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Comparative Study of Machine Foundation and Position of Vibration Isolator

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Abstract*— The present investigation is aimed at comparative study of machine foundation and position of vibration isolator. Heavy machinery with reciprocating, impacting, or rotating masses requires a support system that can resist dynamic forces and the resulting vibrations. When excessive, such vibrations may be detrimental to the machinery, its support system, and any operating personnel subjected to them. For satisfactory performance of machine foundation system, the requirement such as permissible amplitude, allowable soil pressure, permissible stresses of concrete & steel given by IS 2974 should be fulfilled. For this one has to obtain the natural frequency of the system and amplitude of foundation during machine operation. The most important parameters for design of a machine foundation are: 1) natural frequency of machine-foundation-soil system; and 2) amplitude of motion of machine at its operating frequency.

***Index terms* –Machine foundation, Vibratory Isolator, Comparative Study.**

I. INTRODUCTION

The necessity for developing effective and economical designs for machine foundation subjected to dynamic loads has become more important in recent years. This has been caused primarily by the trend towards larger machines subjected to complex dynamic loads and the detrimental effects of vibrations emanating from them in the industrial installations, and the requirements for safety and stability of structures in the regions affected by blasts or earthquakes.

Naturally the foundation engineer has become more Concerned with the effective method of analysis and design, checking the safety of those vibrating systems. Generally two different kinds of problems come under this heading, firstly those subjected to dynamic excitation occurring within it such as vibrating machines foundations and secondly, those subjected to external source of dynamic energy as in the case of buildings subjected to earthquakes. However, the present investigation is limited to the first case only.

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For machine foundations which are subjected to dynamic loads in addition to static loads, the conventional considerations of bearing capacity and allowable settlement are insufficient to ensure a safe design. In general, a foundation weighs several times as much as machine. Also the dynamic loads produced by the moving parts of the machine are small in comparison to the static weight of the machine and foundation. But the dynamic load acts repetitively on the foundation soil system over long periods of time. Therefore, it is necessary that soil behaviour be elastic under the vibration levels produced by the machine, otherwise deformation will increase with each cycle of loading and excessive settlement may occurs.

II. HOW MACHINE FOUNDATION IS DIFFERENT FROM NORMAL FOUNDATION

The design of a machine foundation is more complex than that of a normal foundation which supports only static loads. In machine foundations, the designer must consider, in addition to the static loads, the dynamic forces caused by the working of the machine. These dynamic forces are, in turn, transmitted to the foundation supporting the machine. The designer should, therefore, be well conversant with the method of load transmission from the machine as well as with the problems concerning the dynamic behaviour of the foundation and the soil underneath the foundation.

That the knowledge in this field has lagged behind other branches of technology is partly due to the fact that the responsibility for satisfactory performance of a machine is divided between the machine designer, who is usually a mechanical engineer, and the foundation designer, whose task is to design a suitable foundation consistent with the mechanical requirements and satisfying the required tolerances. It is, therefore, desirable that the mechanical and civil engineers work in close coordination from the planning stage until the machinery is installed on the foundation.

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III. BLOCK TYPE MACHINE FOUNDATION FOR RECIPROCATING MACHINE

Reciprocating machines are common in use. Reciprocating engines having crank-type mechanism, for the satisfactory performance of the machine-foundation system, the requirements given in chapter 3 should be fulfilled. For this, one has to obtain (a) The natural frequency of the system, and (b) The amplitude of foundation during machine operation. The basic assumptions made in the analyses are: (a) the foundation block is considered to have only inertial properties and to lack elastic properties, and (b) the soil is considered to have only elastic properties and to lack properties of inertia.

METHODS OF ANALYSIS

The following two methods are commonly used for analyzing a machine foundation

a) Linear elastic weightless spring method (Barkan, 1962).

b) Elastic half- space method (Richart, 1962).

Foundation subjected to vertical vibration due to reciprocating machine

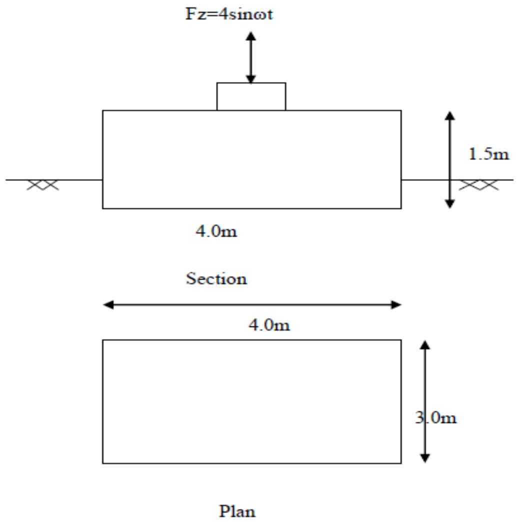

Fig.1. Typical Figure of machine foundation

Machine Properties:

Reciprocating machine rests on 4.0 x3.0 x1.5 m block vibrates with 550 rpm

Vertical unbalanced force = 4 sinwt KN

Dynamic elastic constants of soil:

Young's modulus of soil=E= 3x 10^5 KN/m^2

Shear modulus of soil = G=1.1 x 10^4 KN/m2

Poisson's ratio=0.35

Coefficient elastic Uniform compression=Cu=5.00 x 10^4 kN/m^2

(Assumed as per IS 2974-Pt.1-1969 For medium soil)

Foundation Data:

M20 concrete for block

Unit weight of block= 24 KN/m^3

By changing the plan area but keeping the volume of foundation same discussed 9 cases.

Results:

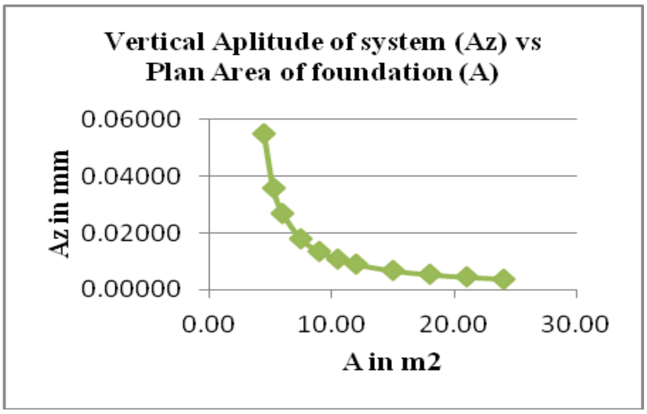

Fig 2

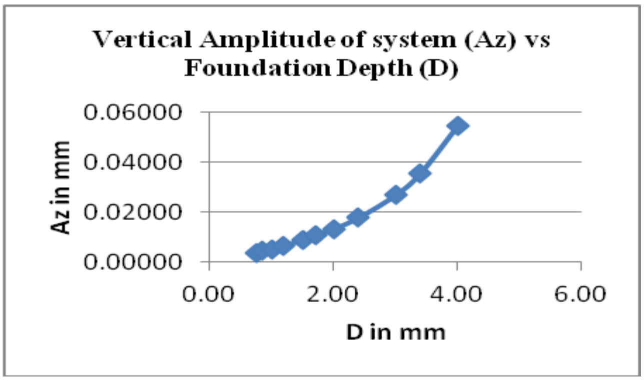

Fig 3

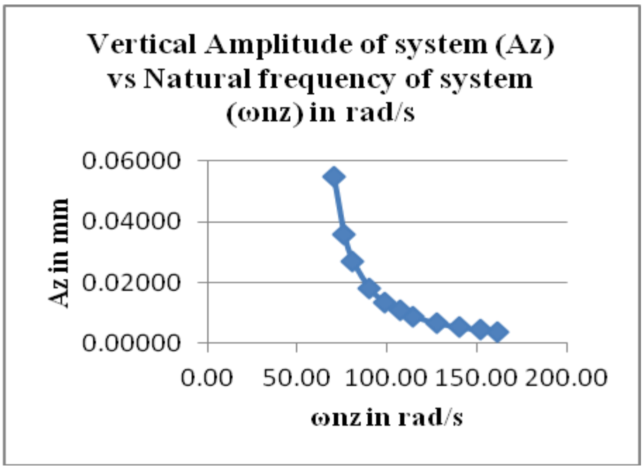

Fig 4

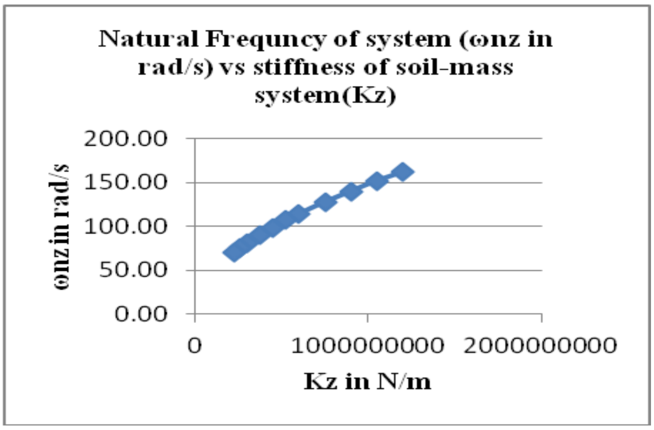

Fig 5

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Observations and Discussions

1. As plan area (A) of foundation block decreases (i.e. depth of foundation (d) increases),the vertical amplitude (Az) of foundation increases and vice versa (refer fig.3.2,and fig.43.3)
2. As natural frequency of system (ωnz) decreases, the vertical amplitude of foundation(Az) increases and vice versa (refer fig.3.4)
3. As vertical stiffness of soil-mass system decreases (Kz), the natural frequency of the system (ωnz) also decreases and vice versa (fig.3.5)

Conclusion

Vertical amplitude of foundation block decreases as plan area of foundation block decreases, for constant mass of foundation and vice versa.

IV. VIBRATION ISOLATOR

If a machine is rigidly bolted to the floor, the vibratory movement of the machine itself may be reduced, but the vibration transmitted to the floor will be large. This may produce harmful effects even at large distances. On the other hand, if a flexible support is provided under the machine or its foundation, the vibration transmitted to the floor will be considerably reduced, but this may cause significant motion to the machine itself during normal operation or during the starting and stopping stages. Some compromise has, therefore, to be reached between the two requirements. This is achieved in design practice by selecting a suitable natural frequency for the machine foundation. Isolator has considerably different natural frequency, compared to the forcing frequency of the applied force.

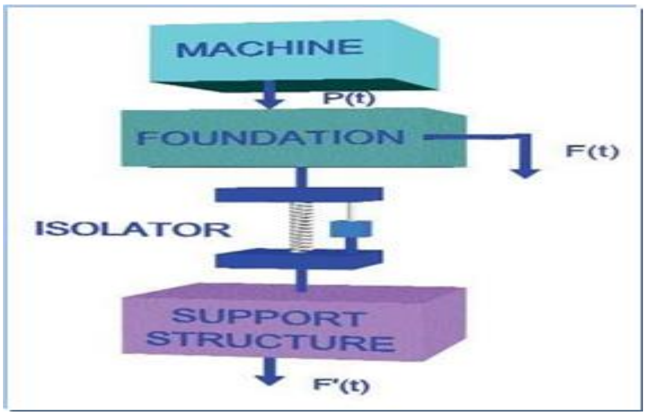

Fig 6. Typical Details of vibration Isolator

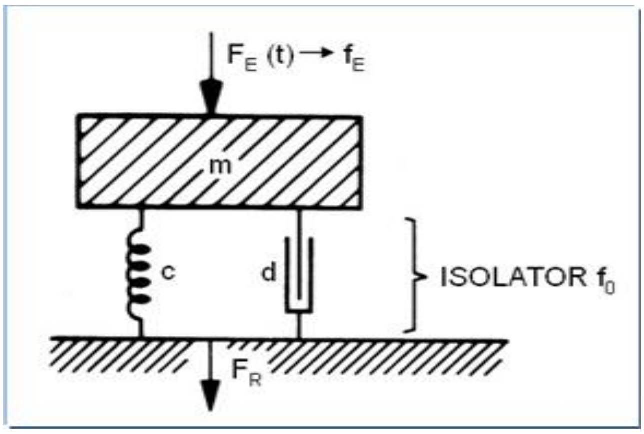

Fig 7. Mathematical model for Vibration Isolator.

Model IA) For Vertical Vibration Only Without vibration isolators.
Model IB) Isolator between machine & foundation
Model IC) Isolator between Machine + 33% weight of foundation & 67% weight of foundation.
Model ID) Isolator between Machine + 50% weight of foundation & 50% weight of foundation.
Model IE) Isolator between Machine + 67% weight of foundation & 33% weight of foundation.
Model IF) Isolator between Machine + 93% weight of foundation & 7% weight of foundation.
Model I) A reciprocating machine is symmetrically mounted on block of size 4.0m x3.0m x1.5m high. The soil at site is sandy. The machine is vibrating with a speed of 550 rpm generates the vertical unbalanced force of 4KN.The machine weight is 18 KN. The Limiting amplitude is 0.0150mm.

Table 1 Results for vibration isolator (Analytically)

Sr. No.	Case	Mass above isolator(m2)	Mass below Isolator (M1)	Mass ratio (μm) m2/m1	Natural frequency of mass m2	Ratio a2	Stiffness of isolator k2 in KN/m	Amplitude of Foundation AZ1	Amplitude of machine Az2	Force
		KNs2/m	KNs2/m		rad/s			mm	mm	N
1	II A	1.83			72.36				0.045	
2	II B	1.83	44	0.0416	33.05	0.574	1998.91358	-0.0205	-0.98	1958.94
3	II C	16.49	29.33	0.5622	65.6	1.139	70962.4064	-0.179	-0.52	36900.45
4	II D	23.83	22	1.0832	71.3	1.238	121144.333	-0.184	-0.433	52455.50
5	II E	31.16	14.6	2.1342	76.43	1.327	182022.539	-0.184	-0.37	67348.34
6	II F	42.75	3.08	13.8799	83.86	1.456	300639.358	-0.184	-0.32	96204.59

Model IA) For Vertical Vibration Only Without vibration isolators (Staad Pro Results).

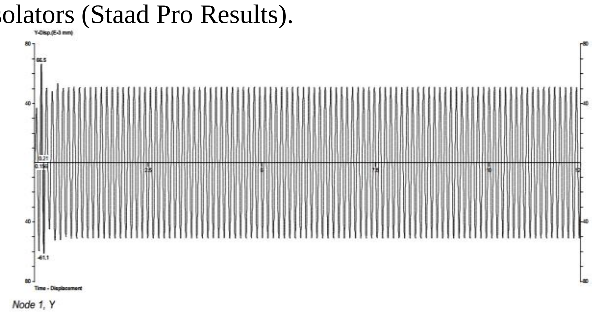

Fig 8. Amplitude of Machine AZ2

Model IB) Isolator between machine & foundation (Staad Pro Results).

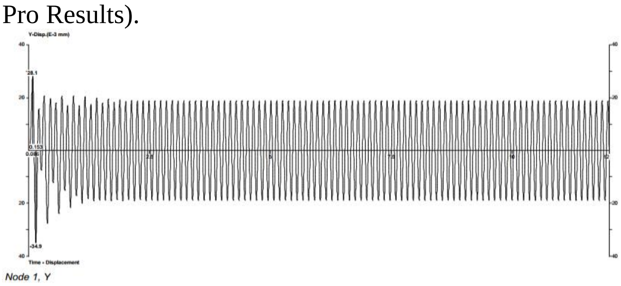

Fig 9. Amplitude of Foundation AZ1

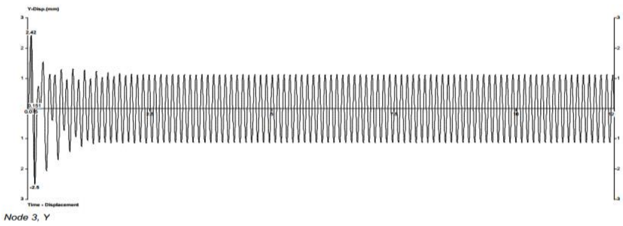

Fig 10. Amplitude of Machine AZ2

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Model IC) Isolator between Machine + 33% weight of foundation & 67% weight of foundation(Staad Pro Results).

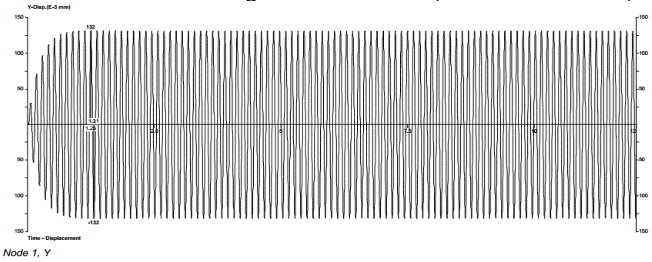


Fig 11. Amplitude of Foundation AZ1

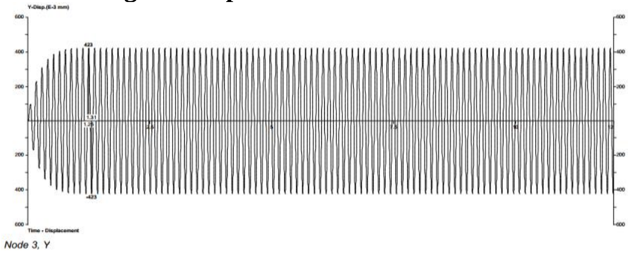


Fig 12. Amplitude of Machine AZ2

Model ID) Isolator between Machine + 50% weight of foundation & 50% weight of foundation (Staad Pro Results).

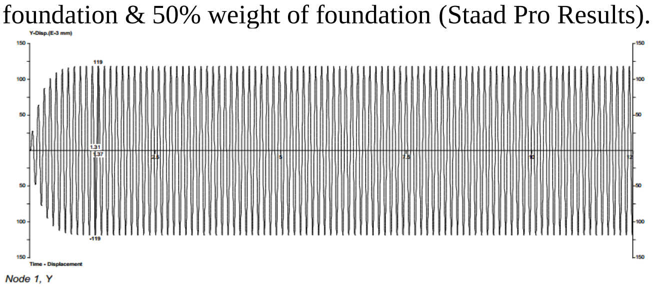


Fig 13. Amplitude of Foundation AZ1

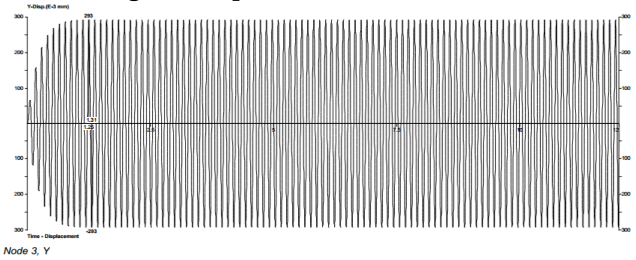


Fig 14. Amplitude of Machine AZ2

Model IE) Isolator between Machine + 67% weight of foundation & 33% weight of foundation(StaadPro Results).

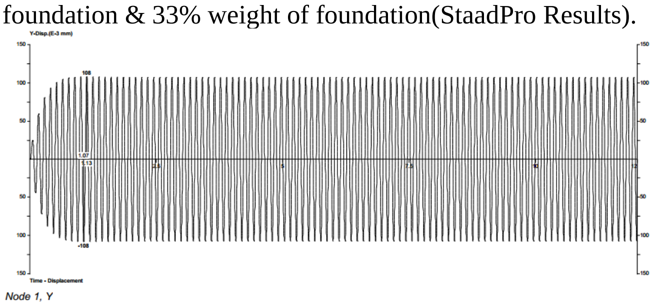


Fig 15. Amplitude of Foundation AZ1

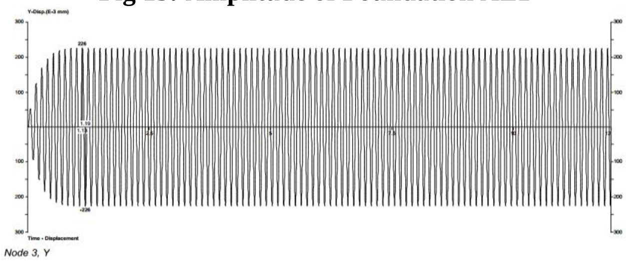


Fig 16. Amplitude of Machine AZ2

Model IF) Isolator between Machine + 93% weight of foundation & 7% weight of foundation(StaadPro Results).

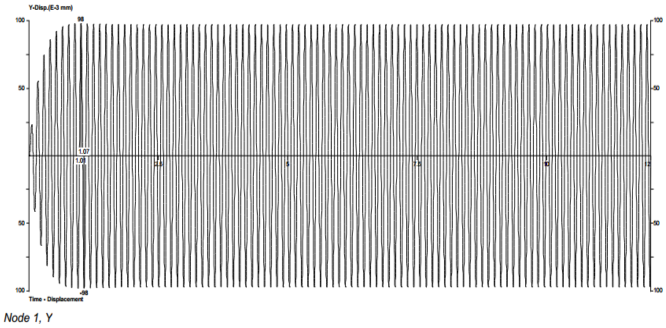


Fig 17. Amplitude of Foundation AZ1

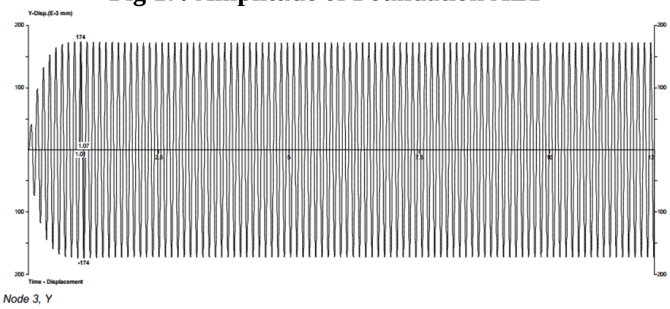
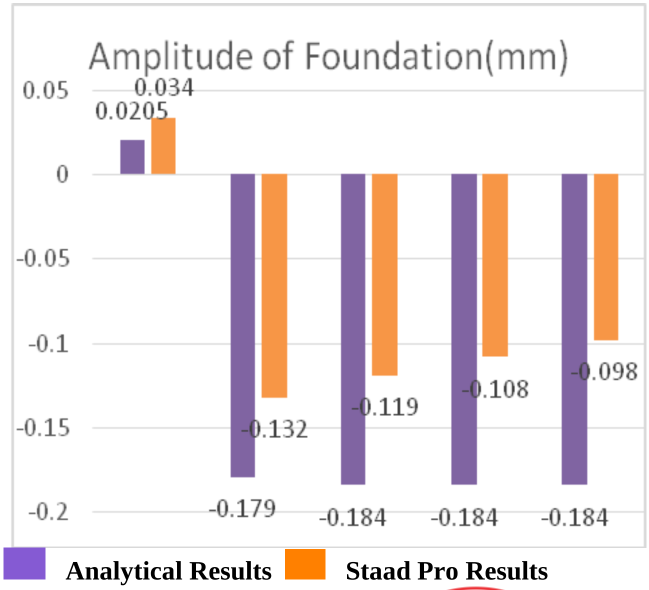


Fig 18. Amplitude of Machine AZ2

Table 2 Comparison Results for Vibration Isolator

Sr. No.	Case	Amplitude of Foundation AZ1 (Analytically) (mm)	Amplitude of Foundation AZ1 (Staad pro) (mm)	Amplitude of Machine AZ2 (Analytically) (mm)	Amplitude of Machine AZ2 (Staad Pro) (mm)
1	IA	-	-	0.045	0.066
2	IB	0.0205	0.034	-0.98	-2.20
3	IC	-0.179	-0.132	-0.52	-0.423
4	ID	-0.184	-0.119	-0.433	-0.293
5	IE	-0.184	-0.108	-0.37	-0.226
6	IF	-0.184	-0.098	-0.32	-0.174



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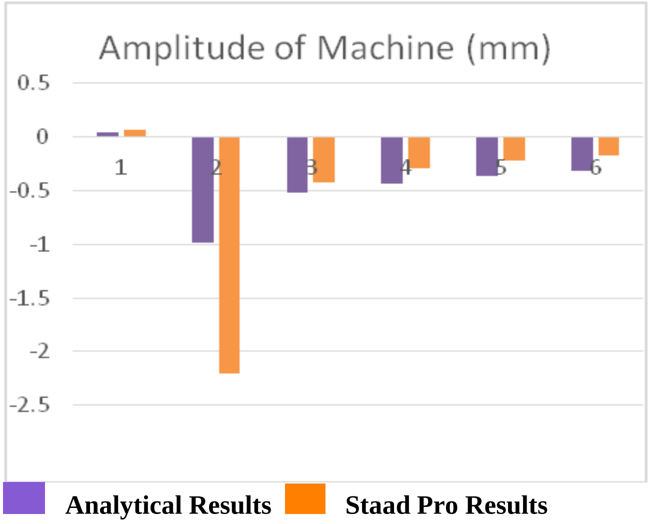

Observations and Discussions

a. Case IIA: When Machine on foundation block (support block) of depth 1.5m is operating with no isolator, the amplitude of support block is 0.045mm
b. Case IIB: When Machine is operating with isolator between machine & foundation block (support block) of depth 1.5m the amplitude of support block is 0.0205mm
c. Case IIC: When Machine is operating with foundation block of depth 0.5m with isolator between machine +foundation block of depth 0.5m and support block of depth 1 m the amplitude of support block is 0.179mm
d. Case IID: When Machine is operating with foundation block of depth 0.75m with isolator between machine +foundation block of depth 0.75m and support block of depth 0.75 m the amplitude of support block is 0.184mm
e. Case IIE: When Machine is operating with foundation block of depth 0.5m with isolator between machine +foundation block of depth 1m and support block of depth 0.5 m the amplitude of support block is 0.184mm
f. Case IIF: When Machine is operating with foundation block of depth 1.4m with isolator between machine +foundation block of depth 1.4m and support block of depth 0.1 m the amplitude of support block is 0.184mm

V. Conclusion

Out of various locations of isolator, when placed between machine and foundation gives minimum vertical amplitude of foundation.

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