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FOUNDATION MODELLING FOR COOLING WATER PUMP MACHINE IN PT PUPUK SRIWIJAYA (PURSI) II-B PROJECTS

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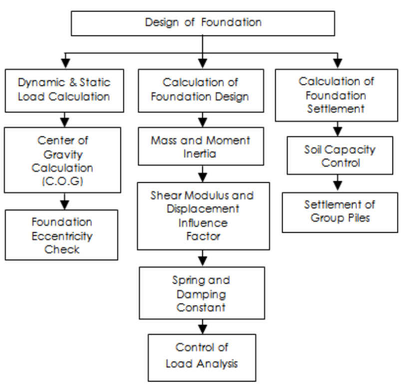
Graphical abstract



Abstract

PT Pupuk Sriwijaya (PUSRI) in Palembang, South Sumatera, Indonesia uses a lot of machines to run the fabric. One of the project is PUSRI II-B, which use cooling water pump machine. The machine will not operate properly if it does not use the appropriate foundation to support static and dynamic loads. The Terzaghi and Meyerhof methods were used in static analysis to measure the settlement in the pile group and soil bearing capacity. The frequency, damping, and vibration amplitude of the vibration that occur in a vertical and horizontal vibration, and the vibration rocking were calculated by using the trial error method for dynamic analysis. Modelling frame foundation machine is the main focus in this research. The result shows that the most effective foundation dimension for cooling water pump machine is frame foundation type with the pile cap dimensions of 9.8 m x 4 m x 1.5 m; column of 0.5 m x 0.5 m x 1 m and slab of 9.8 m x 4 m x 0.3 m, and using the piles with a diameter of 0.35 m, length of 21 m and the spacing between the piles is about 2.45 m. The gravel was compacted to the same level where the pile cap was planned in order to increase the soil shear modulus.

Keywords: Machine; foundation; frame foundation; pump machine; damping ratio

Abstrak

PT Pupuk Sriwijaya (PUSRI) di Palembang, Sumatera Selatan, Indonesia menggunakan banyak mesin untuk membuat fabrik. Salah satu projek adalah PUSRI II-B, penggunaan penyejukan mesin pam air. Mesin ini tidak akan beroperasi dengan baik jika ia tidak menggunakan asas yang sesuai untuk menyokong beban statik dan dinamik. Kaedah Terzaghi dan Meyerhof telah digunakan dalam analisis statik untuk mengukur genapan dalam cerucuk kumpulan dan keupayaan galas beban. Kekerapan, redaman dan getaran amplitud getaran yang berlaku dalam getaran menegak, getaran mendatar, dan getaran goyang dikira dengan menggunakan kaedah cuba jaya untuk analisis dinamik. Model rangka asas mesin merupakan fokus utama dalam kajian ini. Pemodelan menunjukkan yang asas paling berkesan dan dimensi yang diperlukan untuk menyejukkan mesin pam air adalah rangka asas jenis cerucuk dengan tetopi berdimensi 9.8 m x 4 m x 1.5 m; tiang berdimensi 0.5 m x 0.5 m x 1 m dan lantai berdimensi 9.8 m x 4 m x 0.3 m, yang menggunakan cerucuk berdiameter 0.35 m, panjang 21 m dan jarak 2.45 m antara cerucuk. Kerikil telah dipadatkan sehingga ketinggian yang sama dengan tetopi cerucuk bagi meningkatkan modulus ricih tanah.

Kata kunci: Mesin; asas; rangka asas; mesin pam; nisbah redaman

1.0 INTRODUCTION

PT Pusri develops its performance by building the new factory known as Pusri II-B to get the addition value in fertiliser production. The construction of this factory cannot be separated from the structural works that included machines used to help the production inside.

When the machines operate, it will affect the static loads and the dynamic load that have to be resisted by the soil and machine foundation structure underneath [1]. Machine foundation that placed on a concrete foundation has much kind of types and some of them are block type of machine foundation, box type, wall type and frame type. From various kind of machine foundation, the frame type of machine foundation is a kind of machine type that especially discussed in this paper.

The planning of machine foundation by using this frame type need design procedure that more specifically considers that the shape or dimension, mass foundation and soil capacity that have to be precisely strong to resist the vibration impact [2]. Also, to calculate the convenience foundation that will not cause the negative impacts for the environment.

The scope of the foundation plan are as follows:

1. The foundation supports cooling water pump machine at precisely 6209-JA of the Pusri II-B factory construction in Palembang, South Sumatera
2. The machine data used the original data of cooling water pump machine classification
3. The given load combination data does not cover the earthquakes load, wind load, or buoyancy load but only calculates the dead load and the load from its own machine
4. Election for the dimension of foundation conducted by using trial and error method supported by Microsoft Excel program until the dimension that meets the safety and efficient requirements of frame type foundation would obtained
5. Unconsidered the economic aspect such as the cost, advantages and time of the site.

2.0 EXPERIMENTAL

The planning of machine foundation starts with experimental phases which are divided into two main parts; the collecting of data and the loading plan.

2.1 Collecting of Data

The data in this research is the secondary data where all the observed data are as follows:

a. Detailed Engineering Design (DED)
Technically the site plan included mechanical and layout; more complete the DED drawing will make an easier implementation.

b. Soil Data
Soil data used are the Standard Penetration Test (SPT)-N data from bore log, dynamic soil properties and other soil investigation data.

c. Machine Data
The type of machine used in this research is pump machine, gearbox with turbine and lube oil. Table 1 presents the machine dimensions.

Table 1 Dimensions of machine data

Dimensions	Pump machine	Turbine/motors	Lube oil
Length (m)	3.060	4.504	1.753
Width (m)	2.07	2.910	1.321
Height (m)	2.420	2.756	1.376

2.2 Loading Plan

The loading plan for static and dynamic uses the original data from the machine production factory. The load happened as the impact from pomp machine movement such as the vertical force, horizontal force, and rotation.

For the calculation steps (Figure 1), they are here as follows:

1. The Calculation of Dynamic Load, including the dynamic load and static load calculation, the center of gravity calculation and the control of foundation eccentricity.
2. The Calculation of Foundation Design, including the mass and moment inertia calculation, shear modulus and displacement influence factor, spring and damping constant and the control of load analysis.
3. The Calculation of Settlement.

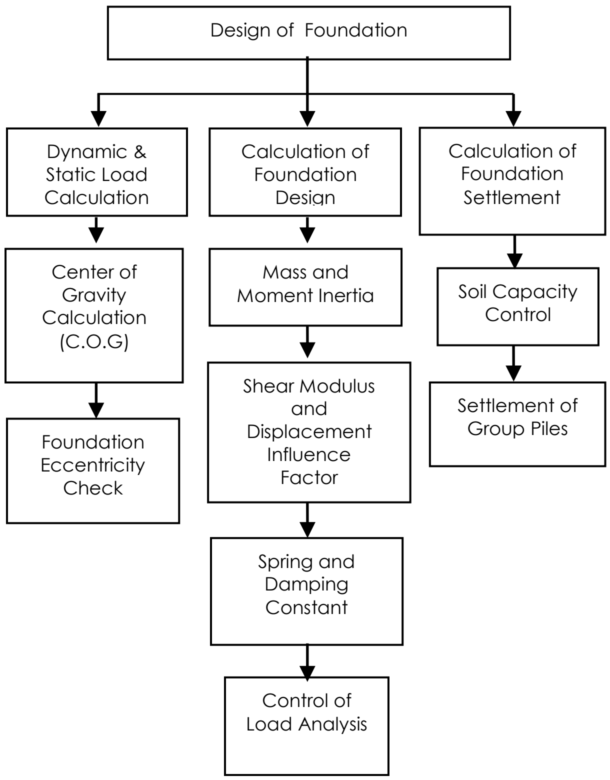


Figure 1 Flowchart for the design of foundation

3.0 RESULTS AND DISCUSSION

The design of vibration machine foundation requires that certain site and loading parameters to be known even before preliminary sizing of the structure can be completed. These design conditions and requirements may be generally classified into three groups; soil parameters, machine properties and environmental requirements [3]. Soil test experiment and machine dimension are presented in this section followed with analysis and discussion of the results.

3.1 Soil Test Experiment Result

Soil investigation data used in this research were tested at the field and at the laboratory. Result shown that the soil type for machine foundation according to UBC 1997 is a stiff soil profile, whereas according to SNI 2002 the soil type is reported as medium soil profile. Thus, this soil is categorise as the clay soil.

3.2 Machine Dimension

The calculation of machine foundation in this frame type was prepared to design the foundation from Cooling Water Pump for Ammonia Utility (6209-JA). The machine sketch above the frame type foundation can be seen in Figure 2.

Whereas the dimension for each machine tool that would be placed above the pedestal of machine foundation will described as follows:

a. Skid A (Pump)
Length = 3.060 m
Width = 2.070 m
Height = 2.420 m
C.O.G = 1.348 m (z) *from bottom of skid*

b. Skid B (Motor)
Length = 4.504 m
Width = 2.910 m
Height = 2.756 m
C.O.G = 1.076 m (z) *from bottom of skid*

c. Skid C (Lube Oil)
Length = 1.753 m
Width = 1.321 m
Height = 1.376 m
C.O.G = 0.540 m (z) *from bottom of skid*

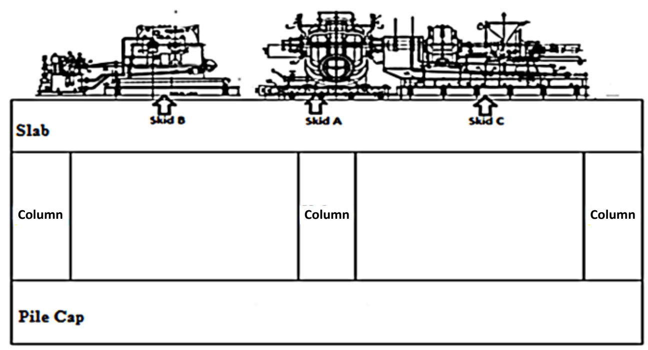


Figure 2 Sketch of the machine placement above the frame foundation

Until the dimension that effective and fulfill the machine foundation requirements, machine configurations were observed.

Hereby some of machine configurations that were considered in calculation to design frame type foundation of cooling water pump plan:

a. A : pile cap (10.8 m x 4 m x 1.5 m); column (1 m x 1 m x 3 m); slab (10.8 m x 4 m x 1.2 m)
b. B : pile cap (10.8 m x 4 m x 1.5 m); column (1 m x 1 m x 4 m); slab (10.8 m x 4 m x 1.2 m)
c. C : pile cap (10.4 m x 4 m x 1.5 m); column (1 m x 1 m x 4 m); slab (10.4 m x 4 m x 1.2 m)
d. D : pile cap (9.8 m x 4 m x 2 m); column (0.5 m x 0.5 m x 3 m); slab (9.8 m x 4 m x 0.5 m)
e. E : pile cap (9.8 m x 4 m x 1.5 m); column (0.5 m x 0.5 m x 1 m) and slab (9.8 m x 4 m x 0.3 m).

3.3 Dynamic Load and Foundation Settlement Analyses

In designing the foundation, there are two phases involved; dynamic load analysis and analysis of the foundation settlement.

3.3.1 Dynamic Load Analysis

After conducting the calculation according to the steps of foundation plan, the effective dimensions that fulfil the safety requirements for machine foundation has been obtained. E configuration has fulfilled the safety requirements. These dimensions are very effective because its volume does not much consume the space and meet all requirements needed.

For the recapitulation of dynamic analysis calculation for frame foundation assumption can be seen on Table 2. According to the Table 2, it can be seen that the smaller dimension and weight of frame type foundation will make some parameters increase; which are damping ratio, transmissibility factor and magnification factor. Conversely, greater dimension of frame type foundation will cause an enhancement of respective parameters; spring constant, amplitude and velocity.

For damping ratio, the configuration for D and E fulfilled the safety requirements because it did not cause the resonance effect with the horizontal, vertical and rocking damping ratio value are reported more than 0.71 which accepted. In contrary, configurations A, B and C have damping ratio value below 0.71 that could cause the resonance. At the parameter of magnification factor for M1 and M2, all the configuration fulfilled the requirements because the value is under 1.5 and also applied with amplitude parameter that fulfilled the safety requirements.

In Figure 3, it can be seen at a frequency of 595 rpm, allowable amplitude value is equal to 0.046 mm, while for the engine of 3600 rpm, frequency amplitude values are allowed 0.008 mm. This value was taken from the boundary limit of the maximum allowable vibration. Figure 4 shows for the frequency of 595 rpm and the displacement value of 0.0004 in the vibration included in the zone "Barely Noticeable to Persons", while for the engine of 3600 rpm frequency and vibration 0.0002 in displacement value included in the zone "Easily Noticeable to Persons ".

Table 2 Recapitulation of dynamic analysis calculation result

Parameter	Variation of dimension configuration					Condition
	A	B	C	D	E	
1. Spring constant (k)						
kz (Vertikal)	187729.936	187729.936	187729.936	187729.936	219759.753	
kx (Horisontal)	175266.246	175266.246	175266.246	175266.246	223512.640	
kΨ (Rocking)	7032003.277	4951685.999	7032003.277	1815247.178	3610175.105	
2. Damping Ratio (D)						
Dz (Vertikal)	0.555	0.566	0.555	0.718	0.723	> 0.71
Dx (Horisolntal)	0.764	0.779	0.764	0.983	0.983	NOT RESONANCE
DΨ (Rocking)	0.484	0.537	0.484	1.169	0.748	
	RESONANCE	RESONANCE	RESONANCE	NOT RESONANCE	NOT RESONANCE	
		Need Analysisis Vibration		OK	OK	
3. Magnification factor (M1)						
M1 (Vertikal)	0.882	0.861	0.882	0.646	0.652	
M1 (Horisontal)	0.651	0.636	0.650	0.490	0.491	< 1,5
M1 (Rocking)	0.857	0.798	0.857	0.403	0.600	
	OK	OK	OK	OK	OK	
4. Magnification factor (M2)						
M2 (Vertikal)	0.037	0.038	0.037	0.069	0.059	
M2 (Horisontal)	0.034	0.036	0.034	0.064	0.059	< 1.5
M2 (Rocking)	0.085	0.083	0.085	0.169	0.114	
	OK	OK	OK	OK	OK	
5. Amplitudo (A)						
Az (Vertikal),in	0.0028	0.0027	0.0028	0.0023	0.0019	
Ax (Horisontal), in	0.0022	0.0022	0.0022	0.0019	0.0015	TABLE 2
AΨ (Rocking), rad	0.000004	0.000006	0.000004	0.000008	0.000006	
	OK	OK	OK	OK	OK	
6. Velocity (in/sec)						
Vz (Vertikal)	0.110	0.105	0.110	0.065	0.059	
Vx (Horisontal)	0.091	0.089	0.091	0.011	0.045	< 0.08 (GOOD)
VΨ (Rocking)	-	-	-		-	
	FAIR	FAIR	FAIR	GOOD	GOOD	
7. Tranmissbility factor						
Tr (Vertikal)	1.0146	0.9613	1.0146	0.4780	0.5653	
Tr (Horisontal)	0.9791	0.9327	0.9790	0.4895	0.5255	< 1
Tr (Rocking)	0.4153	0.4146	0.4153	0.1810	0.2831	
	NOT OK	OK	NOT OK	OK	OK	

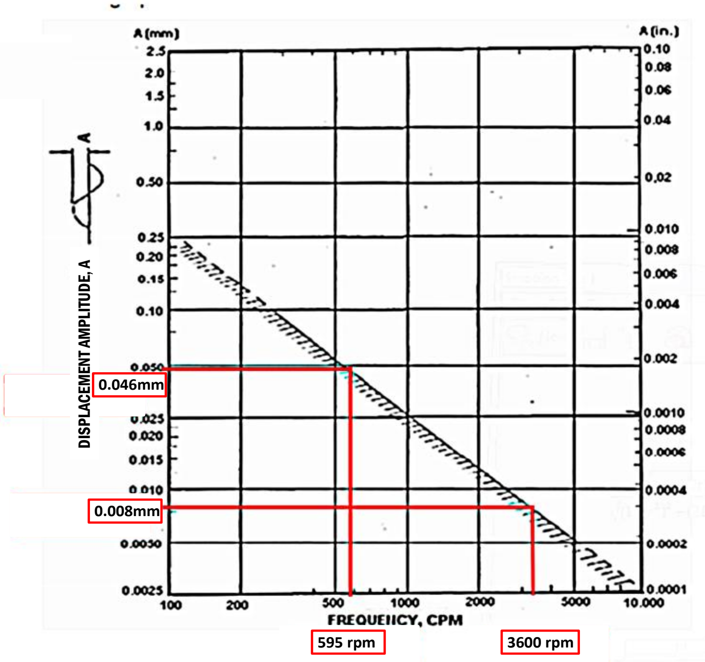


Figure 3 Allowable vertical amplitude [3]

For velocity parameter according to Table 3, the maximum velocity value has to be below 0.080 in/sec or include in "good" zone for the maximum. Therefore, from the fifth configuration of the above qualified peak velocity is safe horizontal configuration D and E.

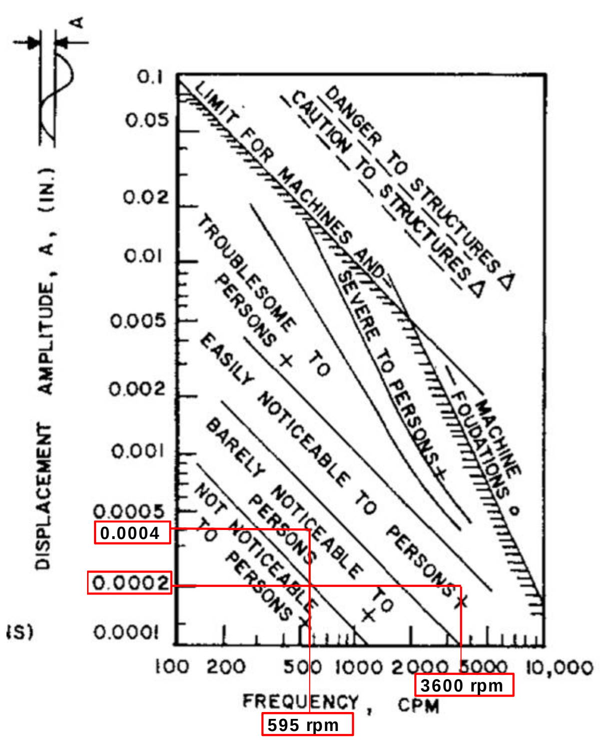


Figure 4 Criterion of vibration zone [3]

Table 3 General machinery – vibration – severity data [3]

Horizontal Peak Velocity (in/sec)	Machinery Operation
< 0.005	Extremely smooth
0.005 – 0.01	Very smooth
0.01 – 0.02	Smooth
0.02 – 0.04	Very good
0.04 – 0.08	Good
0.08 – 0.16	Fair
0.16 – 0.315	Slightly rough
0.315 – 0.63	Rough
> 0.63	Very rough

In Table 3 it can be seen that the dimensions of frame type foundation that fulfilled the safety requirements were: pile cap of 9.8 m x 4 m x 2 m; column of 0.5 m x 0.5 m x 3 m; slab of 9.8 m x 4 m x 0.5 m and pile cap of 9.8 m x 4 m x 1.5 m; column of 0.5 m x 0.5 m x 1 m and slab of 9.8 m x 4 m x 0.3 m.

Therefore, the selected dimension of frame type foundation is pile cap of 9.8 m x 4 m x 1.5 m; column of 0.5 m x 0.5 m x 1 m and slab of 9.8 m x 4 m x 0.3 m because this dimension is found to be very effective due to small volume that do not consume much of space and can fulfil all the safety requirements.

3.3.2 Analysis of Bearing Capacity and the Foundation Settlement

From the calculation, result of bearing capacity for group piles according to NSPT data is 75532 tons, where the value is still above the applied load of 44835 tons. Configuration used for pile group can be seen in Figure 5.

The calculation controls for single pile towards the consistent load are the static load of machine including the moment obtained from dynamic load calculation and temporary load/emergency that stated safe for the piles.

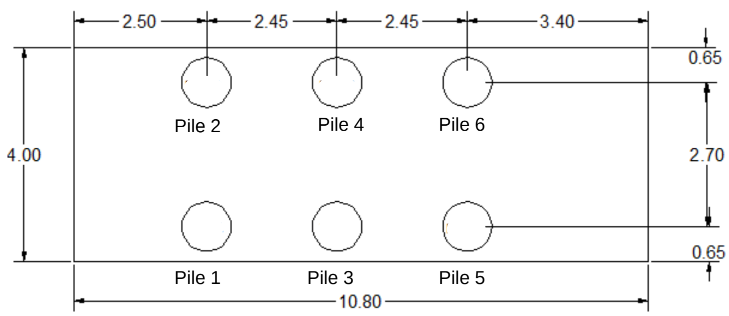


Figure 5 Configuration of piles group (all dimensions in m)

For the result of elastic settlement calculation, the recapitulation result of group piles settlement for all variations of frame type foundation dimensions are stated in Table 4.

Table 4 Settlement of group piles foundation

Variation of Configuration	A	B	C	D	E	Condition
Settlement	7.626	7.325	7.626	4.616	6.297	< 25 mm

In Table 4, it can be seen that the dimension of frame type machine foundation can fulfil all the requirements needed. The settlement of group piles is smaller than the approved limit of settlement for buildings, the value is 25 mm according to ASTM D1143-81 and thus the settlement of group piles for all the dimension variations fulfils all the requirements [4].

4.0 CONCLUSION

The conclusions drawn from the study are as follows:

(a) From the calculation result of designing the frame type machine foundation, it was observed that two dimensions of frame type foundation fulfils the safety requirements for all its parameter which are: pile cap of 9.8 m x 4 m x 1.5 m; column of 0.5 m x 0.5 m x 1 m; slab of 9.8 m x 4 m x 0.3 m and pile cap of 9.8 m x 4 m x 2 m; column of 0.5 m x 0.5 m x 3 m; slab of 9.8 m x 4 m x 0.5 m. However, the chosen dimension for frame type machine foundation is the combination of pile cap of 9.8 m x 4 m x 1.5 m); column of 0.5 m x 0.5 m x 1 m and slab of 9.8 m x 4 m x 0.3 m because from the volume and weight, these dimensions are more effective compared to the other dimensions.

(b) According to the calculation result of group piles that is the elastic depression with Meyerhof formula by using SPT-N data, it was observed that the value of group piles settlement for each dimension of frame type foundation is still categorised as safe because the approved limit of piles fulfilled the settlement requirements at the approved buildings for ASTM D 1143-81.

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References

[1] 1] Irsyam, M. 2008. *Dinamika Tanah dan Fondasi Mesin*, ITB, Bandung.
[2] Srinivasulu, P and Vaidyanathan, C.V. 1978. *Handbook of Machine Foundations*, Tata Mc Graw-Hill Publishing Co. LTD, New Delhi.
[3] Prakash, S. and Puri, V.K., 1988. "Foundations for Machines: Analysis and Design", John Wiley & Sons, New York, U.S.A.
[4] Fattah, M.Y., Al-Azal, A.A., Al-Badri, H.T., 2007, "Design Charts For Machine Foundations", *Journal Of Engineering*. 13(4)
[5] Arya, S., O'neill, M., and Pincus, G. 1981. *Design of Structures and Foundations for Vibrating Machines*, Gulf Publishing Company Book Division, Houston.
[6] Swami, S., 1999, "Soil Dynamics and Machine Foundation", Galgotia Publications Private Limited, New Delhi
[7] Das, B. M. 2008, *Advanced Soil Mechanics* (3th Edition), Taylor & Francis Group, New York.
[8] Jayarajan P., Kouzer K.M., " Dynamic Analysis of Turbo-generator Machine Foundations". *Journal of Civil Engineering and Environmental Technology*, 1(4): 30 -35.
[9] Bhatia, K.G, 2008, "Foundation For Industrial Machines and Earthquake Effects', ISET *Journal of Earthquake Technology*., 45(1-2): 13–29.
[10] Bhatia, K.G. (2008). "Foundations for Industrial Machines—A Handbook for Practising Engineers", D-CAD Publishers, New Delhi
[11] Ramdasa, K., Singh, A.K. and Bhatia, K.G., 1982, "Dynamic Analysis of Frame Foundation Using FEM", Proceedings of the 7th Symposium on Earthquake Engineering, Roorkee. 1: 411–416
[12] Bowles, J.E, 1988, "Foundation Analysis And Design (4th Edition), Mc Graw-Hill, New York
[13] Prakash, S., 1981, "Soil Dynamics", McGraw-Hill Book Company, New York, U.S.A
[14] Richart, F.E. Jr. , 1962, " Foundation vibrations, Trans, ASCE, part 1, pp. 863 – 898
[15] American Society for Testing and Materials, Annual Book of ASTM Standard, D1. 143-81