Analysis of Reciprocating Engine by Considering Soil Stiffness

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Abstract

The dynamic analysis of reciprocating engine is carried out by using software analysis in SAP-2000 with fixed base and with foundation spring. The comparison is made with the mentioned clauses if IS-2974-1982 (Part I). The software results were compared with the manual results which all are found to be safe. The parameters of soil structure interaction is compared with normal foundation. The conclusion made confirming to IS code and the codal provisions satisfied. The results were validated with the book of Dr.K.G.Bhatia "Foundations for Industrial Machines".
Keywords: Machine foundation; Dynamic loads; Amplitude; Natural frequency; Soil stiffness; Soil structure Interaction

I. Introduction

Foundations may subjected to static or combine effect of static and dynamic loads; further depend upon soil parameter and effect of foundation on the soil. The foundation design may be considered as a portion in soil dynamics. Soil dynamics analyse behaviour of soil subjected to earthquake and vibration loadings. The effect of soil subjected to earthquake loading is the advanced method of Geotechnical Engineering. There are many origins of generating dynamic forces are such as earthquakes, blasting, pile driving, landing of an aircraft in the nearby vicinity, effect of wind, effect of water etc.. Machines create various dynamic effect which take the initiative on the soil. Most motion considered in soil dynamics are translational, rotational, pressure on soil, unbalanced forces amplitude of motions, effect of foundation, effect of soil etc. the motion may be periodic, steady and transient including vibrations and oscillations. Impact forces or seismic forces cause shock accounting degree of unexpectedly and severity, inducing a periodic motion in pulse or transient vibration. This causes failure of foundation and resulting damage to the whole structures. Energy imparted by dynamic forces on soil grains, may cause several changes in soil structure, internal friction and adhesion. Shock and vibration create liquefaction. The target of soil dynamics to study behaviour of soil subjected to dynamic loads and develops design procedure for foundation. The field petition of soil dynamics are varied and include:

- Shaking movement and settlement of structures, and foundation of machinery.
- Densification of soil by dynamic effect of vibration and compaction.
- Energy transfer mechanism.
- Effect of embedment of foundation.
- Earthquake effects and design resistant to earthquake of foundations.

It has been noticed that the performance of machine foundation relay on the forces which are acting but also on their behaviour subjected to dynamic loads which relay on the speed of machine and the frequency. Thus the vibration analysis became necessary. In another way it can be specified that every type of machine foundation needs detailed vibration study to know the dynamic property of foundation and its component part for proper function of machine.

The whole knowledge of load transfer process from machine to foundation and as well the knowledge of excitation forces and related frequencies are required for the correct evaluation of machine foundation. It is known fact that cost of foundation is a minute but contributing a lot in the company process cost. To study governing parameters required for design of machine foundation. To study the response of machine foundation under dynamic loads. To study the effect of varying capacity & frequency of machine on design of foundations. To study soil structure interaction.

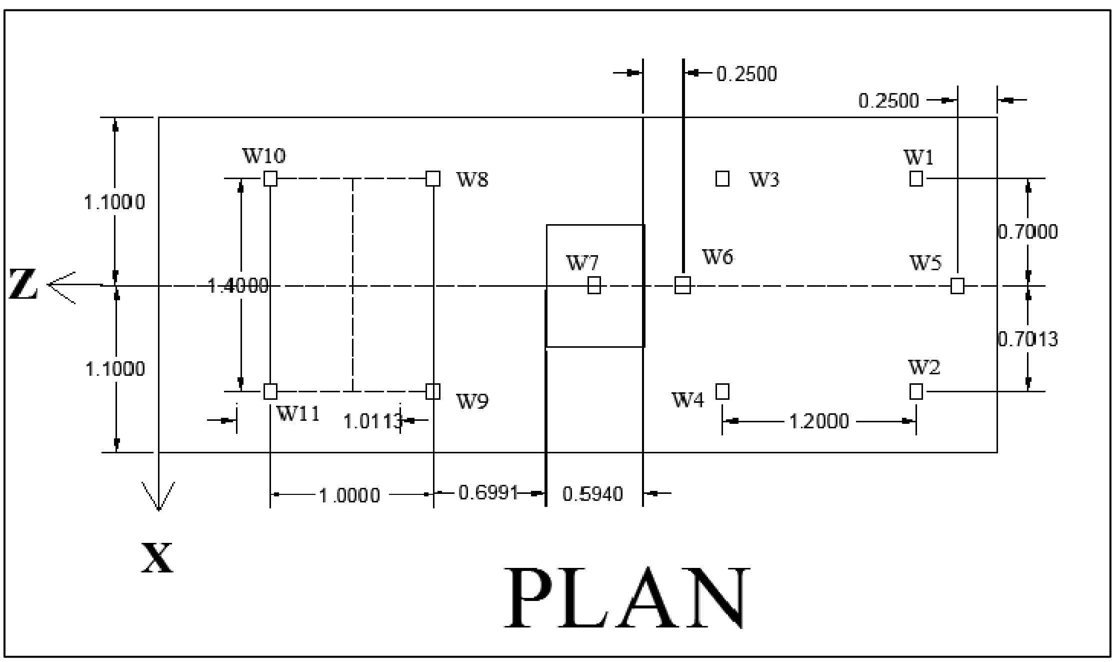
A brief overview state that from the past few year many researcher contribute their efforts towards the analysis if machine foundation. Gieger carried out investigation to determine the natural frequencies of foundation. Rauch deal with the machine and turbine foundation and contributed special efforts to practical and theoretical development of the science. Silva discussed about the design procedure elevated reinforced concrete foundation problem formulation and optimization techniques. Anyaegbunam suggested the formula was given to predict displacement within the allowable limits one variable type of equations had been developed to obtain mass of the concrete block. A special effort was laid on the vibration problems in machine foundations. Timoshenko & Den Hartog dealt with many vibration problems in engineering practices. Bhandari was studied that dimension of foundation plays important role. The foundation were design with varying depth to study various modes of vibration. Dobry was presented about arbitrary shape of foundation the whole problem with six DOF is converted in to single degree problem with calculation of damping and stiffness. Damping effect on soil was also considered with simple numerical methods. Z.Huang discussed about optimization of size of foundation for heavy machine by the shape parameters and stiffness of machine the reinforcement provided in the foundation and the thickness of the concrete in the machine pit the number of the piles and the spring the between piles and the various combination of loads varying stiffness. George Garetas in this paper brief about the comparison between the ancient methodology to design the machine foundation and the new developed technologies or analytical methods. The response of soil also plays importance part in the design process of foundation. Tripathy discussed foundation turbo generator is very important for power generation, gas ,steam, hydra, geo thermal and nuclear power plants a very less research was carried out on this topic in this Winkler spring soil model solid finite element modeling and dynamic analysis of turbo generator was carried out the frequency ,stiffness and dumping for various modes are found out by using SAP-2000 and the dynamic effect of foundation was analysis and the interpretation of result was compare with the text book of machine foundation. Kumar discussed the damping and various type of soil, theoretical process was use base on elastic half spare theory to calculate the soil stiffness, shear wave velocity. The result was presented by using dimension less graph.

II. PROBLEM FORMULATION

The design of foundation for a single cylinder horizontal reciprocating engine coupled with motor through gear box. Reciprocating engine mounted over base frame. The design carried out with coupled and uncoupled modes, where vertical and torsional in uncoupled modes, and rocking and translational in couple modes. The mathematical model of force vibration is use to solve the problem.
Formula for calculating dynamic forces = $f(t) = me^2\omega\ sin\omega t$

Given Data:		
Machine Weight:		
compressor =	*220*	*KN*
motor (excluding rotor) =	*100*	*KN*
motor rotor =	*14*	*KN*
Wt of motor bearing pedestal =	*4*	*KN*
Wt of operating Gear =	*8*	*KN*

Machine speed :		
operating speed of engine =	*360*	*rpm*
operating speed of motor =	*720*	*rpm*
Ht of rotor centerline above GL =	*2000*	*mm*
Ht of machine centroid below rotor center line =	*100*	*mm*



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III. RESULT AND DISCUSSION

The following graphs shows the comparison of machine foundation with fixed base and spring support the amplitude and frequency and the stress pattern.

Table 1: shows the comparison of manual and FE Analysis results.

DEPTH (m)	*Manual Method Of Analysis*		*FE Analysis Values*	
	WITHOUT SSI	*WITH SSI*	*WITHOUT SSI*	*WITH SSI*
1	*2.86*	*2.36*	*2.68*	*1.55*
2	*2.93*	*2.59*	*3.31*	*2.86*
3	*3.01*	*2.77*	*2.13*	*2.05*
4	*3.07*	*2.93*	*3.89*	*2.2*
5	*3.14*	*3.06*	*2.98*	*3.26*

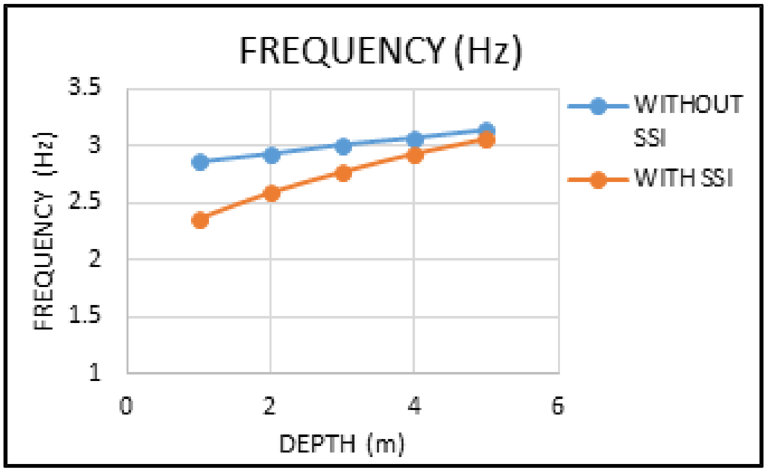
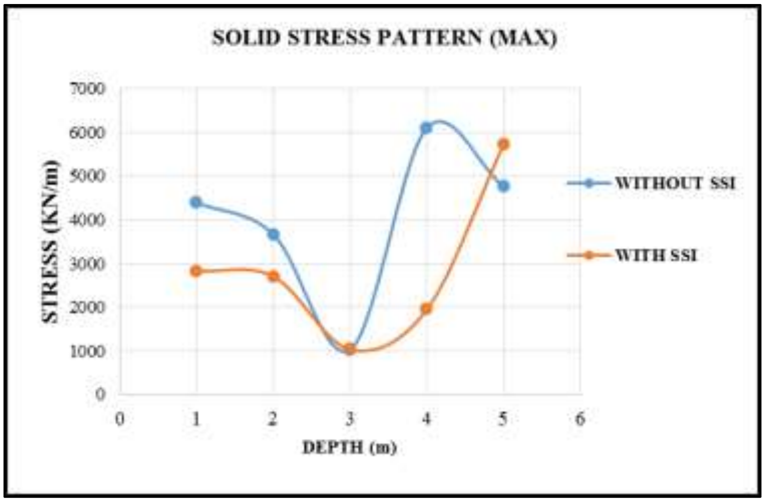


Fig. 1: shows the graph of natural frequency with and without SSI.



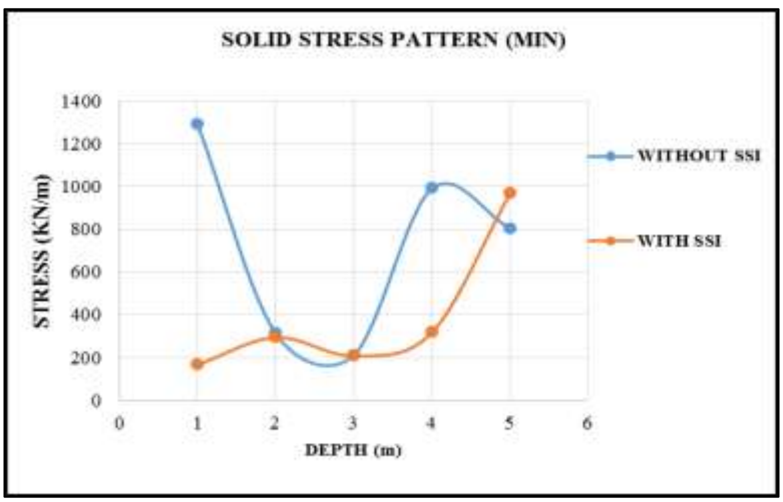


Fig. 2: shows the graph of stress pattern for max and min values.

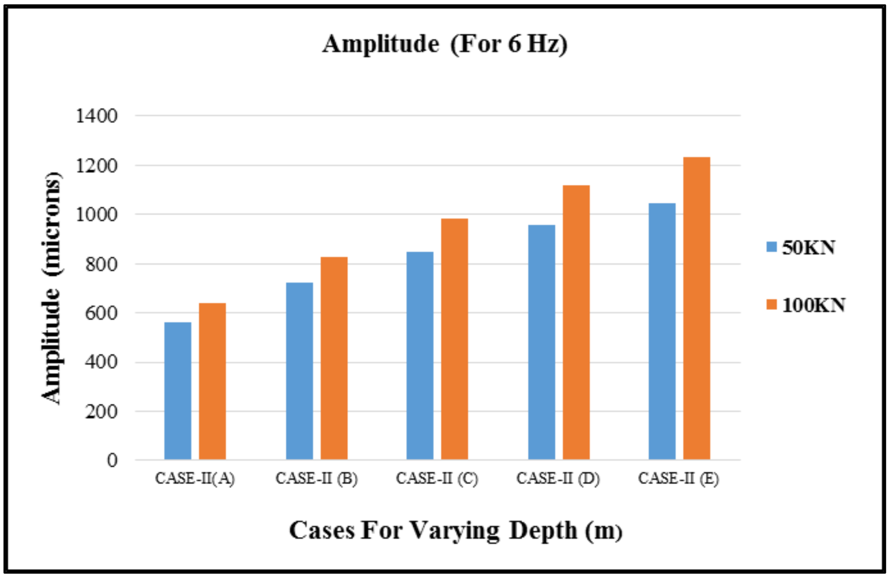


Fig. 3: shows the amplitude of machine by varying weight of machine with the increment of 50KN and 100KN (For 6 Hz)

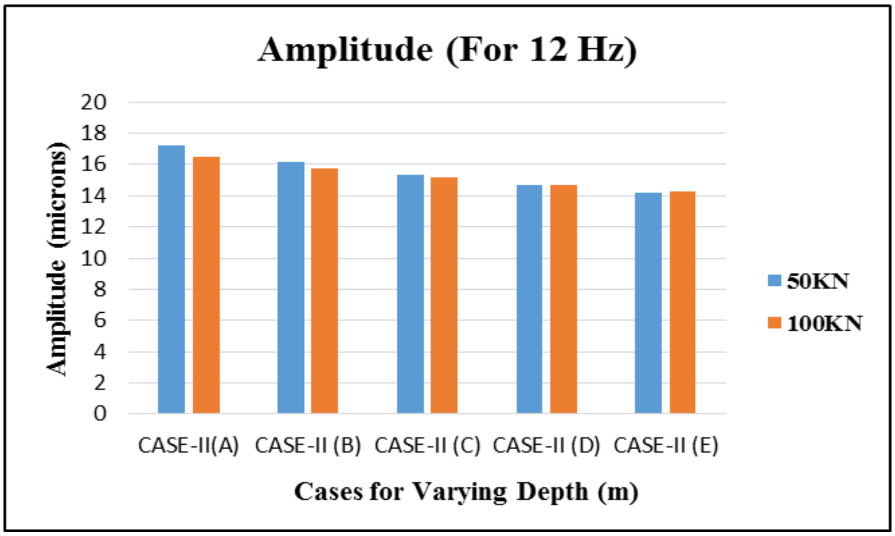


Fig. 4: shows the amplitude of machine by varying weight of machine with the increment of 50KN and 100KN (For 12 Hz).

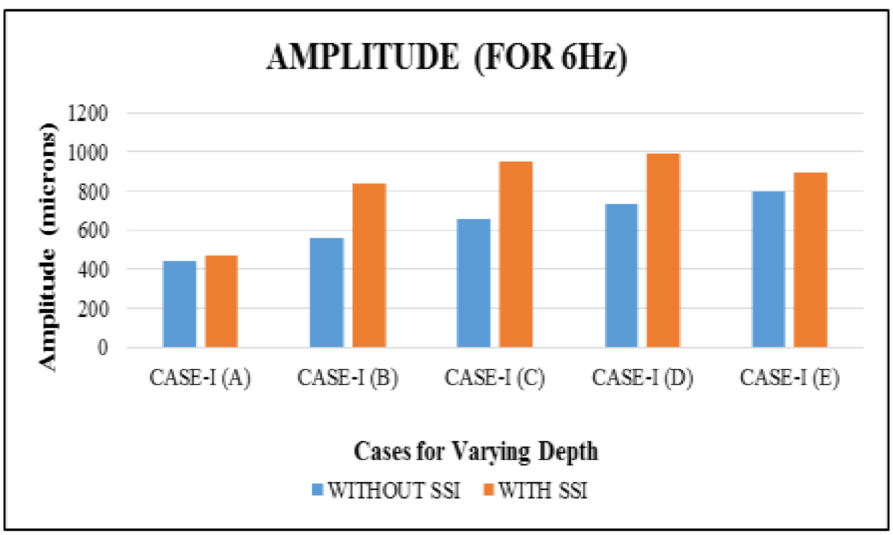


Fig. 5: shows the graph of amplitude of machine without SSI and with SSI (For 6 Hz).

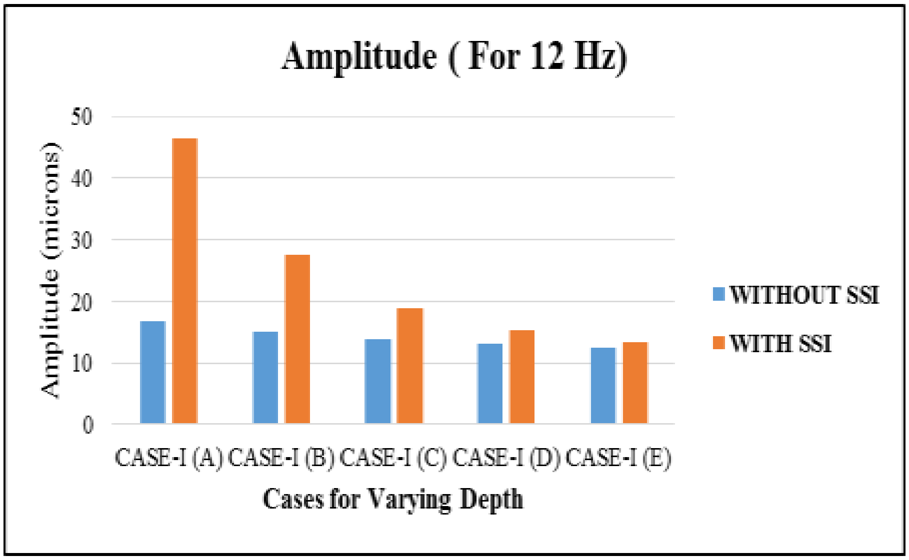


Fig. 6: shows the graph of amplitude of machine without SSI and with SSI (For 12 Hz).

Table – 2
Shows the value of Deflection without spring support.

Time Period (sec)	*For 1m*	*For 2m*	*For 3m*	*For 4m*	*For 5m*
0	*0*	*0*	*0*	*0*	*0*
0.083	*0.03325*	*-1.03103*	*-1.88076*	*0.33139*	*-0.10457*
0.166	*0.03484*	*-0.46434*	*1.11534*	*0.38787*	*0.84446*
0.249	*0.02714*	*0.32263*	*-0.79777*	*0.08466*	*1.1602*
0.332	*-0.00582*	*0.19773*	*-0.46779*	*-0.24627*	*1.86539*
0.415	*0.00337*	*-0.19177*	*-0.54322*	*0.3491*	*1.33*
0.498	*0.02675*	*-0.40139*	*-1.03088*	*-0.01029*	*1.45645*
0.581	*0.01625*	*-0.19405*	*0.70754*	*0.24258*	*1.22997*
0.664	*0.01331*	*-0.19198*	*-1.95097*	*0.00326*	*1.28334*
0.747	*0.01987*	*-0.28618*	*0.13209*	*0.12755*	*1.29332*
0.83	*0.00979*	*-0.1851*	*-0.69897*	*0.10003*	*1.11938*

Table – 3
Shows the value of Deflection with spring support.

Time Period (sec)	*For 1m*	*For 2m*	*For 3m*	*For 4m*	*For 5m*
0	*0*	*0*	*0*	*0*	*0*
0.083	*0.00642*	*-1.15724*	*-1.70792*	*-1.6688*	*-0.06247*
0.166	*0.94527*	*1.46334*	*0.88784*	*-1.55285*	*0.14118*
0.249	*-0.69223*	*0.24297*	*-0.72704*	*0.08587*	*-0.05546*
0.332	*0.0586*	*-0.22529*	*-0.49062*	*0.06271*	*-0.02516*
0.415	*0.17465*	*1.43301*	*-0.63798*	*-1.26253*	*-0.15867*
0.498	*-0.53843*	*0.23298*	*-0.8939*	*-1.374*	*0.05608*
0.581	*0.23205*	*0.08387*	*0.4775*	*-0.79592*	*-0.10363*
0.664	*0.46011*	*1.00486*	*-1.76272*	*-0.64929*	*0.07469*
0.747	*-0.11305*	*0.24788*	*-0.02884*	*-0.83823*	*-0.07588*
0.83	*-0.22143*	*0.29623*	*-0.66423*	*-1.14983*	*0.05287*

IV. CONCLUSION

The conclusion is made by:

1) The value of amplitude increases with the increase in depth and also under the limiting value which is specified by IS-2974 (Part I) -1982.
2) The value of natural frequency compared with the frequency ratio found out to be within the permissible limit so that the foundation is safe upto the depth of 5m with the five modes of vibration it does not show any harmful effect during the operation of machine.
3) The variation with varying weight of machine shows the amplitude within permissible limit upto the depth of 3.5m depth exceeding 3.5m shows the value beyond the permissible limit but it doesn't show any drastic effect.

4) The displacement value is less in case of foundation with fixed base but with spring base the value of displacement increases as it provides the movement of foundation.
5) The frequency found out to be less than 20 Hz it does not causes disturbing effect to the machine.
6) The amplitude of machine at 12 Hz frequency shows all the value less than 200 microns will not suffer any undue settlement due to dynamic loads.
7) For design use M30 Grade of concrete with modulus of elasticity as $37 * 10^6$ for dynamic condition.

REFERENCES

[1] Marcelo A. Silva1; Jasbir S. Arora; Colby C. Swan,; And Reyolando M. L. R. F. Brasil, "Optimization Of Elevated Concrete Foundations For Vibrating Machines", J. Struct. Eng., 128(11): Pp.1470-1479, 2002
[2] J. Anyaegbunam, "Minimum Foundation Mass For Vibration Control" J. Geotech. Geoenviron. Eng., 137(2):Pp. 190-195, 2011
[3] Piyush K. Bhandari, Ayan Sengupta, 'Dynamic Analysis Of Machine Foundation' International Journal Of Innovative Research In Science, Engineering And Technology 3(4), April 2014
[4] Ricardo Dobry1 And George Gazetas,. "Dynamic Response Of Arbitrarily Shaped Foundations" J. Geotech. Engg, 112(2): Pp.109-135, 1986
[5] K.G. Bhatia, "Foundations For Industrial Machines And Earthquake Effects" ISET Journal Of Earthquake Technology, 45(1,2), Pp. 13–29, March-June 2008
[6] Shamsher Prakash Vijay K. Puri, "Foundations For Vibrating Machines" Journal Of Structural Engineering, , April-May 2006
[7] Rafael Marin Ferro; Walnório Graça Ferreira; Adenilcia Fernanda Grobério Calenzani, "Dynamic Analysis Of Support Frame Structures Of Rotating Machinery" Global Journal Of Researches In Engineering: Civil And Structural Engineering, 14(5), 2014
[8] Bin Niu; Niels Olhoff, "Design Optimization Of Foundation For Rotating Machinery Against Standing-Wave Vibration In A Building," pp 1-17, May 2011
[9] Gorge Gazetas; " Analysis Of Machine Foundation Vibrations: State Of Art," Soil Dynamics And Earthquake Engineering, 2(1), 1983
[10] M. Bharathi; Dr. Swami Saran; Dr. Shyamal Mukerjee, "Analysis Of Reciprocating Machine Foundations Resting On Piles," Indian Society Of Earthquake Technology, Oct 2012
[11] Vivek B. Dhait; Dr. D. K. Parbat; Bhushan R. Ambade, "Geotechnical Aspects In Modelling Framed Type Foundation For 210 MW Turbo Generator Using Computer Software," International Journal Of Modern Trends In Engineering And Research, 2(2), 2015
[12] Z. Huang; S. Hinduja, " Shape Optimization Of A Foundation For A Large Machine Tool," Int. J. Mach. Tool Des. Res: 26(2), Pp 85-97, 1986.
[13] M. Gohnert, I. Luker and C. Morris, "Designing Foundations with Piles for Vibrating Machinery" The Open Construction and Building Technology Journal, 2008, 2, 306-312.
[14] Ataulla Attar, Dr P G Rakaraddi, " Economical Method of Reducing vibration on Machine Foundation," 11(4), Jul- Aug. 2014.
[15] Sungyani Tripathy, Dr. A.K Desai, "Dynamic Analysis Of Turbo Generator Frame Foundation Using SAP: 2000 V 17.1 Software," 50th Indian Geotechnical Conference, 2015.
[16] Ankesh Kumar, Dr. Bappaditya Manna, Prof. K. S. Rao, "Effect of Vertical Vibration on Block Foundation Resting on Homogeneous and Layered Medium," 2(7), pp : 452-456, 2013.