Analysis of Machine Foundation with and without Base Isolation

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Abstract - The design of machine foundation is more complex than other foundations which support only static loads. In machine foundation, the designer must consider, the dynamic forces caused by working of the machine, in addition to the static loads. These dynamic forces produced by machine transmitted towards the supporting foundation. So, it should be very important to understand the method of load transmission from the machine as well as dynamic behavior of the foundation and the soil underneath the foundation.
A hydraulic press was installed in Tile Industry having weight of 185 tones. Considering heavy weight of press machine, in addition to normal size block foundation six piles provided below the foundation which made foundation rigid. Weight of press machine was successfully taken by foundation but while in operation press machine causes high amplitude of vibration which shakes floor and adjacent structure excessively. This high amplitude of vibration also makes it very hard for workers to work in nearby area. When Base Isolation mechanism applied in between foundation and piles, it reduces up to 78% of amplitude of vibration. So, main aim of this work is to isolate the vibration caused by the press machine to required extent by using base isolation technique.

Key Words:Hydraulic Press Machine, Base Isolation, FEA, Amplitude, Resonance.

1 .INTRODUCTION

The design of machine foundation is more complex than other foundations which support only static loads. In machine foundation, the designer must consider, the dynamic forces caused by working of the machine, in addition to the static loads. These dynamic forces produced by machine transmitted towards the supporting foundation. So, it should be very important to understand the method of load transmission from the machine as well as dynamic behavior of the foundation and the soil underneath the foundation.

In recent times, many new systems have been developed, either to reduce the earthquake forces acting on the structure or to absorb a part of seismic energy. One of the most widely implemented and accepted seismic protection systems is base isolation. The fundamental principle of base isolation is to modify the response of the structure so that the acceleration between ground and rigid structure should be reduced or neutralized.
Types of base isolation

Elastomeric Isolators
• Natural Rubber Bearings
• Low-Damping Rubber Bearings
• Lead-Rubber Bearings
• High-Damping Rubber Bearings

Sliding Isolators
• Resilient Friction System
• Friction Pendulum System

By comparing above techniques Elastomeric base isolation technique is suitable for machine foundation to isolate high amplitude of vibration. In the elastomeric base isolation technique low-damping rubber bearing technique is used. Elastomeric bearings use either natural rubber or synthetic rubber (such as neoprene), which have little inherent damping, usually 2% to 3% of critical viscous damping.

2. Foundation Failure's Cases in Hydraulic Press Machine

In tiles manufacturing process hydraulic press is the heaviest machine to its foundation than other machines used during tiles manufacturing process. The manufacturing operations consist of other heavy machines like Kiln & Polishing machine but the whole mass of these machines is horizontally distributed on foundation along its length. In that case machine foundation is not that much affected with time although vibrations are produces. But in case of Hydraulic press machine, whole mass of the machine is concentrated on small area and these machines having weight up to 98ton to 185ton and above. Also press machine having vertically moving plunger and the weight of plunger is up to 45ton. Plunger moving frequency is ≤20 c/min. which gives huge impact on foundation. In such cases foundation failure chances will increases.

Case I: Press install on normally designed foundation

Some serious things come-off in ceramic tiles industry in Morbi, Gujrat when they install 185 tons KEDA 7808W hydraulic press on normally designed foundation after some years they observe that tiles are breaking when they come out from press machine, because level of press machine is down than conveyor roller table attached in front of press machine. This is happened due to settlement of foundation below press machine. In that case no solution found out by company besides reconstruction of whole foundation.

Case II: Press install on heavy designed foundation

185 tones size of model hydraulic press (KEDA 7808W) was installed in Johnson Tiles India (division). Taking reference of above case, they modified design of foundation normally to heavy foundation. In addition to normal size block foundation 6 no. of piles provided below. Finally press was installed on foundation and weight of press was successfully taken by foundation. But while press is running it vibrates adjacent floor and structure due to rigidity of foundation which creates problems to employees during working. To overcome these problems application of new techniques like base-isolation, dampers should be effective in future.

3. Strategics for foundation failure cases

The press machine installed in Prism Jonson India Division is causing high amplitude of vibration to nearby structure. Main aim of this work is to isolate the vibration cause by the press machine to required extent by using base isolation technique by finding out resonance frequency of the foundation to avoid resonance. And comparing analytical and FEA results for frequency and maximum amplitude.

4. Design Criteria of Machine Foundation

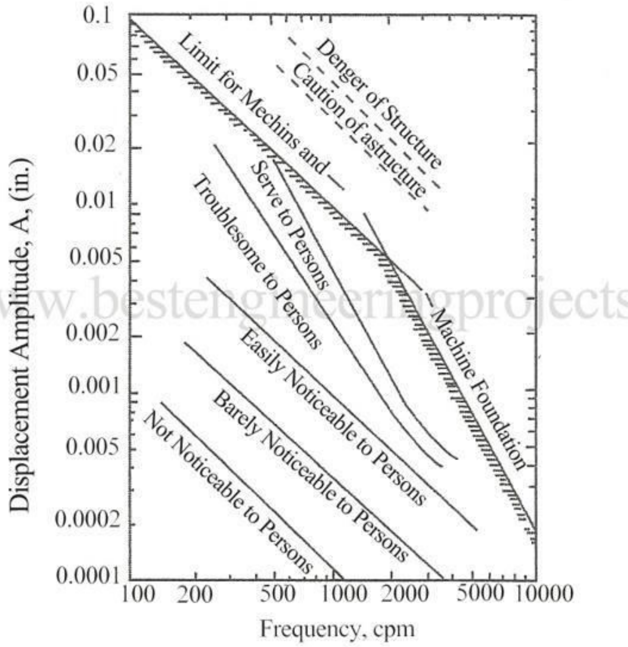

Fig -1 General limits of displacement amplitude for a particular frequency vibration (Richard, 162)

Table -1: Values of permissible amplitudes for foundation of different machines

S.N	Type of Machine	Permissible Amplitude (mm)	Reference
1	Reciprocating Machine	0.2	IS:2974(Pt-I)
2	Hammer		IS:2974(Pt-II)
	(a) For foundation block	1.0 to 2.0	
	(b) For Anvil	1.0 to 3.0	
3	Rotary Machine		
	(a)Speed < 1500 rpm	0.2	
	(b) Speed 1500 rpm to 3000 rpm	0.4 to 0.6 Vertical Vibration 0.7 to 0.9 Horizantal Vibration	IS:2974 (Pt-IV) IS:2974 (Pt-III): 1992
	(C) Speed > 3000 rpm	0.2 to 0.3 Vertical Vibration 0.4 to 0.5 Horizantal Vibration	

5. Methodology

A cad model prefer following and the input parameters

Table 2: Input parameters of CAD model

Sr.No	Parameter	Values	
1	Natural Frequency	3.56 cps	
2	Radius of equivalent circular base	22.53 cm	
3	Equivalent spring stiffness of soil	5305.89 Kg/cm	
4	Natural Frequency of vibration	15 cps	
5	Amplitude of maximum dynamic displacement	X direction = 6.77 mm	Z direction = 0.8 mm
6	Amplitude of maximum dynamic displacement at resonance	X direction = 11.79 mm	Z direction = 11.75 mm

Result Obtained by Mass-Spring-Dashpot MSD model

- 340cm*470cm*119cm,
- Machine weight $a0=185ton$
- Damping coefficient η = 15%,
- Poisson's ratio = 0.15
- Foundation + machine weight = 231 ton Soil with elasticity value,
- G=50.98 Kg/cm2,
- Frequency = 330 rpm

6. Cad Modelling and Finite Element Analysis

A. CAD Model

CAD model of each part of the system and assembly of modeled parts was prepared in CREO Parametric 6.0.1.0 software. Machine was considered as simple block as shown is figures below.

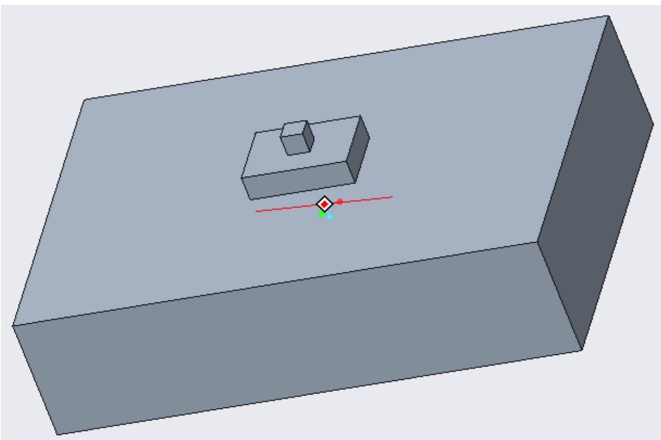

Fig -2: Solid Model of the Assembly with soil

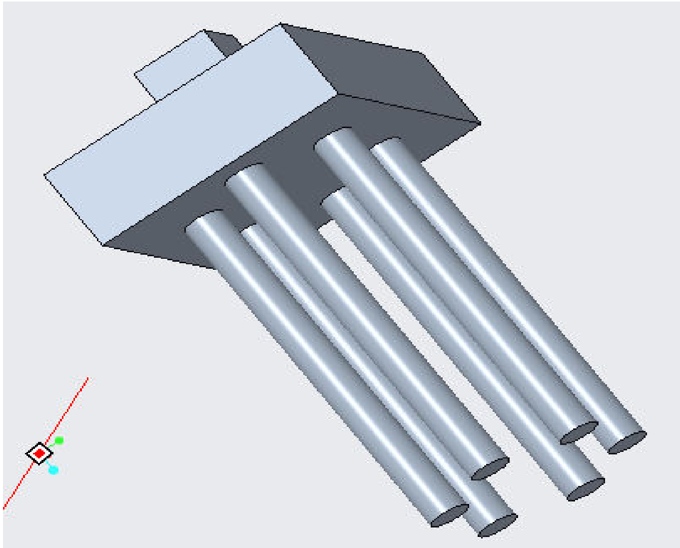

Fig -3: Solid Model of the Assembly with soil

B. Material Properties

- **Steel**
  Density – 7800 Kg/m3
  Modulus of elasticity – 200 GPas
  Poisson's ratio – 0.3

- **Reinforced Cement Concrete**
  Density – 2500 Kg/m3
  Modulus of elasticity – 23.5 GPas
  Poisson's ratio – 0.15

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C. Mesh and Element type

The mesh refinements are considered at more utilization parts of assembly. The mesh density of model is shown in following figure. Fine mesh is used at the contact interfaces and also at the radius of interest. A triangular elements with reduced integration and hourglass control is used for all parts.

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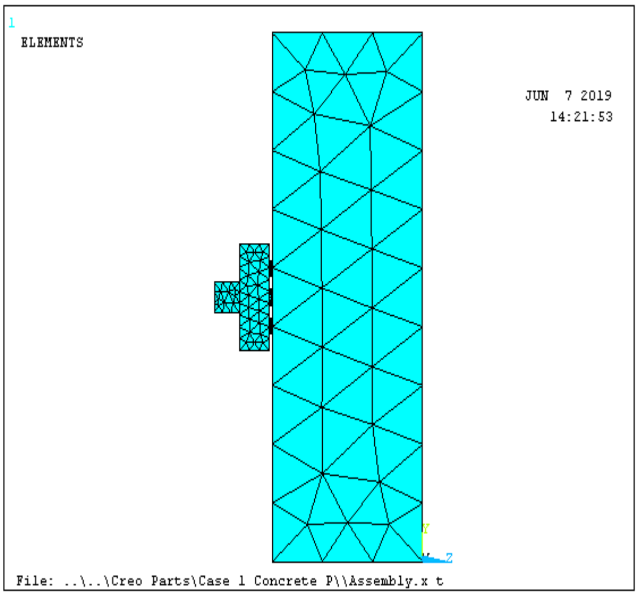

Fig -4 Mesh Model

7. Result

Table -3: Comparison of Amplitude of vibration without base isolation

S.N	Amplitude of vibration Without base isolation	Frequency (HZ)	Analytical (mm)		FEA (mm)	
			Sliding	Vertical	Sliding	Vertical
1	Maximum Dynamic displacement	5.5	6.77	0.8	6.28	0.79
2	Resonance	6	11.79	11.75	10.76	10.26

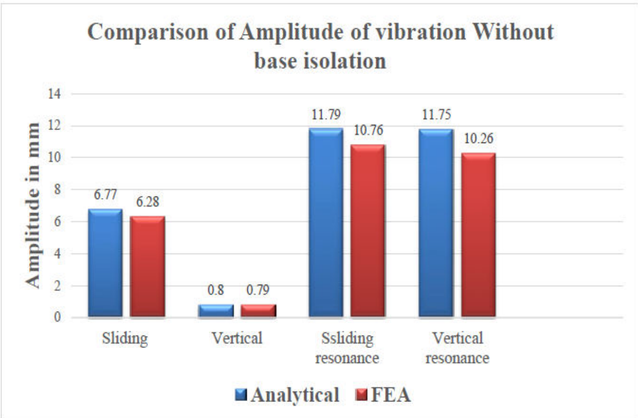

Fig -5 Comparison of Amplitude of vibration without base isolation

Table -4: Comparison of Amplitude of vibration without base isolation and with base isolation from FEA

S. N	Amplitude of vibration Without base isolation	Frequency (HZ)	Analytical (mm)		FEA (mm)	
			Sliding	Vertical	Sliding	Vertical
1	Maximum Dynamic displacement	5.5	6.28	0.79	1.59	0.348
2	Resonance	6	10.76	10.26	2.92	1.765

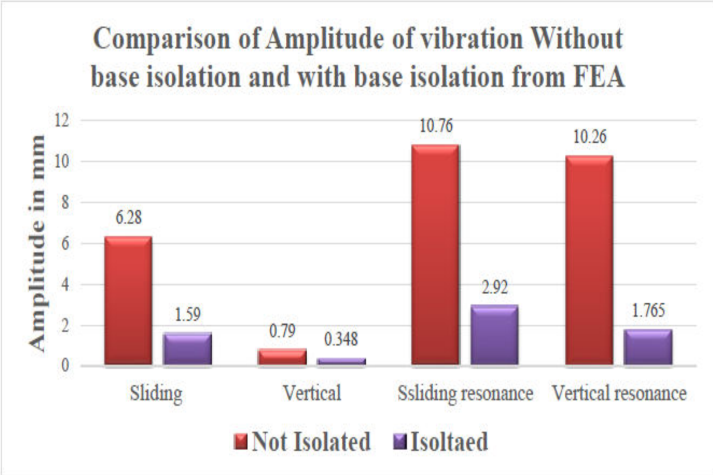

Fig -6 Comparison of Amplitude of vibration Without base isolation and with base isolation FEA.

8. CONCLUSIONS

First, analytical results of foundation without base isolation were compared with FEA results.

Table -7: Comparison of Amplitude of vibration without base isolation

S.N	Amplitude of vibration Without base isolation	Frequency (HZ)	Analytical (mm)		FEA (mm)	
			Sliding	Vertical	Sliding	Vertical
1	Maximum Dynamic displacement	5.5	6.77	0.8	6.28	0.79
2	Resonance	6	11.79	11.75	10.76	10.26

- Results obtained from Analytical and FEA methods does not vary much thus FEA methods can be applied to obtained the vibration amplitude caused by the base isolation techniques.
- Results obtained from without base isolation are beyond 3 mm that is beyond safe limit for vibration amplitude because of that structure nearby press machine was vibrating excessively.

Table -8: Comparison of Amplitude of vibration without base isolation and with base isolation from FEA

S. N	Amplitude of vibration Without base isolation	Frequency (HZ)	Analytical (mm)		FEA (mm)	
			Sliding	Vertical	Sliding	Vertical
1	Maximum Dynamic displacement	5.5	6.28	0.79	1.59	0.348
2	Resonance	6	10.76	10.26	2.92	1.765

- FEA result with base isolation shows that the vibration amplitudes are 1.59 in sliding direction mm and 0.248 mm in vertical direction. These results are under safe limit of 3 mm thus machine will not cause excess vibration for nearby structure.
- It can be concluded that the base isolation technique can be implemented for hydraulic press machine in order to limit its excessive vibration under safe limits.

Table -9: Reduction of amplitude in percentage

Maximum Amplitude	Sliding Direction	Vertical Direction	Resonance in Sliding Direction	Resonance in Vertical Direction
Reduction in %	**74.68**	**56**	**72.86**	**78.95**

9. FUTURE SCOPE

- In present work effect of with and without base isolation technique with rubber pad is analysed, base isolation with different lengths of rubber pads can be analysed.
- Future study should be carried out for extreme seismic conditions.

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