International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

Block Type of Machine Foundation Design and Excel Automation

Kavya R P[1], Sandeep Kumar D S[2], Mallesh N G[3]
[1,]*M.Tech Student, CAD Structures, Department of Civil Engineering, PES College of Engineering, Mandya, Karnataka*
[2]*Assistant Professor, Department of Civil Engineering, PES College of Engineering, Mandya, Karnataka,*
[3]*Associate Engineer, Atkins India, Bangalore, Karnataka*

Submitted: 15-07-2022 Revised: 27-07-2022 Accepted: 29-07-2022

ABSTRACT: The analysis and design of machine foundation requires more attention since it involves not only dynamic load but also static loads caused by the working of the machine. The Disturbing frequency and amplitudes of a machine are the most important parameters. In this paper the analysis and design of block type of machine foundation is done on the basis of standard load data manually which are used power plants, oil and gas industry. The design is as per the code IS 456:2000 and IS:2974 (Part 1) – 1982. Dynamic analysis is done to fix the size of foundation and static analysis is to design the reinforcement. To analysis and design functions are created in macro work book in VBA (Visual Basic Applications) functions used in excel automation to make the work easier. The distributing frequency is 2.5Hz and amplitude of vibration is 94.02µm from calculations the relationship when it is taken from the graph of code book is line ABB' limit to ensure reasonable comfort to persons.The eccentricities are within the permissible limit of 5% of the length of the foundation in either direction. The plan and detailing of the block type of machine foundation is also shown.

Keywords:-Block type of machine foundation, Excel VBA functions.

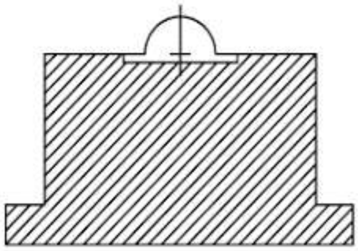
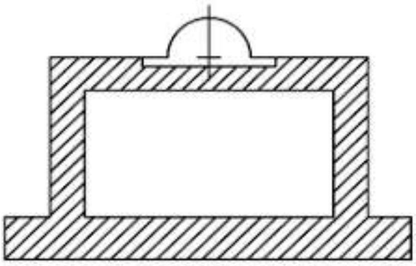
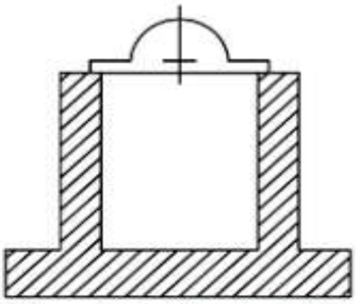
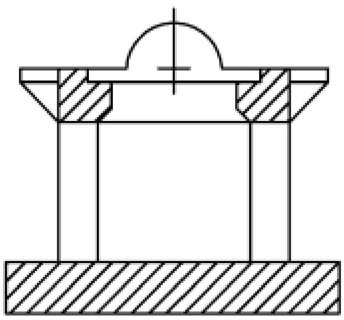
I.INTRODUCTION

The design of machine foundation is more complex than that of a static-only foundation. In addition to static loads on the floor of the machine, designers must consider the dynamic forces generated by the operation of the machine. This dynamic force is in turn transferred to the base supporting the engine. Therefore, designers must be familiar with how the machine transfers loads and the problems associated with the dynamic behaviour of the foundation and the soil underneath the foundation. Until recently, the practice of designing machine foundations by engineering companies was almost entirely based on rules of thumb, as little Advances in underground and structural mechanics gradually established design principles without the use of conventional empirical methods. The purpose of this guide is to present these design criteria in a way that designers can easily apply to real world problems. The sub-frame located under the vibrating and rotating superstructure of the assembly machine is called the foundation of the machine. Static loads and kinetic forces are taken into account when designing the frame. The mechanical load is static load that is of secondary importance in the design of a machine foundation. The moving parts of the machine create the main force, the force of inertia to be considered in the design. Kinetic or inertial forces are periodic and vibratory, and their magnitude depends on the type of machine.

1.1Visual Basic for Applications is a programming language developed and owned by Microsoft. With VBA, you can create macros to automate repetitive text and data processing functions, and create custom forms, charts, and reports. This is not a standalone product with VBA functionality for MS Office applications. Users cannot directly cannot the core Excel software through VBA, but can learn the art of creating macros to optimize time in Excel.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

Table 1 Various machine foundations and applications

Machine Foundation Types	Applications
 Block Type Foundation	This type of foundation consisting of a pedestal of concrete on which machine the rests having large mass and small natural frequency. For reciprocating type machines, block type foundations are generally used.
 Box Type Foundation	This type of foundation consisting of a hollow concrete block supporting the machinery on their top. The mass of this foundation is less than block type, as it is hollow. The natural frequency of the box type machine foundation is increased.
 Wall Type Foundation	This type of foundation consisting of a pair of walls which support the machinery on their top. It is used for larger machines. The vertical and horizontal members of this foundation can be constructed by different materials.
 Framed Type Foundation	This type of foundation consisting of vertical columns supporting on their top a horizontal frame-work which forms the seat of essential machinery. Machines producing impulsive and periodical at low speeds are generally mounted on block type foundations, while those working at high speeds and the rotating type of machinery are generally mounted on framed foundations.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

II. OBJECTIVES

- The main objective is to analysis and design of block type of machine foundation.
- To use visual basic functions to automate design process using excel automation to make work easier.
- Relation between frequency and amplitude.

III. METHODOLOGY

- Study the types of machine foundation.
- The analysis and design of the block type of foundation is done on the basis of the standard load data manually. The design is as per the code IS 456:2000 and IS:2974 (Part 1) – 1982.
- The dynamic analysis has to be done to fix size of foundation and static analysis for design of foundation reinforcement.
- To use visual basic functions to automate design process using excel automation to make work easier.
- Study the relation between frequency and amplitude.

IV. DESIGN DATA

The specific data required for design vary depending upon the type of machine. The general requirements of data for the design of machine foundation are, however, as follows:

a. Loading diagram showing the magnitude and positions of static and dynamic loads exerted by the machine on its foundation.

b. Power of engine and the operating speed.

c. Diagram showing the embedded parts, openings, grooves for foundation bolts, etc.

d. Nature of soil and its static and dynamic properties as required in design calculations.

The analysis and design of the block type of foundation is done on the basis of the standard load data manually.

Machine Data

- Operating speed of engine (f_m) 150rpm
- Horizontal unbalanced force in the direction of the piston (P_x) 117.72kN
- Weight of machine (W) 353.16kN
- The horizontal unbalanced force acts at a height of 0.6m above thetop of the foundation (level+0.0).

Soil Data

- Nature of soil sandy
- Bearing capacity of soil 2kg/cm^2
- Coefficient of elastic uniform shear (Cτ) 2.25kg/cm^2
- **Grade of Concrete** M-20

The following are the calculations done in excel using visual basic functions from the above data:

Computations For Centre Of gravity And Mass Moments Of Inertia

Element (i) of the system	Dimensions of elements			Weight	Mass	Co-ordinates of C/G of element			Static moment of mass (Kg-m²)			Moment of inertia of element about y axis passing through C/G of the element			
Machine foundation	L_{xi} (m)	L_{yi} (m)	L_{zi} (m)	W_i(kN)	M_i (sec²/m)	x_i (m)	y_i (m)	z_i(m)	$m_i x_i$	$m_i y_i$	$m_i z_i$	$m_i/12(L_{xi}^2+L_{zi}^2)$	$X_{oi}=(\bar{x}-x_i)$	$Z_{oi}=(\bar{Z}-Z_i)$	$m_i(x_{oi}^2+Z_{oi}^2)$
Part No	-	-	-	353.16	36	3.65	3.75	2.8	131.4	135	100.8	-	1.095	1.561	135.332
1	9.5	7.5	0.6	1006.506	102.6	4.75	3.75	0.3	487.35	384.75	30.78	774.716	0.005	0.972	102.603

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

2	8	6	1.6	1808.6	184.32	4.75	3.75	1.4	875.53	691.21	258.05	1022.4	0.005	0.161	14.987
3A	3.7	2.2	0.4	76.66	7.814	5.5	5.65	2.4	42.979	44.151	18.75	9.019	0.755	1.161	14.987
3B	3.7	2.2	0.4	76.66	7.814	5.5	1.85	2.4	42.979	14.456	18.75	9.019	0.755	1.161	1.466
4	2.5	1.8	1.6	-169.51	-17.27	2	3.75	1.4	-34.558	-64.797	-24.19	-12.685	2.745	0.161	-135.91
5	2.8	1.6	1.2	-126.57	-12.90	6.35	3.75	1.6	-81.928	-48.383	-20.64	-9.977	1.605	0.361	-34.847
Total				**3025.2**	**308.4**				**1463.8**	**1156.4**	**382.4**	**1792.5**			**102**

It is required to check the dynamic stability of the foundation and to suitability design the same.

Stages In Computation

Sl.No	Description	Formula	Results	Reference
1 a)	Centre Of Gravity	x = ∑mx/∑m y = ∑my/∑m z = ∑mz/∑m	**4.745 m** **3..718m** **1.239m**	From Table:1
2	Eccentricity in x direction Eccentricity in y direction	(4.75-4.745)/9.5*100 (3.75-3.718)/7.5*100	**0.053%** **0.427%**	The eccentricities are within the permissible limit of 5% of the length of the foundation in either direction.
b) i.	Design Parameters: Mass of the foundation (m)	∑m	**308.4kN-sec²/m**	From Table: 1
ii	Moment(M,) caused by the horizontal exciting force (P,) acting at a height of 0.6m above the top of foundation(M,)	P,(2.2+0.6- z)	**176.58kN-m**	Hand book on machine foundation Page No:88

iii	Operating frequency of the machine. Circular Frequency (ω_m)	(f_m) $2\pi(150/60)$	150rpm 150sec^{-1}	Given
iv	Moment Of Inertia (I_y)	$bd^3/12$	535.86m^4	
v	Mass Moment Of Inertia(ϕ_y)	$\phi_y = 1/12 \sum m_i (l_{xi}^2 + l_{zi}^2) + (x_{0i}^2 + z_{0i}^2)$	1894.5kN-m-sec^2	From Table 1
vi	The mass moment of inertia (ϕ_o) about the axis passing through the centroid of the base area and perpendicular to the plane of vibration	$\phi_{ov} = \phi_y + m\bar{z}^2$	2415.7kN-m-sec^2	Hand book on machine foundation Page No:89
vii	The ratio(α_y)	$\alpha_y = \phi_y / \phi_{ov}$	0.8	From eq.4.31 from hand book of machine foundation Page No:71
viii	Limiting frequencies	$\omega_{ov}^2 = (C_a\ Iv - W\bar{z}) / \phi_{ov}$ $\omega_x^2 = C_r A_r / m$	20.08X10^{3}sec^{-2} 5.098X10^{3}sec^{-2}	From eq.4.33a Eq.4.33b from hand book of machine foundation Page No:71

c	Coupled natural frequencies Corresponding natural frequencies	$\omega_{n1}^2 = 1/2\alpha_y [\omega_{ov}^2 + \omega_x^2 + \sqrt{(\omega_{ov}^2 + \omega_x^2)^2 - 4 \alpha_y * \omega_{ov}^2 * \omega_x^2}]$ $\omega_{n2}^2 = 1/2\alpha_y [\omega_{ov}^2 + \omega_x^2 - \sqrt{(\omega_{ov}^2 + \omega_x^2)^2 - 4 \alpha_y * \omega_{ov}^2 * \omega_x^2}]$ $f_n = \omega_n / 2\pi$	26.676X10^{3}sec^{-2} 4.796X10^{3}sec^{-2} f_1=26.00cps f_2=11.03cps	From eq.4.34a From eq.4.34b from hand book of machine foundation Page No:71
d) i	Amplitudes	The coefficient $f(\omega_m^2)$ $f(\omega_m^2) = m\,\phi_y (\omega_{n1}^2 - \omega_m^2)(\omega_{n2}^2 - \omega_m^2)$	$f(\omega_m^2)$=72.5X10^{10}	From eq.4.37 from hand book of machine foundation Page No:72
ii	Horizontal Amplitude (a_x)	$a_x = [(C_a\ I_y - WS + C_r A_r S^2 - \phi_y\ \omega_m^2) P_x + (C_r A_r S) M_y] 1 / f(\omega_m^2)$	a_x=0.0882mm	From eq.4.36a from hand book of machine foundation Page No:72

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

iii	Rotational Amplitude(a_{ψ})	a_{ψ} = (C.A.S/ f(ω_n^2)) P.+(C.A.-m ω^2/ f(ω_n^2))M.	aev=0.0072mm	From eq.4.36b from hand book of machine foundation Page No:72
iv	Net Amplitude at base level	a_x - Sa_{ψ}	**0.0792mm**	From hand book of machine foundation Page No:90
v	Net horizontal amplitude at top of the foundation	a_x+(H-S) a_{ψ}	**0.0951mm**	<0.2mm (permissible) from Page No:90
e) i	Dynamic Forces(F_d)	F_d=0 =3*2.25X10^5*9.5*7.5 *0.0792X10^-3	**372.78kN**	From hand book of machine foundation Page No:80 of table 4.8
ii	Dynamic moment (M_d)	M_d=0 =3*9X10^5*535.86*0.0072X10^-3	**1022.2kN-m**	From hand book of machine foundation Page No:80 of table 4.8
f	Check for soil stress(σ). Max and Min stresses on soil	σ = W/A ± M_d(l-x)/I	σ_{max}= 43.4kN/m² σ_{min}=41.6kN/m²	From hand book of machine foundation Page No:90
g i	Structural Design Static Loads Intensity of soil reaction	=3025.2/(9.5*7.5)	= **42.5 kN/m²**	From hand book of machine foundation Page No:90
Ii a)	Dynamic Loads Exciting moment	= 56.196*6/9.5²	= **40 kN/m**	From hand book of machine foundation Page No:90
b)	Dynamic moment	= 6*1022.2/9.5²	= **68** kN/m	From hand book of machine foundation Page No:90

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

Evaluation Of Inertial Forces

Element (i) of the system	Weight of the element W_i (kN)
Machine Foundation Part	353.16
1	1006.51
2	1808.2
3A	76.66
3B	76.66
4	-169.51
5	-126.57

x_i (m)	z_i (m)	$X=(x_i-x_o)$ (m)	$Z=(z_i-z_o)$ (m)	Inertial forces	
				Vertical (kN)	Horizontal (kN)
-1.095	-1.561	-1.095	10.646	-0.02148	2.0493
0.005	0.939	0.005	13.146	0.00028	7.2113
0.005	-0.161	0.005	12.046	0.0005	11.8691
0.755	-1.161	0.755	11.046	0.00321	0.4610
0.755	-1.161	0.755	11.046	0.00321	0.4640
-2.745	-0.161	-2.745	12.046	0.02585	-1.1125
1.605	-0.361	1.6033	11.846	-0.01128	-0.8171
				$\sum=0$	20.12

Table contains the weight of various parts of the foundation block Following are the net Bending moments induced at various sections under the influence of static loads resulting soil pressure.

$(M_e)_I$	=	628.13	kN-m
$(M_e)_{II}$	=	791.8	kN-m
$(M_e)_{III}$	=	212.48	kN-m

Net Moment:(M_e=M_s):

=	756.64 KN-m	;	499.62 KN-m
=	1013.9 KN-m	;	569.77 KN-m
=	250.15 KN-m	;	174.81 KN-m

Dynamic Moments At Base Level

Section	Moment due to dynamic forces (kN-m)	Moment due to exciting forces (kN-m)	Net dynamic moment (kN-m)
I-I	±277.91	±149.4	±128.51
II-II	±480.4	±258.3	±222.1
III-III	±81.52	±43.85	±37.67

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

Excel automation functions for the The analysis and design of the block type of foundation is done on the basis of the standard load data.

```
Function divide2numbers(x, y)
divide2numbers = x / y
End Function

Function add2numbers(x, y)
add2numbers = x + y
End Function

Function eccentricity(a, b, c)
 eccentricity = a - b / c * 100
End Function

Function MomentIv(b, d)
MomentIv = b * d ^ 3 / 12
End Function
```

```
Function MomentMv(a, b)
MomentMv = a * (2.2 + 0.6 - b)
End Function

Function Massmoment(c, d)
Massmoment = c + d
End Function

Function Massmomentofinertia(a, b, c)
Massmomentofinertia = a + b * c ^ 2
End Function

Function ratio(p, q)
ratio = p / q
End Function
```

```
Function limitingfrequencies(p, q, r, s)
limitingfrequencies = (9 * 10 ^ 3 * p - q * r) / s
End Function

Function frequencies(a, b, c)
frequencies = 2.25 * 10 ^ 3 * a * b / c
End Function

Function coefficient(a, b, c, d, e, f)
coefficient = a * b * (c - d ^ 2) * (e - f ^ 2)
End Function

Function HorizontalAmplitude(a, b, c, d, e, f, g, h, I, j, k, l, m, n, o)
HorizontalAmplitude = [ a * b - c * d + e * f * g ^ 2 - h * i ^ 2 ) * j + ( k * l * m ) * n ] * l / o
End Function
```

```
Function Rotationalamplitude(a, b, c, d, e, f, g, h, I, j, k)
Rotationalamplitude = (a * b * c / d) * e + ((f * g - h * I ^ 2) / j) * k
End Function
Function NetAmplitude(a, s, b)
NetAmplitude = a - s * b
End Function
Function Horizontalamplitudeattop(a, s, b)
Horizontalamplitudeattop = a + (2.2 - s) * b
End Function
Function Dynamicforce(a, b)
Dynamicforce = 3 * 2.25 * 10 ^ 3 * a * b * 10 ^ -3
End Function
```

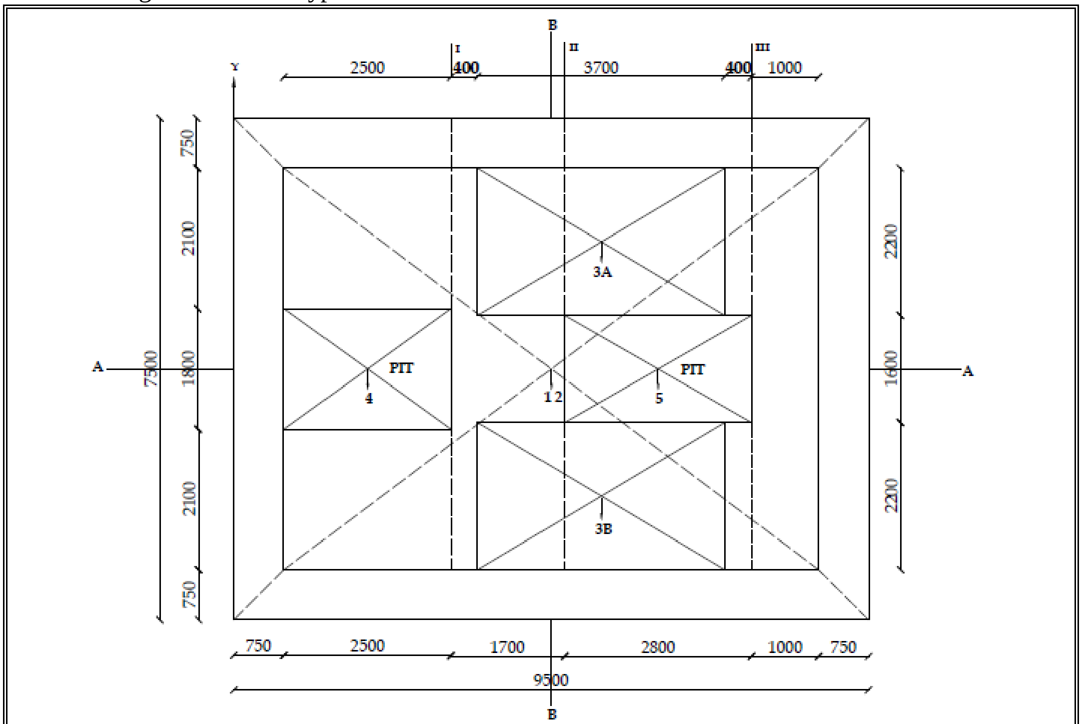
```
Function Dynamicmoment(a, b)
Dynamicmoment = 3 * 9 * 10 ^ 3 * a * b * 10 ^ -3
End Function
Function Maximumstress(W, a, m, l, x, I)
Maximumstress = W / a + m * (l - x) / I
End Function
Function Minimumstress(W, a, m, l, x, I)
Minimumstress = W / a - m * (l - x) / I
End Function
Function staticload(W, a)
staticload = W / a
End Function
Function excitingmoment(m, l)
excitingmoment = m * 6 / l ^ 2
End Function
```

```
Function Dynamic(d, b)
Dynamic = d * 6 / b ^ 2
End Function
Function inertialforce(m, a, W)
inertialforce = 3 * m * a * 10 ^ -3 * W ^ 2
End Function
Function Inertialmoment(a, b, c)
Inertialmoment = 3 * a * b * 10 ^ -3 * c ^ 2
End Function
Function Coordinates(x, a)
Coordinates = x / a
End Function
```

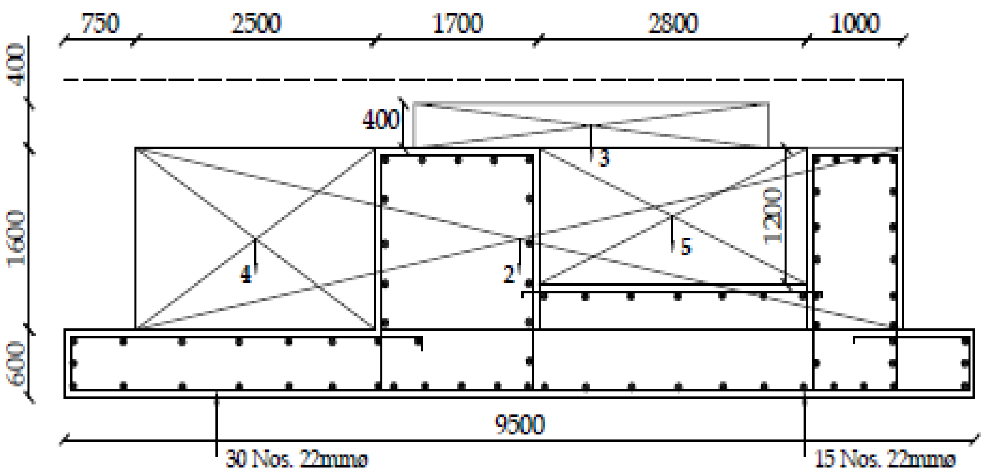
International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252

V. DESIGN AND DETAILING OF BLOCK TYPE OF MACHINE FOUNDATION

- The design of block type of machine foundation is done in excel sheet by using excel VBA functions as shown above.
- The detailing is done in Auto CAD and it is shown below,

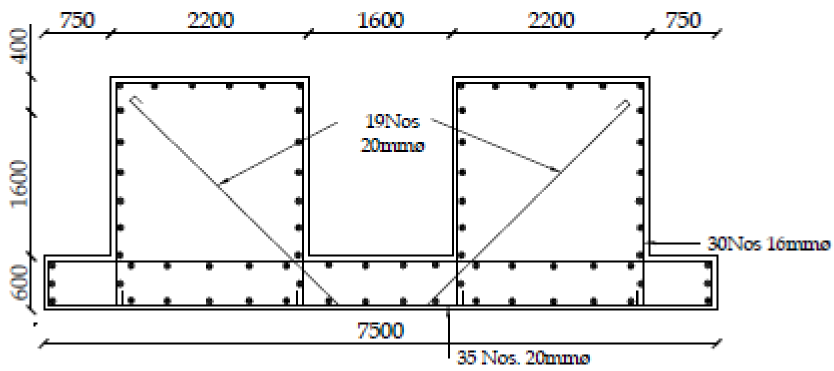


BLOCK TYPE OF MACHINE FOUNDATION PLAN



SECTTION A-A

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 1622-1633 www.ijaem.net ISSN: 2395-5252



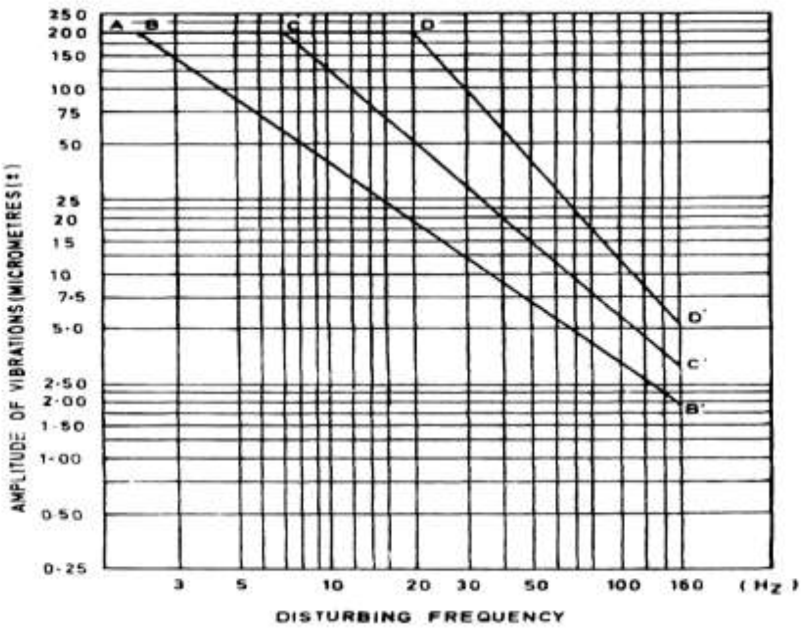
SECTTION B-B

.

VI. RESULTS AND CONCLUSIONS

A. A machine foundation is special type of foundation required for machines, machine tools and heavy equipment with varying speeds, loads and operating conditions.

B. This foundation is designed to take into account shocks and vibrations (dynamic forces) caused by mechanical work.



C. Since machine will be on the top of the foundation so, machine manufacturer will give what is the amplitude i.e. rpm and allowable amplitude that is to check whether it is within the limit. Hence, The distributing frequency is 2.5Hz and amplitude of vibration is 94.02µm from calculations the relationship when it is taken from the graph of code book is line ABB' limit to ensure reasonablecomfort to persons.

D. The eccentricities are within the permissible limit of 5% of the length of the foundation in either direction.

E. By using VBA functions same as block type of machine foundation we can design any type of foundations.

REFERENCES

[1] **KartikChaudhary and IshantDahat**– “Comparative structural analysis of block type machine foundation – a technical note” (2021).

[2] **Nidhi R. Somkuwar**– “Machine foundations for power plant: some design issues with real time examples (2019)

[3] **Kalpak M Vora–** “Dynamic analysis of block type machine foundation by

D.D.Barkan method by application software (2018).

[4] **Piyush K. Bhandari, AyanSengupta –** "Dynamic analysis of machine foundation (2014).

[5] **Ataulla Attar, Dr P G Rakaraddi – "**Economical method of reducing vibration on machine foundation" (2014).

[6] **Raghavendrasing S. Rajput, S.K.Dubey – "**Analysis and Design of framed and block machine foundation".

[7] **S K Guha**– "Vibration studies of Block type machine foundations" (1984).

[8] **IS 456:2000 –** Plain and reinforced concrete-code of practice.

[9] **IS 875: (Part 1) –** 1987 Indian standard code of practice for design loads (other than earthquake) for building and structures. Part 1 Dead Loads.

[10]. IS 875: (Part 2) – 1987 Indian standard code of practice for design loads (other than earthquake) for building and structures. Part 2 Imposed Loads.

[11]. IS 875: (Part 3) – 1987 Indian standard code of practice for design loads (other than earthquake) for building and structures. Part 3 Wind Loads.

[12]. IS 2974 (Part 1) – 1982 Indian Standard code of practice for design and construction of machine foundations. (Part 1 Foundations for Reciprocating Type Machines).