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Impact of Static & Dynamic load at the base of High Speed Turbo Generator Using Three Dimensional Finite Element Stresses

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Abstract

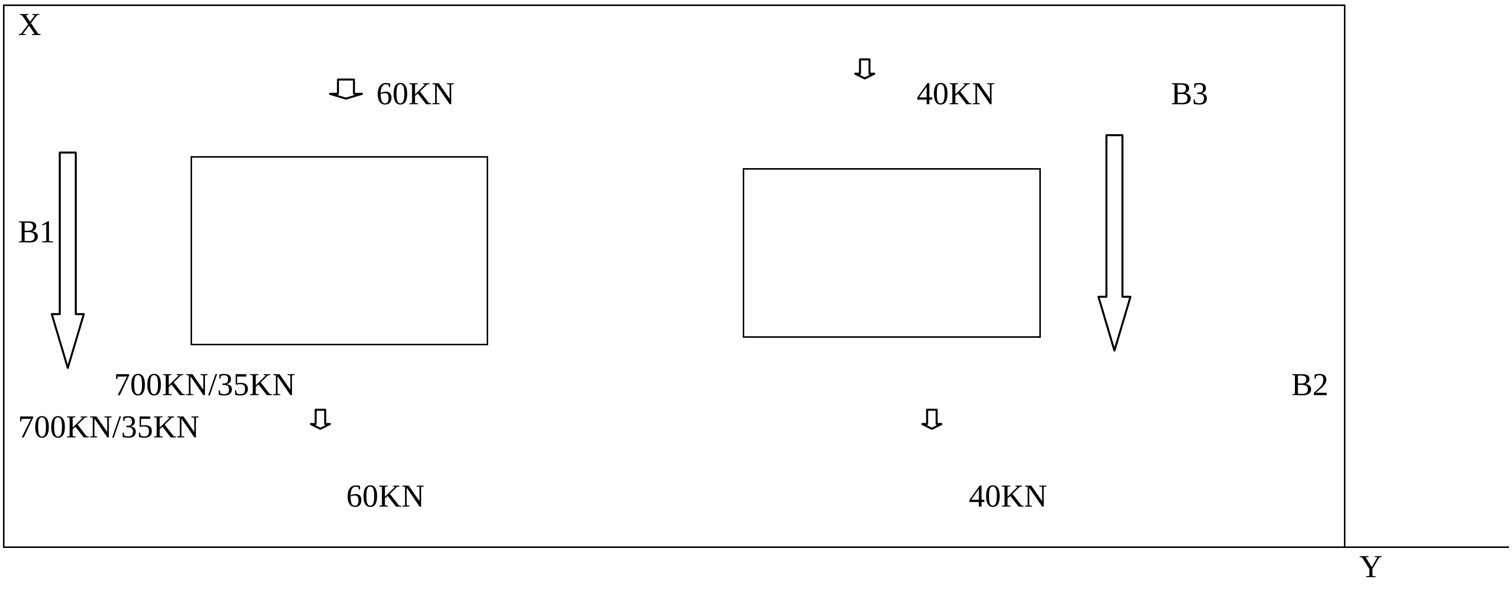
This paper is meant to disseminate the state-of-the-art works on the importance of vertical ground motion and horizontal ground movement under high speed generator in the power sector. The author particularly likes to raise these with worst possible moment when the turbine gave high amplitude under the high frequency compared to the natural frequency. From the collection of works worldwide, it is concluded that neglecting vertical component of the ground motion may lead to serious underestimation of the demand, over-estimation of the capacity and thus jeopardize overall structural safety . At this sensitive period of transition the author from his capacity, as a keen professor of the structure of structural dynamics and vibration engineering for vertical motion and its effects on the structure likes to make few recommendations to analyze the important structure in civil engineering Hence the author highly recommends the modern approach and soft ware to analyze structure using Finite element method for any desired depth below the important structure. The mathematical modeling followed with the finite element modeling. The impacts of the worst possible moment with the help of vertical and horizontal movement are evaluated. The basis of the design load over the foundation and the impact of the stresses over the large area are predicted.

The bearing pressure at the different layers may be predicted to deign for the large amplitude of vertical movement. The structural components for design of the turbine can be verified with the help of the three dimensional stresses. The realistic approach became the three dimensional stresses analysis compared to two dimensional stresses were established .

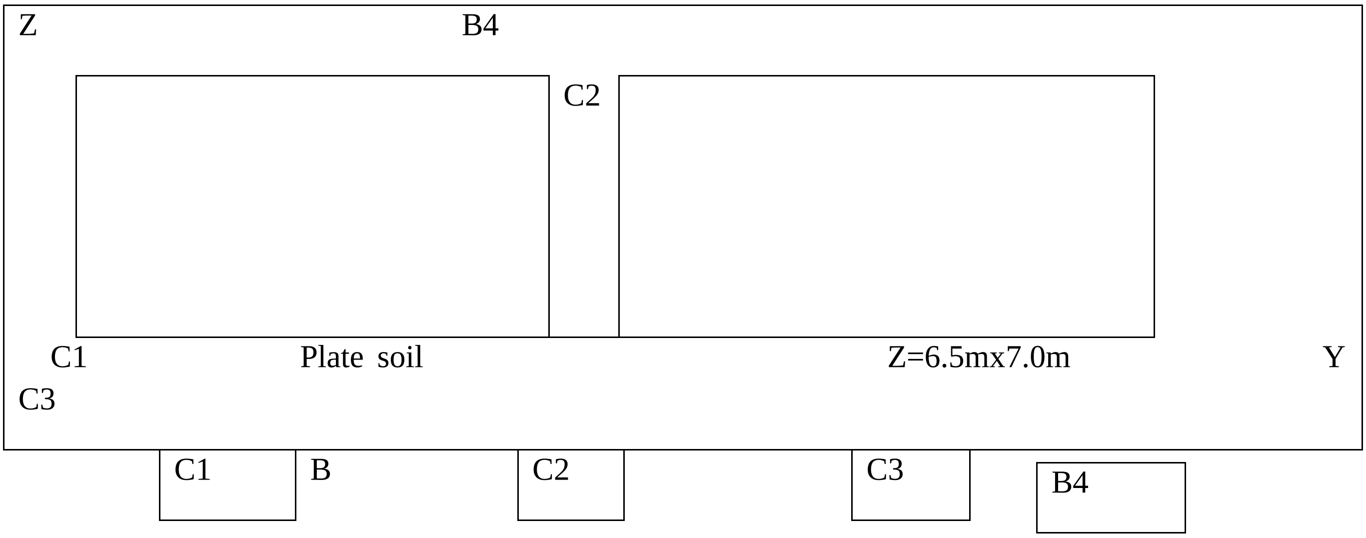
Keyword: *Ground motion, vibration engineering, vertical motion, worst possible moment, mathematical modeling, bearing pressure, three dimensional stresses.*

Introduction of Problem; An extension of the author international published paper of the structural dynamics problem to the hydro power engineering. The Turbo generator had been analyzed for the depth of 12.0 m from the ground level. The design of foundation structure parameter were to analyze three dimensional stresses in three dimensional excavation during application of of static and self weight of the foundation applied on the surface of the excavated surface. The application of the static, dynamic and foundation weight were applied on the top surface of the foundation. The speed of the turbo generator was 3200 r.p.m. The eccentricity of the loading equal to 0.005 m and the thickness of base of raft were taken as 1500mm .The plan area of the excavated surface was taken as 7000mmx4400mm. The unit weight of the concrete was 24 KN/m2, young's modulus of framed foundation materials was taken 3x10e+7 KN/m2, poisson's ratio of concrete = 0.25, weigt of raft was taken 7.000mx4.400mx1.500mx24. Beam were expressed as c1, c2, c3 .The dimension of B1=1.0 m X 1.2 m , B2= 1.4 m X1.2 m, B3=1.2 m X 1.2 m, B4=1.0 mX1.2 m,C1=1.0 mX1.0 m ,C2=1.4 mX1.0 m,C3=1.2 mX1.0 m. 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.

Analytical analysis for the worst possible combination of moment based on vibration, vertical dynamic amplitude, static and dynamic load condition as under:

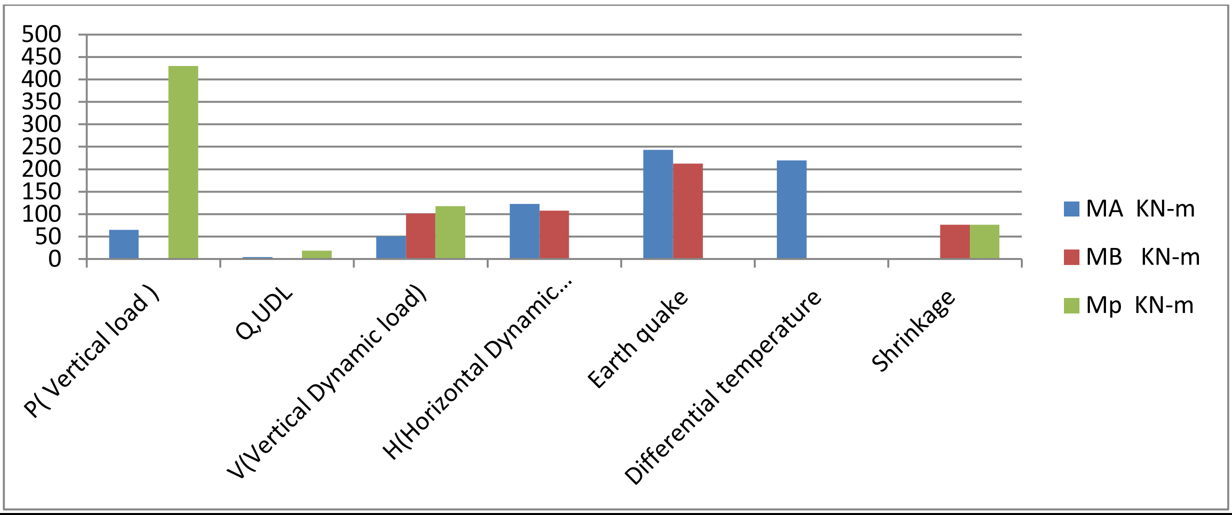


X-Y Axes 4.4mX7.0m

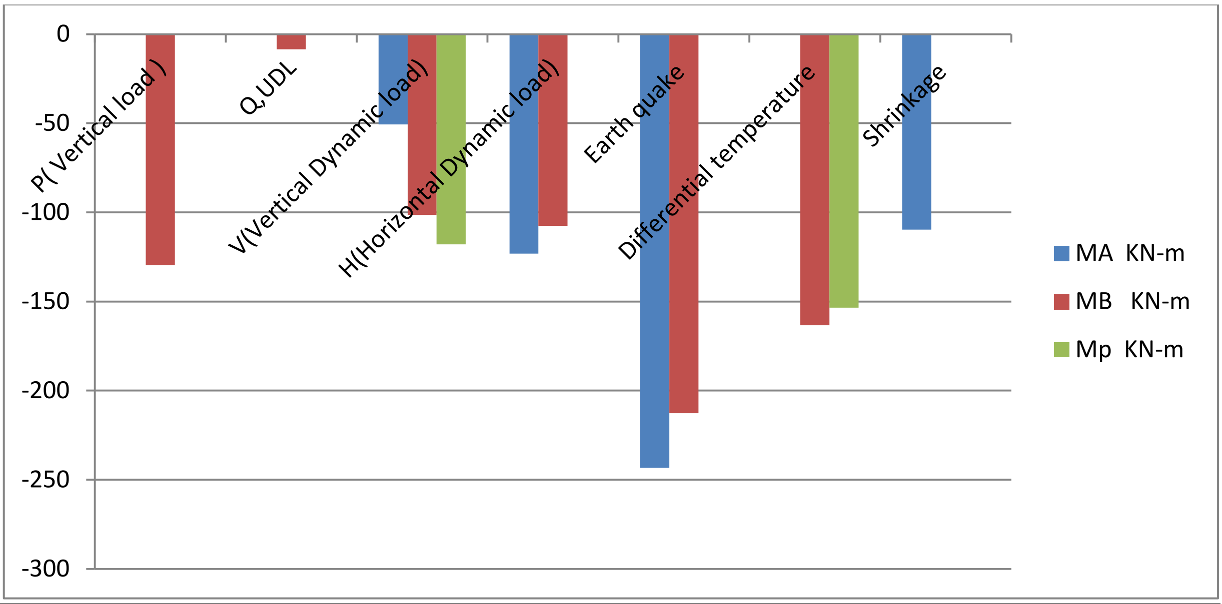


2.Methodology of Analysis

2.1 The solution of the above problem gave Bending Moment chart and worst possible combination of moment:



2.2 The variation of Sagging Moment for vertical load, UDL,Vertical and Horizontal Dynamic Load, earth quake ,differential temperature etc

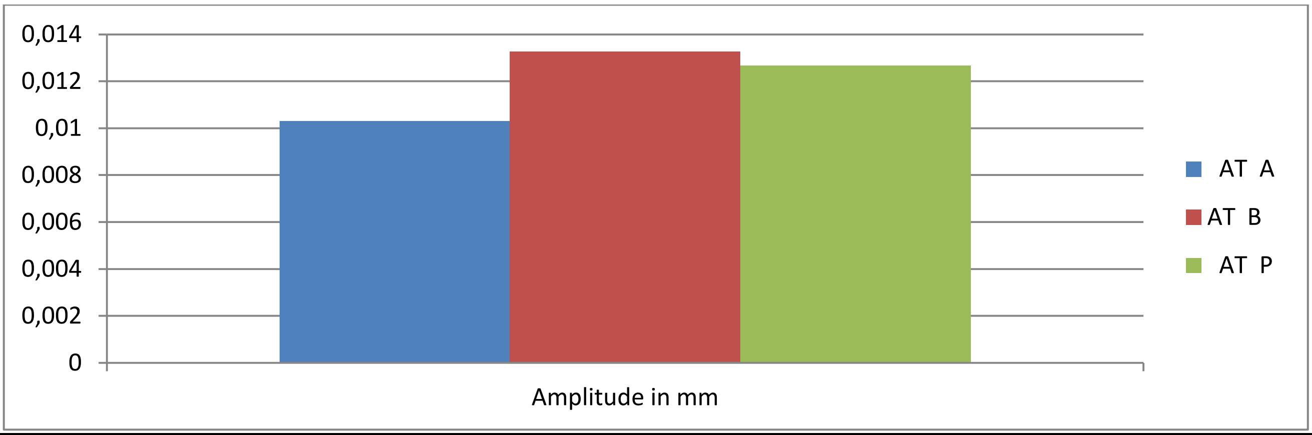


The variation of Hogging Moment for vertical load, UDL, Vertical and Horizontal Dynamic Load, earth quake, differential temperature etc

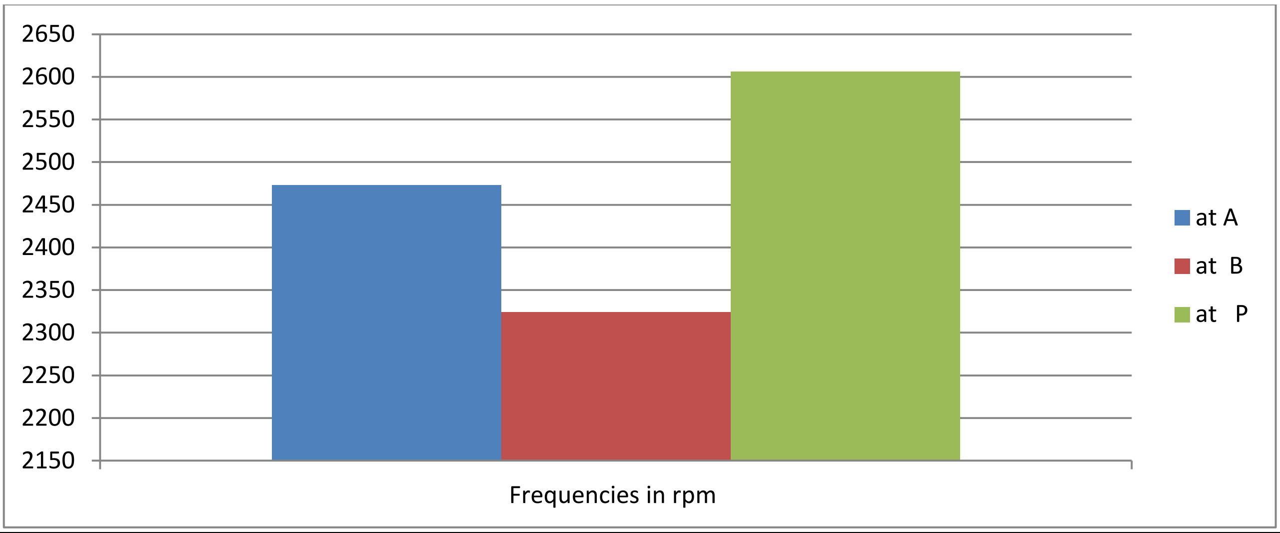
The graphical representation in plate number 01 showed the higher moment in the Mp in KN m were sagging in nature, however at the MB the moment were shown hogging in nature and at MA, the nature of the moment were observed as sagging .These three moment were estimated only for the vertical load. The similar type of the moment were estimated in case of the application of uniformly distributed load. The percentage of variation of 16% of Mp and 20 % of Mp for Moment MA in case of Vertical load and uniformly distributed. The moment due to vertical and horizontal dynamic load over the structure were estimated for all these location such as MA, MB and Mp. The vertical Dynamic load over the above location developed the Hogging as well as sagging moment, the maximum moment due to the above condition were estimated and were shown in the graph for Mp location only. However the moment for the MA and MB were estimated and shown in graph. The nature of the moment were seen as sagging and hogging in nature. The earth quake moment were also estimated. The highest value were estimated and shown in the graph for MA. The highest sagging moment were estimated for the MA location due to differential temperature compared to MB. The nature of the moment is sagging in nature. However the nature of the moment other than MA were estimated as Hogging in nature. The Highest Hogging moment were estimated in MA compared to MB and Mp where the moment were estimated as Positive. The combination of all Moment gave an estimation to analyze the most worst and critical condition of moment. The variation of the moment in all three case were estimated and shown in the graph. The highest sagging moment for the case MA were seen in the graph sheet. The MB showed the hogging moment in the graph.

2.3 Result of Amplitude and Frequencies

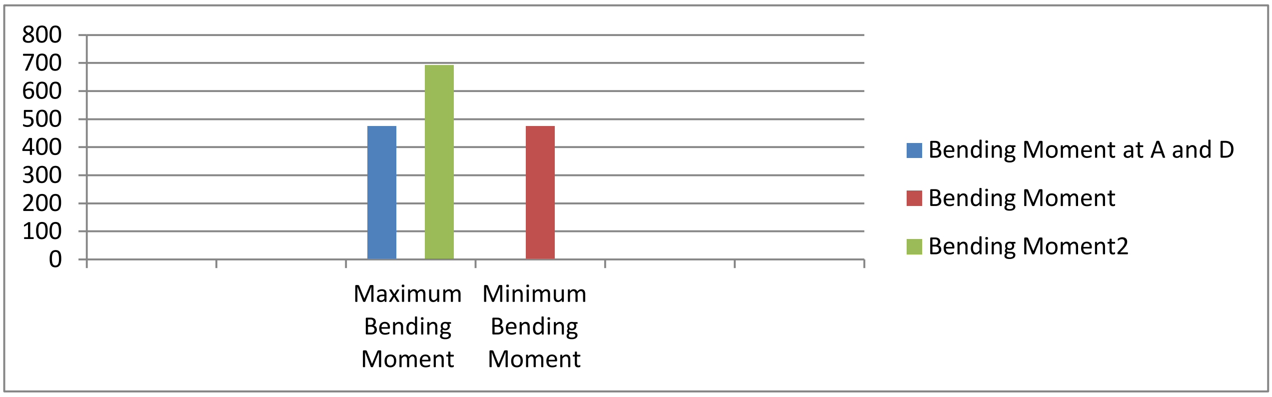
The vertical amplitude were estimated



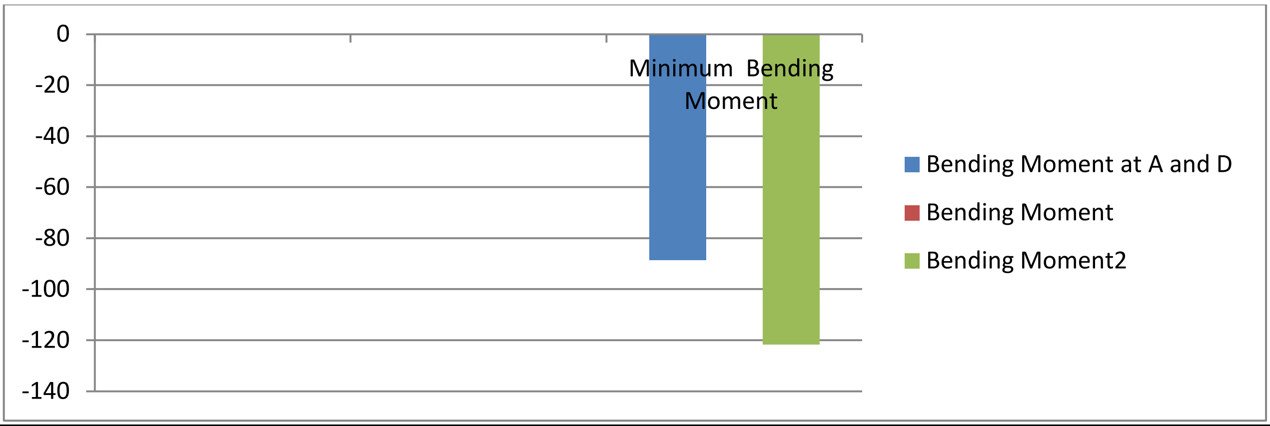
Variation of the amplitude along the vertical plane shown at the different location of the structure; The highest amplitude at the location B were estimated and showed in the above bar chart. But the amplitude at the location A and P were estimated lower than the location B.



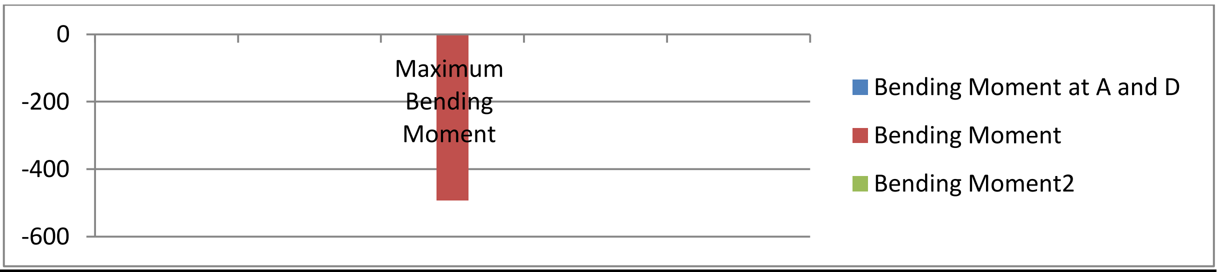
2.4 Variation of the frequency along the plane shown at the different location of the Structure: The highest frequency was observed on the location P , However the lowest Frequency was seen on the location B as shown in the Bar chart. The variation of the frequency on the location B was estimated as 7% less compared to the location P.



2.5 Worst Possible combination of Bending Moment: Worst possible combinations of the moment along the location P were visualized highest in respect of the maximum value of the moment. However the nature of the moment were estimated as Sagging in nature as shown in the bar chart. The maximum hogging moment were estimated along the location B . However hogging moment were created minimum at the location A as represented in the Bar Chart. The variation of moment maximum and minimum represented in Bar chart.



2.6 Varition of minimum Hogging moment at the different locaton A,D AND AT 2



2.7 Variation of Hogging moment

2.8 Service Moment and Shear Forces

Moment MA= +475.129 KN-m, Moment MB = - 492.256 KN-m, Maximum Possible Moment at center of span BC =692.162- 492.256 =199.906 KN-m

Factored Moment were computed as under MUA =1.5 * 475.129 = 712.6935 KN-M

MUB=1.5*492.256 = 738.384 KN-m,

Positive B.M. at the center of BC = 1.5* 199.960 = 299.859 KN-m, Factored shear forces at B=1.5 * 907.62 = 1361.43 KN, Working Shear forces at A =(MA + MB)/4 = 241.84625 KN

Factored shear Forces at A =1.58 *241.84 = 362.769 KN

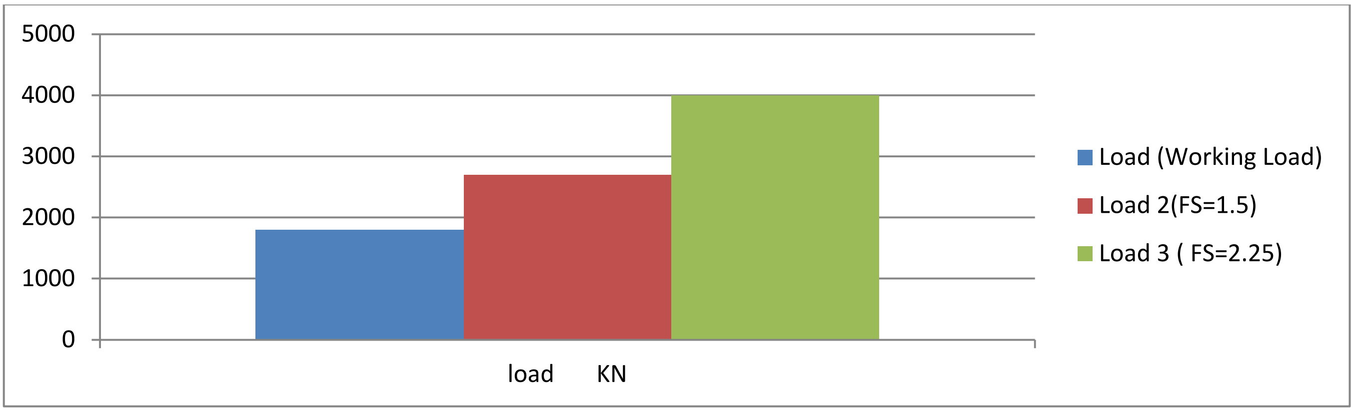
Design of Beam Section

IS: 456-2000, clause 38.1, The ultimate Moment = 299.859 KN-m

The moment of resistance of the T-section assuming the normal axes

MUR = 0.36 fck bf Df *(d-0.42 Df) = 3.581000/6 + 1.2*1000 + 6*120 = 2503 mm

Design of foundation structure using modern techniques based on the result of three dimensional excavation using finite element method: Axial load on column = 1361.43 KN, self wt of column = 1.0*1.0*12*24 = 288 KN, self wt of foundation at 10 % = 164.93 KN, Total load W = 1814.36 KN, Moment at the base =475.129 KN-m, Eccentricity e = M/P,=475.129/1814.36 = 0.26187 m ==261.87 mm The worst Possible combination of load at the bottom of the foundation structure



The applications of load over the area were considered as 4000 KN/m2.

3.0 Result and Discussion: FEM analysis to Obtain the Three Dimensional stresses

3.1 Normal Stresses and shear stresses based on Three Dimensional Excavation Using Finite Element method;

i. The element Number 01 had nodal points 170,4,,71,71,1,1,1,1 . The normal stresses based on Finite element method were estimated as under -0.225207 Kg/cm2 ,-0.225207 Kg/cm2 , -0.225207 Kg/cm2 , -0.225207 Kg/cm2 , -0.225207 kg/cm2 , -0.225207 Kg/cm2 , -0.225207 Kg/cm2 , -0.225207 Kg/cm2 for the above nodal points . However the shear stresses obtained were 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 , 0.018124 Kg/cm2 . The Normal stresses were tensile in nature.

ii. The element Numbero2 had nodal points 86,87,15,150,128,128,128,128. The normal stresses based on Finite element method were estimated as under .522335 Kg/cm2,522335 Kg/cm2,522335 Kg/cm2, .522335 Kg/cm2 ,522335 Kg/cm2,522335 Kg/cm2, 522335 Kg/cm2,522335 Kg/cm2for the above nodal points . However the shear stresses obtained were 0.1209933 Kg/cm2 , 0.1209933 Kg/cm2, 0.1209933 Kg/cm2 , 0.1209933 Kg/cm2, 0.1209933 Kg/cm2 , 0.1209933 Kg/cm2, 0.1209933 Kg/cm2 , 0.1209933 Kg/cm2 .

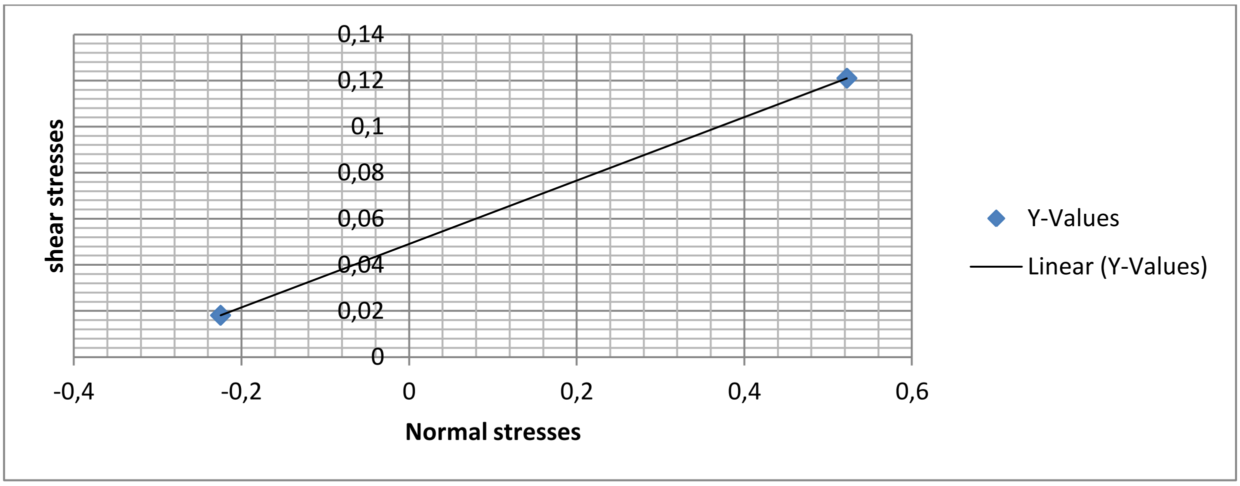
iii. The element Number 03 had nodal points 87,150,106,106,86,86,86,86. The normal stresses based on Finite element method were estimated as under -.592155 Kg/cm2 , -.592155 Kg/cm2 , -.592155 Kg/cm2 , -. 592155 Kg/cm2 , -.592155 Kg/cm2 , -.592155 Kg/cm2, -.592155 Kg/cm2 , -.592155 Kg/cm2 for the above nodal points . However the shear stresses obtained were .04532 Kg/cm2 , .04532 Kg/cm2, .04532 Kg/cm2, .04532 Kg/cm2, .04532 Kg/cm2, .04532 Kg/cm2, .04532 Kg/cm2. The Normal stresses were tensile in nature.

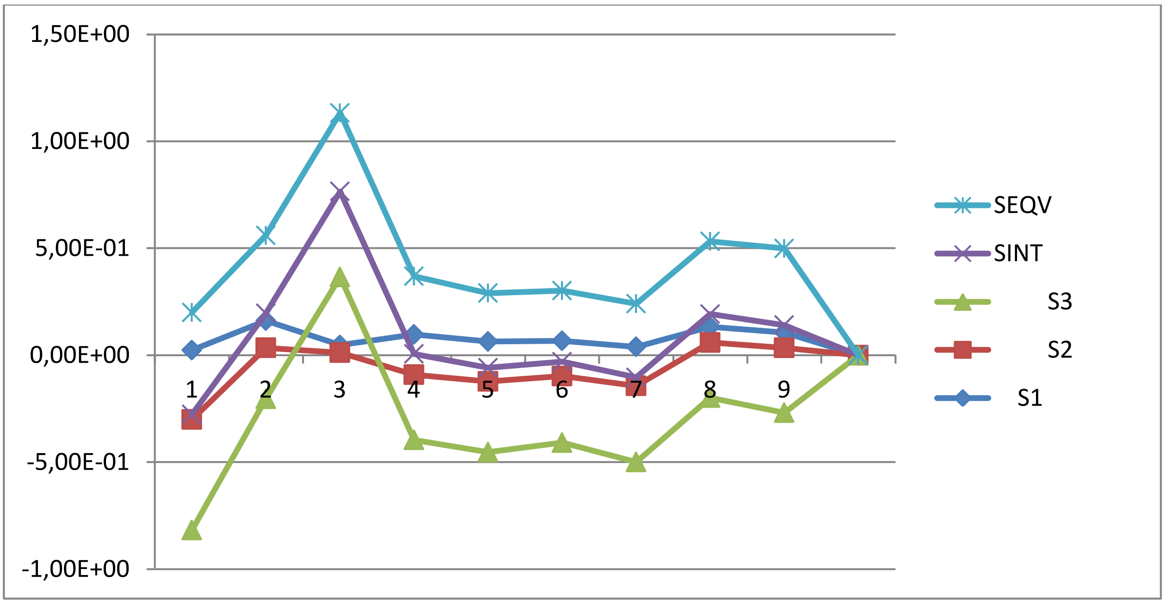
iv. The element Number 4 had nodal points 162,145,163,163,146,146,146,146. The normal stresses based on Finite element method were estimated as under 0.137919 Kg/cm2 , 0.137919 Kg/cm2, 0.137919 Kg/cm2, 0.137919 Kg/cm2, 0.137919 Kg/cm2 , 0.137919 Kg/cm2 ,f0.137919 Kg/cm2 , 0.137919 Kg/cm2 or the above nodal points . However the shear stresses obtained were 0.0695 Kg/cm2, 0.0695 Kg/cm2 , 0.0695 Kg/cm2, 0.0695 Kg/cm2, 0.0695 Kg/cm2, 0.0695 Kg/cm2, 0.0695 Kg/cm20.0695 Kg/cm2.

V. The element Number 5 had nodal points 162,146,147,147,144,144,144,144. The normal stresses based on Finite element method were estimated as under .247228 Kg/cm2, .247228 Kg/cm2, .247228 Kg/cm2,. 247228 Kg/cm2, .247228 Kg/cm2, .247228 Kg/cm2 , .247228 Kg/cm2 , .247228 Kg/cm2 for the above nodal points . However the shear stresses obtained were 0.090535 Kg/cm2, 0.090535 Kg/cm2 0.090535 Kg/cm2, 0.090535 Kg/cm2,0.090535 Kg/cm2 ,0.090535 Kg/cm2,0.090535 Kg/cm2,0.090535 Kg/cm2..

vi. The element Number 06 had nodal points 171,162,162,163,112,112,112,112. The normal stresses based on Finite element method were estimated as under-0.51437 Kg/cm2 , -0.51437 Kg/cm2 , -0.51437 Kg/cm2, -0.51437 Kg/cm2, -0.51437 Kg/cm2, -0.51437 Kg/cm2, -0.51437 Kg/cm2, -0.51437 Kg/cm2for the above nodal points . However the shear stresses obtained were .1764976 kg/cm2 , .1764976 kg/cm2, .1764976 kg/cm2, .1764976 kg/cm2,. 1764976 kg/cm2 , .1764976 kg/cm2, .1764976 kg/cm2 , .1764976 kg/cm2. The Normal stresses were tensile in nature.

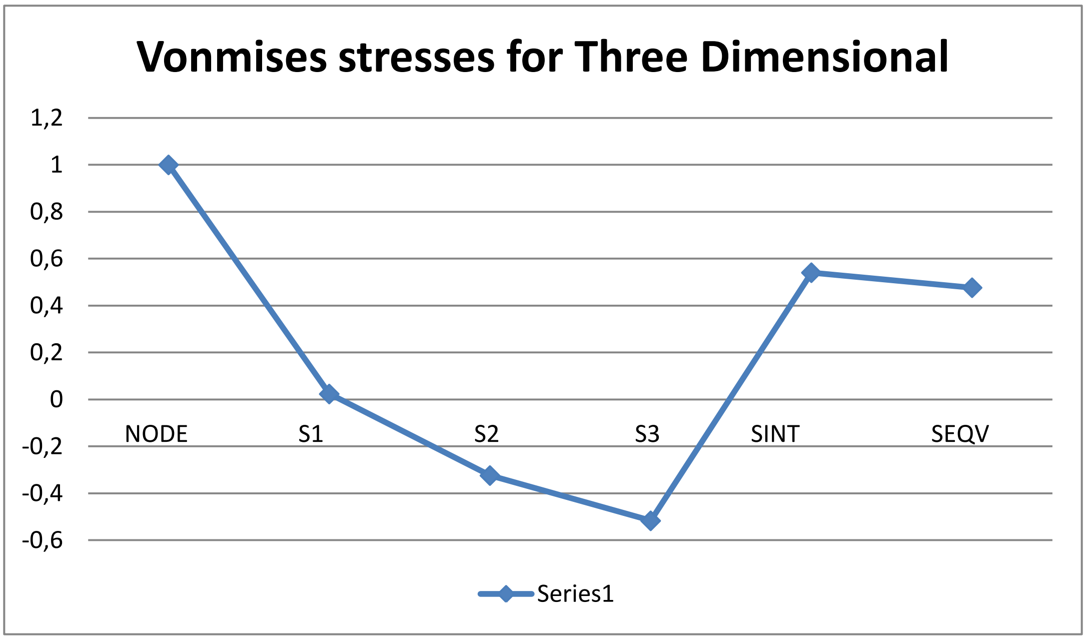
3.2 Cohesive strength of clay material evaluated based on Finite Element method for three Dimensional excavation;





Estimation of stresses in excavation using Finite Element method on Clay;

Analysis of Vonmises stresses for three dimensional stresses



3.3 Estimation of stresses in excavation using Finite Element method on Clay; Analysis of Vonmises stresses for three dimensional stresses

i. The cohesive strength of the clay material were estimated as under 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2 for the nodal point 170,4,,71,71,1,1,1,1 were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

ii. The cohesive strength of the clay material were estimated as under 0.02 N/m2, 0.02 N/m2,0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2, 0.02 N/m2 for the nodal point 86,87,150, 150, 128, 128, 128,128were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

iii. The cohesive strength of the clay material were estimated as under 880N/m2, 880N/m2,880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2for the nodal point 151,87,150,150,106,106,106,106 were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

iv. The cohesive strength of the clay material were estimated as under 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2, 880N/m2for the nodal point 87,150,106,106,86, 86,86,86. 162,145,163,163,146,146,146,146 were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavations.

v. The cohesive strength of the clay material were estimated as under 0.07 N/m2, 0.07 N/m2,0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2 for the nodal point 162,145,163,163,146,146, 146,146 were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

vi. The cohesive strength of the clay material were estimated as under 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2 for the nodal point 162,146,147,147,144,144,144,144 were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

Vii .The cohesive strength of the clay material were estimated as under 0.07 N/m2, 0.07 N/m2,0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2, 0.07 N/m2for the nodal point 171,162,162,163,112,112, 112,112. were estimated with the help of Mohr's Diagram and Vonmises Theorem using Finite element techniques for three dimensional excavation .

3.4 Bearing Pressure based on Finite Element method of three dimensional excavation non clay Materials;

i. The element number 1 had nodal point 170,4,71,1,1,1,1 had the bearing pressure of 191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2 respectively of the above nodes .

ii. The element number 2 had nodal point 86,87,150,150,128,128,128,128had the bearing pressure of 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2 respectively of the above nodes .

Iii. The element number 3 had nodal point 151,87,150,150,106,106,106,106 had the bearing pressure of 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2,, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2 respectively of the above nodes .

Iv. The element number 4 had nodal point 87,150,106,106,86,86,86,86 had the bearing pressure of 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2,, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2, 1194.0696 KN/m2 respectively of the above nodes .

V. The element number 5 had nodal point 162,145,163,163,146,146,146,146 had the bearing pressure of 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2 respectively of the above nodes .

Vi. The element number 6 had nodal point 162,146,147,147,144,144,144,144 had the bearing pressure of 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2 respectively of the above nodes .

Vii. The element number 7 had nodal point 171,162,162,163,112,112,112,112had the bearing pressure of 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2, 1191.4507 KN/m2 respectively of the above nodes .

4.0 Analysis of Area of foundation based on the modern techniques : three dimensional excavation using finite element method and experimentally verified value of FEM result

The area of foundation based on the modern techniques for three dimensional excavation using finite element method :Refer to the chart of Bearing Pressure below 12.0 m depth of Excavation for power house turbo generator for 3D –case study were 1196.17 KN/m2 .

Area of Foundation Required = 1814.3/1196.17 = 1.516 m2

Adopt a Foundation Area = 1.00 m x 1.60 m

Intensity of Maximum pressure = 1361.4 / 1.00*1.6 = 850.876 KN/m2 < 1196.17 KN/m2

Pressure Intensity below the face of the column ,P' = 850.896*1.3/1.6 = 772.58 KN/m2

Total Pressure on cantilever = .5* (850.876 + 772.58) /2 = 405.86 KN

Working Bending Moment = 405.86 *.667 = 175.737 KN-m

Factor Bending Moment = 1.5* 175.737 = 263.6 KN-m

Effective depth of footing =d= 250 mm, Overall Depth of the footing = 300mm

Increased depth required to restrict the shear stresses with the safe permissible limit.

263.6* e+6 = 0.87*415*Ast*250 [1 - 415 Ast/1000*250*20] , Ast = 7041.34 mm2

20mm diameter @ 40 mm c/c, Vv = 1.5*0.5* (408+544)/2 = 357 KN

T = 357 *(e +3)/1000*250 =1.423 N/mm2

100*Ast/b*d = 100*7041 /1000*250 = 0.3104 N/m2, Refer to Appendices 19 IS Code 456 2000: k Tc =1* 0.38 N/mm2= 0.38 N/mm2 ,K Tc = Tv

Shear stresses within the permissible limit

5.0 Conclusion

i. The area of foundation for three dimensional analyses were estimated 50% less compared to the analysis of the two dimensional finite element analysis . Hence realistic and exact analyses were visualized in case of the three dimensional finite element stresses analysis.

ii. The maximum pressure intensity was estimated 40% more in case of three dimensional finite element stresses compared to two dimensional finite element stresses.

iii. The total pressure on the cantilever was estimated 50 % more in case of Three dimensional finite stresses analysis compared to two dimensional finite element stresses analysis.

iv. The working bending moment was estimated as 20 % more in case of three dimensional finite element stresses compared to two dimensional finite element stresses .

v. The factor bending moment was estimated as 20 % less in case of three dimensional stresses compared to two dimensional stresses .

vi. The area of steel was estimated 10 % less in case of the analysis made with three dimensional fifnite lelemnt stresses (i.e. 7041 mm2 based on 3d finite element stress) compared to area of steel based on two dimensional finite element stresses (was estimated as 7786 mm2) .

Vii. he shear stresses at higher depth of the excavation were estimated very high ,but these shear stresses were along all three mutually perpendicular axes. The six shear stresses components were analyzed in the three dimensional analysis. The major principal stresses and shear stresses were estimated very critical.

viii. The major, minor and intermediate stresses were analyzed in the three dimensional stresses. The variation of the major principal stresses were 46% and 57 % for minor and intermediate stresses.

ix. The principal strain was high along major principal axes. The direction of the principal strain was steeper in major axes and intermediate axes compared to minor axes. The magnitude of principal strain along major axes were more than minor axes and intermediate axes.

x. The bearing pressure based on the finite element method value was estimated. The soil might be analyzed based on the result .The exact value of bearing pressure could be estimated based on three dimensional excavation.

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