0 KN:(Cb)A3=3.02 KN:(Δv) A1 =(Cb l²/96 Ef Ib)* 2k+1/k+2 + (3/5)*(1/EfAb)*Cb + h/EfAc (Cb+Cc)/2:(Δv) A1 =(4.75*3.2³/96*3*E+7*0.144)*(2*2.322+1)/(2+2.322) +3/5 (3.2*4.75/3*E+7*1.12)+ 4.3/3*E+7*1.1(4.75+4.07)/2 =.49*E-7+.253*E-6+.632*E-6 ,= 1.3*E-6 m: (av) A1 = M(Δv)A1 = 7.85*1.375*e-6,=10.79*E-6 m ≤ E-2*2 mm:(Δv)A2 =(8.4*3.2³/96*3*E+7*.2016)*2*(2.322+1)/(2+2.322) ,+3/5(3.2*8.4/(3*E+7*1.68)+4.3/3*E+7*1.4(8.4+6)/2 = .62*E-6 + .32*E-6+ .737*E-6 =1.677*E-6 m:(av) A2 = M((Δv) A2) = 7.82*1.677*E-6 = 13.16* E-6 m ≤ .02mm:(Δv) A3 =(7.55*3.2³ /96*3*E+7*.1728)* 2*(2.322+1)/(2+2.322) +3/5*(3.2*7.55/(3*E+7*1.44)+4.3/3*E+7*1.2(7.55+3.02)/2: (av) A3 = M((Δv) A3) = 7.85*1.615*E-6 = 12.67*E-6m ≤ 0.02 mm

Horizontal Amplitude :Higher horizontal frequency ,R= ∑ (Rb + Rc) :∑ Cn = 0.2 ∑ I (Rb + Rc) $(fn/fm)^2$ =.2*255*(776.6/3000) ^{2} =3.42 KN,Lateral deflection= ∑Ch /∑Kh:=3.42/1878800 = 1.82*E-6 m,Amplitude (an) = 14.28*E-6 ≤ 0.04 mm

Dynamic Forces, Vertical dynamic forces for Frame A1 with corrected frequencies f n

fn' = fn * 1.2 ,(fn')ΔI = 2968.6 ≤ 3000, Dynamic Forces are taken as under,Fb = 16 Rb $(fn'/fn)^2$

Frame –A1,(Fb) A1 = 16*35*(2968.6/3000) ^{2}= 548.3 KN:Frame –A2,(Fb)A2 = 16*70*(1.2*2324.6/3000)^2 = 968.3 KN:Frame A3,fn' = 1.2 *2606.82 = 3128.1,(fn) A3 = 3128.1 3000

(Fb)A3 = 2 Fmax/ [{ 1-(fm/fn)+ (fn/fn') ^{2}(Δ/∏)^2}]½: = 2*50/[{ 1-(3000/3128.1)+ (3000/3128.1) ^{2}(.4/∏)^2}]½ =684.4 KN,**Horizontal Dyanamic forces ,** Fn = 16∑(Rb+Rc) (fn h'/fm) ^{2} =16*255*(1.2*7877.6/3000) ^{2} =394.7 KN,(Fn) i = Fh * Khi/ ∑Khi,(Fn) A1i = 394.7 * 510980 / 1878800i,(Fn) A2 =394.7 *510980/1878800i,(Fn) A3 =132.5 Kn

Design of Cross Frame ,Frame A1 ,Moment Due to concentrated load P= 700 KN ,K= Ib/Ic =2.322,MA = MD =Pl/8(k+2) = 700*3.2/8*4.972=64.78 KNm ,MB=MC = -2MA =-129.56 KNm

Maximum Moment at beam center ,Mp = P'/4 + MB = 430.4 KN-M:Shear forces ,Q B = QC =250 KN,**Moment due to Uniformly distributed load , Q**=q*L = 69.12 KN,MA = MD= ql2 /12(k+2) = 69.12 *3.2/1284.322 = 4.26 KN m:MB = MC= -2MA =-8.53 KN m,MP= ql2/8 + MB=19.12 KN m,QC=QB= 34.56 KN,**Moment due to vertical Dynamic ,v**= 548.3 KN,MA=MD = Ŧ 50.7 KNm,MB=MC = -2 MA = Ŧ 101.4 KNm ,Mp = (548*3.2/8-101.4) = 117.92 KN m ,QB = QC= Ŧ 274.1 KN , **Moment and shear due to Horizontal Dynamic force for (Fn) A1**= 107.3 KN,MA= ½*Fn*(3k+1)/(6k+1) =Ŧ(1/2)*107.3*4.3*[3*(2.322+1)/6*(2.322+1)] = Ŧ 123.1 KN m:MD = -MA = Ŧ 123.1 KN m,MB = Fn* h/2 *3k/(6k+1) = 107.6 KN m,:Shear Force QB =-2MB/l = Ŧ 67.2 KN,QC=-QB= Ŧ 67.2 KN ,**Moment and shear due to earth quake forces ,Assuming that the site is located in zone iv and seismic coefficient =0.65 ,Increase it by 50 % (as per IS Code 1893 -1970 , The coefficient become 0.075** ,**Lateral earth quake force =0.075*2828.34 = 212.1 KN**

MA=-MD= Ŧ 243.3 KN-m,MB=-MC = Ŧ 212.6 KNm,QB= Ŧ 132.8 KN :Temperature Effect ,MB=MC = -3EfIb∑T/h(K+2),T= 20 ° (assumed design value for the temperature),∑ = thermal expansion coefficient =11* E-6/° C = -3*3*E-7*.144*11*e-6*20/4.3*4.322 =153.41 KN-m ,MA = MD = - MB(k+1)/k =152.41(3.322/2.322)= 219.4 KN-m Shrinkage Load due to shrinkage equivalent to -10° c.

2. Conclusion for Bending Moment chart and worst possible combination

Moment due to	**MA KN-m**	**MB KN-m**	**Mp KN-m**	**Remarks**
P(Vertical load)	64.78	-129.56	430.04	
Q,UDL	4.26	-8.53	19.12	
V(Vertical Dynamic load)	Ŧ 5Ŧ0.7	Ŧ 101.4	Ŧ 117.92	
H(Horizontal Dynamic load)	Ŧ 123.1	Ŧ 107.6	0	
Earth quake	Ŧ 243.3	Ŧ 212.6		
Differential temperature	219.4	-163.4	-0153.4	
Shrinkage	-109.7	76.7	76.7	
Worts possible combination				
Maximum	654.8	-611.7	643.7	
Minimum	407.06	258.8	177.8	

3. Result of Amplitude and Frequencies

Amplitude –Vertical in m	10.79*E-6	13.16*E-6	12.67*E-6	
Frequencies in rpm	2473	2324	2606	

Worst Possible combination of Bending Moment

End of Portal – Fixed	**Bending Moment at A and D**	**Bending Moment B and C**	**Bending Moment At P**
Maximum Bending Moment	+475 KN-m	_ 492.256 KN-m	692.1`62 KN-m
Minimum Bending Moment	- 88.588 KN-m	+ 474.62 KN-m	-121.731 KN-m

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