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Analysis of Static and Dynamic Loads on Equipment Foundation in Modular Design of Cold Rolling Mill

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ABSTRACT: The foundation of Cold Rolling Mills and associated auxiliary equipments are subjected to very high static load and forces due to self weight and severe dynamic loads during rolling operation. Because of the considerable weight of most commercial cold rolling mills and the dynamic forcers to which they are subjected such facilities must have firm foundations. The weight of the mill is carried by the feet of the housing resting on girders above the foundation, these girders being known as housing shoes or bedplates. These devices may be considered as beam on the resilient base and are fastened with bolts to the foundation. These bolts must be capable of withstanding the same forces as the bolts securing the feet of the housing to the shoes.

The term "foundation loads" as used here related to single forces, force couple, load per unit area or pure torques. The ideal case is that a foundation is only loaded by weight forces due to the machine or equipment and the material being rolled. Adding up to this in most cases are forces and torque taking effect between the machine or components of a machine via the foundation. An another group comprises of those kinetic forces which are produced due to movement of the materials being rolled (for instance stop, free fall) and which have to be accommodated by the foundation. The calculation, analysis and design of foundation loads shall be explained with reference to examples from the rolling mill field. There are various equipments foundations in modular design of cold rolling mill like mill housing, base frame at strip preparation station, base frame of reversing (tension) reel no.1, base frame of reversing reel no.2 etc. So the calculation, analysis and design of foundation loads have been carried out for these equipments. This project work covers various types of load acting on the equipment, and their effect on the foundation.

KEYWORDS: Foundation loads, Mill housing, Base frame at strip preparation station, Reversing reel.

I. INTRODUCTION

Analysis of static and dynamic loads on equipment foundation in modular design of cold rolling mill has biggest challenges that any design engineer could face during rolling mill design. If not properly analyzed, it could lead to a large amount of destruction in terms of performance of the cold rolling mill, property, loss of life and money. A prescriptive approach to mechanical design in the form of various codes and standards, has been utilized which helps to solve the problem to a greater extent by regulating strict norms for design, material and construction of the equipments. Factors of important for dimensioning a foundation besides magnitude and orientation of loads are also their evolution within unit time, their frequency and their mutual superposition. Since it would take too much effort to represent in a part very complicated loads in all detail, the load indication has to be expressed in a general term. Distinction is being made between three types of loads, namely static, dynamic and maximum loads. The static load refers to self weight of the equipment. The dynamic loads ("dyn") cover all regular operational loads while the maximum loads ("HL") define just seldom occurring loads peaks due to malfunctions and/or trouble and similar exceptions. Dynamic loads and maximum loads are determined separately because load frequency is one essential criterion for dimensioning of a foundation. Loads that only occur jointly are summarized in one single statement wherever possible. This means that all loads given in the load plan may occur separately or simultaneously. The max load (HL) denotes the actual

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maximum load exposure of the foundation and hence has to comprise all static and kinetic load components that are taking effect in case of a trouble or malfunction.

II. COLD ROLLING MILL

The present work involves Static and dynamic loads on the foundation of modular frames of compact rolling for cold rolling mill (CCM). Basically there are three types of loads acting on the mill foundation. The loads are static loads, dynamic loads, and maximum load. Static load refers weight of the equipment. Dynamic load comes in to the picture mainly because of cylinders actuation. These cylinders produce high dynamic load on the mill foundation. The effect of inertia is neglected. Maximum load comes because of malfunctions. The cold rolling mill is divided in 6 modules i.e. mill housing, base frame at strip preparation station, base frame of reversing (tension) reel no.1 & 2, guard frame, chimney for fume exhaust system which is shown in fig. 1

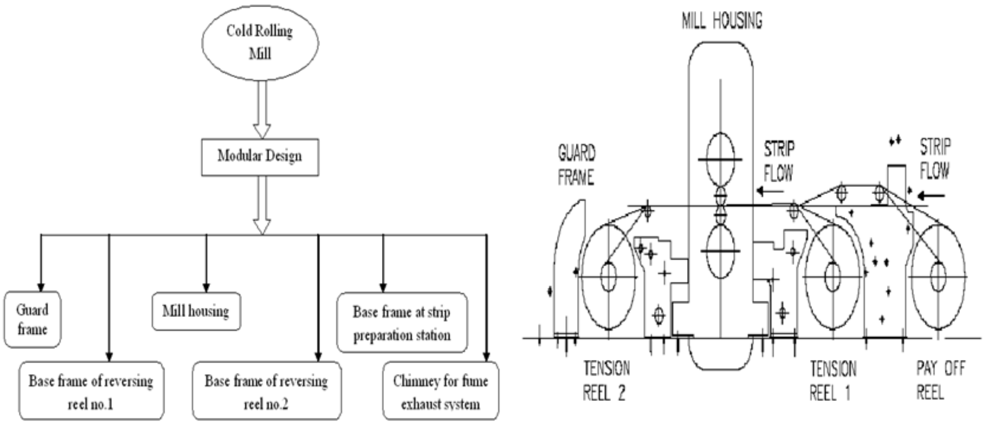

Figure 1: High Reversing cold rolling mill modules & equipments

The important factors which affect foundation structures are due to operational troubles or malfunctions. This occurs when drives stops operating because a specified maximum or breakdown torque is reached, the overpressure relief valve of the hydraulic system, material bending, upsetting or breaking, use of simple low-caste component, Foundation breakage and fracture must be avoided by all means.

A. Calculation of foundation loads

Foundation loads are basically three types. Therefore it is required to define three different load classifications as under:

[i] Static loads: These are loads that build up gradually over time, or with negligible dynamic effects, and act continuously and uniformly in just one direction and that are not subject to quick or frequent variation. This refers dead weight of the equipments and machines.

[ii] Dynamic loads ("dyn"): These are loads which occur during operation of mill. This covers all loads which are produced by moving components.

[iii] Maximum load (HL): This is the load which occurs suddenly due to trouble or maloperation.

The dynamic and maximum loads depend on various factors, especially on the speed of the process and the rigidity of the load exposed component. Safety factor has been taken to cover these influences. The essential rule for calculation and design of foundation loads will be explained with reference to examples from the rolling mill field.

[a] Rolling mill stands: When strip passes through the mill housing foundation loads are produced due to non-uniform roll torques (via the drive spindles) or longitudinal forces in the material being rolled (tension force in continuous rolling, compression force due to blocking of material heads in the pass line). Besides the rolling force that must be withstood by the mill housing, the housing is also subject to a tilting moment (M). This moment is attributable to the sum of two components M_1 and M_2 where, M_1 is the moment acting on the stand from the mill drive as a direct result of rolling and M_2 is the moment resulting for forces acting on the rolls via the work piece, for example, the strip tensions. If the two spindle torques is equal and opposite, M_1 will be zero. On the other hand, M_1 will assume its largest values (M_{max}) if only one roll is driven. The value of M_2 may be computed from the product of the unbalance of the tensile

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forces in the strip (F_A or R) and the elevation of the rolling plane above the housing shoe (C). The largest value of R in many cases can be equated to $2M_{max}/D$, see table 1, while in case of continuous stands a dynamic load can be calculated from roll tension strength at failure (calculated from high temperature strength σ_W and delivery area A_1).

Table 1: Various types of load plan.

EXAMPLES		DRAWING ENTRIES
MACHINE	SKETCH	LOAD PLAN
MILL WITH SINGLE–COIL ROLL, TWIN DRIVE	Ao, A1, FA, FD,Z, M	X dyn/Y HL, H
MILL WITH SINGLE–COIL ROLL, MILL PINION DRIVE	Ao, A1, FA, FD,Z, M	Xdyn/Y HL, H
MILL WITH CONTINUOUS ROLL, MILL PINION DRIVE	Ao, A1, FA, FD,Z,R, M	Xdyn/Y HL, H
GEAR UNIT REDUCER	MINP, MSTAND, MOUT	Xdyn/YHL
ELECTRIC MOTOR		X dyn/Y HL
DRIVE CYLINDER	AE, AP, FH, a	X dyn/YHL, H, Xdyn/Y HL, H

The tension strength at failure of the material F_R will be assumed as maximum load (HL) for single stands as calculated from high temperature strength and delivery area with impact 3. It is Also to be calculated for single stands is the compression force F_Z from the maximum torque and roll radius with impact factor 1.5, and the lower value (F_D or F_Z) is to be stated as 'HL' in the load plan.

[b] Gear units: Load imposed on a foundation by gear units normally comprise the restoring torque of the gearbox. This torque is defined as the sum of input and output torque when input and output shaft turning in opposed direction, the difference between these torque when input and output shaft turning in same direction, see table 1.

[c] Motors: Electric motors can apply pure torque to the foundation only. The dynamic load will normally range between half and twice the rated torque. The maximum or breakdown torque, hence in most cases three times the rated torque, has to be assumed as maximum torque, see table 1.

[d] Drive cylinder: The dynamic load can be calculated from the operating pressure via the piston area. The maximum loads are assessed from the maximum pressure as set on the basis of an impact factor F_{ST} = 1.5, see table 1.

[e] Crank drives: Crank drive mechanisms are capable of producing forces of any magnitude due to toggle lever action, but force is mostly restricted by the load involved in normal operation, for instance by the weight of the raised components. The dynamic load can here be calculated via the weight with an impact factor F_{ST} = 2 to 3.The crank rod stroke can be expected to be restricted in a maximum load case.

III. LOAD ANALYSIS

A. Arrangement and Function of base frame at strip preparation station

Base frame at strip preparation station is mounted between the pay off reel and reversing reel no.1

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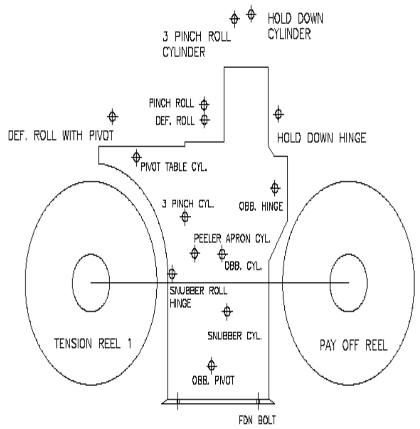

Figure 2: Base frame at strip preparation station equipments.

Base frame at strip preparation station provides supports for various equipments, see figure 2.

1. Driven hold down roll
2. The pay off reel outboard bearing support frame
3. Pivoting strip guiding table with coil peeler
4. Strip center control device
5. 3-roll pinch and leveling unit
6. Pivoting strip carryover table
7. Side guides
8. Deflector roll
9. Snubber roll no.1

B. Load calculation of snubber roll no.1

Snubber roll no.1 is placed at entry side of the reversing reel no.1. and it contains the outer wrap of the coil when tailing out.

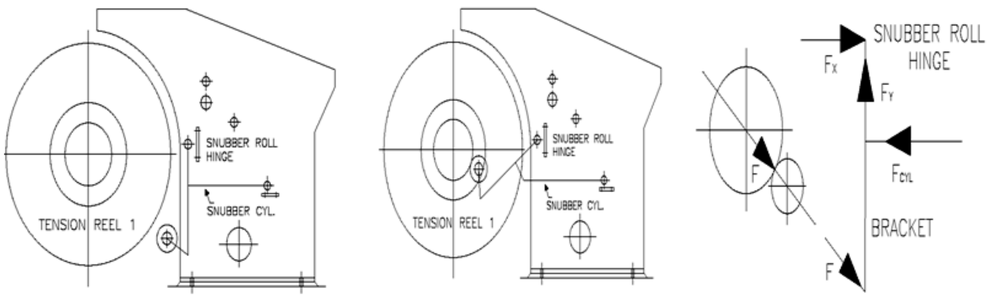

Figure 3: Cylinder full collapsed and Expanded with Free body diagram

There are basically two position of the cylinder i.e. full collapsed and full expanded, see figure [3]. When cylinder is in full collapsed position, if it starts to expand and there is some obstruction to the bracket then whole force produced by cylinder is transferred to snubber cylinder hinge. This maximum force has tendency to topple the base frame at strip preparation station. We can calculate the contact force between bracket roll and tension reel 1(coil), stress in bracket, snubber roll hinge reactions.

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C. Load calculation of outboard bearing support

Outboard bearing support is mounted on the preparation station base frame pivoting to the free end of the payoff reel mandrel and it Provides supports for the free end of the reel mandrel during rolling.

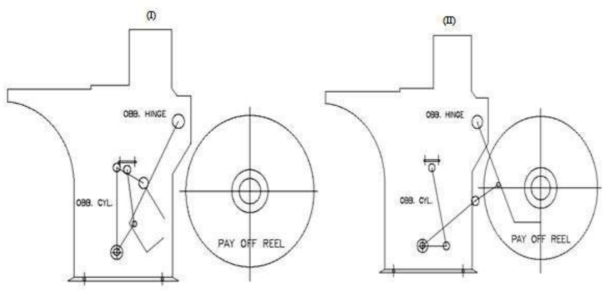

Figure 4: Cylinder (I) full collapsed, (II) full expanded.

There are basically two position of the cylinder i.e. full collapsed and full expanded, see figure [4]. When cylinder is in full expanded position, and there is some obstruction to the bracket then whole force produced by cylinder is transferred to outboard bearing cylinder hinge. This maximum force has tendency to topple the base frame at strip preparation station. We can calculate the contact force between bracket roll and payoff reel mandrel, outboard bearing hinge reactions. Calculate of contact force between bracket roll and payoff reel mandrel, see figure [5].

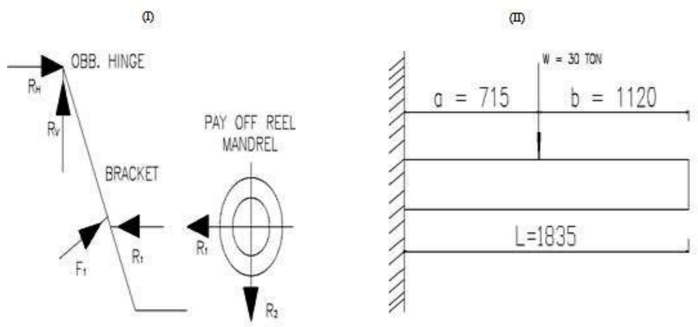

Figure 5: (I) Free body diagram of bracket, (II) Payoff Reel Mandrel.

D. Load calculation of driven hold down roll

Driven hold down roll is placed at entry side of the payoff reel. The hold down roll is used to aid the payoff reel in threading the head end of the strip to the preparation station.

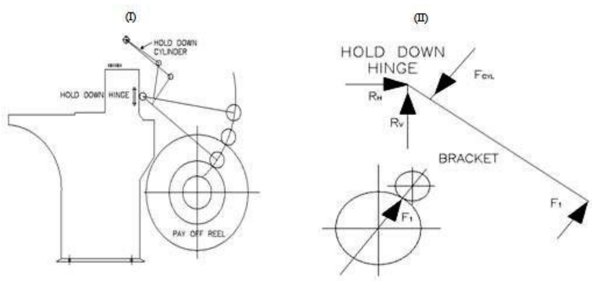

Figure 6: (I) Cylinder full collapsed and expanded, (II) Free body diagram of bracket.

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There are basically two position of the cylinder i.e. full collapsed and full expanded, see figure [6]. When cylinder is in full expanded position, and there is some obstruction to the bracket then whole force produced by cylinder is transferred to hold down cylinder hinge. This maximum force has tendency to topple the base frame at strip preparation station. We can calculate the contact force between bracket roll and payoff reel (coil), stress in bracket, hold down hinge reactions.

E. Load calculation of 3 roll pinch and leveling unit

Arrangement of 3 roll pinch and leveling unit
3 roll pinch and leveling unit is placed at exit side of the payoff reel.
Function of 3 roll pinch and leveling unit
3 roll pinch and leveling unit is used to deflect and feed the head end of the strip to the mill and to straighten the head end of the strip by means of bending with the leveling roll shown in figure [7].

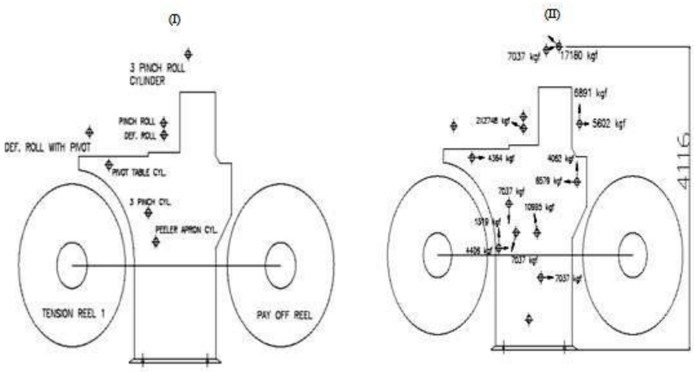

Figure 7: (I) 3 Roll pinch and levelling unit assembly, (II) Resultant load on Base frame at strip preparation station.

IV. Housing And Their Fastenig To The Foundation

A. General

All the pressure of the metal on the rolls when rolling is taken by the stand housings. They are, therefore, required to be very strong and rigid. Two types of housing are most common: the closed top- in the form of a solid rigid frame, and the open top- with a removable cap. To position and ensure the correct alignment of the rolls, very rigid housings are utilized to accommodate the rolls and their chocks. Generally, for cold rolling operations, closed top housings are used since they provide greater rigidity in a more economical manner than the open top type. The windows are machined so that roll chocks can conveniently slide within them. Wear plates of hardened materials may be located on vertical faces of the windows to assist in preserving the proper roll alignment. To prevent lateral movement of the rolls, keeper plates or latches are used to tie the chocks to the mill posts. Closed-top housings are more rigid and cost less and their use is obligatory in all flat rolling mills and also in blooming, tube rounds and sometimes section mills. Open-top housings are not used if possible. They are used only in section mill when the stands are arranged in train, as in this case roll changing with closed-top housings would be extremely difficult.

B. Calculation for tilting moment and the forces acting on the supports

Apart from the rolling force that must be withstood by the mill housing, the housing is also subject to a tilting moment (M), see figure [8]. This moment is attributable to the sum of two components M_1 and M_2 where M_1 is the moment acting on the stand from the mill drive as a direct result of rolling and M_2 is the moment resulting for forces acting on the rolls via the work piece, for example, the strip tensions.
If the two spindle torques are equal and opposite, M_1 will be zero. On the other hand, M_1 will assume its largest values (M_{max}) if only one roll is driven. The value of M_2 may be computed from the product of the unbalance of the tensile

forces in the strip (R) and the elevation of the rolling plane above the housing shoe (C). The largest value of R in many cases can be equated to $2M_{max}/D$.

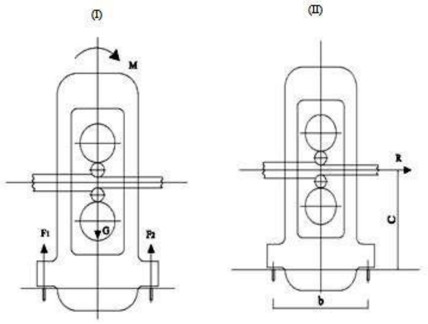

Figure 8: (I) Forces on the mill housing, (II) Tilting forces acting along the work pieces.

IV. GOVERNING EQUATIONS

[i] Resultant force (F) = $F_H + F_V$ F_H = Horizontal force, F_V = Vertical force
[ii] Tensile stress (σ) σ = M/Z M = Moment, Z = Section modulus
[iii] Torque (T) = F x R R= Radius of mandral
[iv] Deflection at load point (δ_w) $\delta_w = Wa^3/3EI$ E = Modulus of elasticity, I = Moment of inertia, W = Weight
[v] $I = (\pi/64) \times (D^4 - d^4)$ Outer diameter of the shaft (D) Inner diameter of the shaft (d)
[vi] Deflection at end point (maximum deflection) (δ)

$\delta = Wa^2 (2a+3b)/6EI$

$\delta = WL^3/3EI$

L = Length of shaft, a= Distance between the load and fix end, b= Distance between the load and free end

V. RESULT AND DISCUSSION

A. The foundation load analysis of base frame at strip preparation station:

The foundation load analysis of base frame at strip preparation station depends on the various types of equipments supported with this frame. There are basically three types of load acting on the foundation. When these all equipments are in static condition, then only static load comes in to the picture, similarly when these all equipments are in dynamic condition or working condition, then only dynamic load comes in to the picture. Heaviest load comes because of malfunction. The foundation load analysis of base frame at strip preparation station shows that there is resultant downward force acting on the foundation which is nullified by the ground. In this base frame there is a resultant force which is acting at a certain height which produces a moment on the base frame at strip preparation station. The tendency of this moment is try to topple the base frame. This tilting moment is restricted by using appropriate foundation bolt.

B. The foundation load analysis of mill foundation:

The mill housing is one of the most important units of cold rolling mill. In mill housing two work rolls and two backup rolls are used. The work rolls are provided with positive and negative bending, Actuated by hydraulic cylinders located in the bending blocks. The top back-up roll balance cylinders are located in the cylinder blocks which are mounted to the housing posts. The When strip passes between these two work rolls, there is a large amount of strip tension is produced. Strip tension is the main cause of tilting moment acting on the mill housing, and because of this tilting moment the mill housing is try to topple. To avoid this topple action we need a strong foundation bolt, which is designed according to the load acting on it.

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Table 2: Load Calculation

In Cylinder Analysis				
Types	Pressure (p) in bar	Diameter (d) in mm	Area (A) in m^2	Force in kgf
Snubber Roll No.1	140	80	5026.55	7037
Outboard Bearing Support	140	100	7854	10996
Driven Hold Down Roll	140	125	12265.625	17180
Pinch Roll Cyl	140	80	5026.55	7037
Deflector Roll Cyl (2 No.)	140	50	1963.495	5496
Pivot Table	140	63	3117.245	4364
Peelar Apron Cylinder	140	80	5026.55	7037
3 Roll Pinch Cyl	140	80	5026.55	7037
Snubber Roll No.2	140	80	5026.55	7037

Table 3: Resultant loads on snubber roll no.1 & 2

Total weight of the base frame with equipments	Total upward reaction	Total downward reaction	Resultant vertical reaction	Total horizontal reaction
250 kN downward	358.08 kN	250 + 136.5 = 386.5 kN	386.5 – 358.08 = 28 kN downward	180 kN clockwise at 4.116 m, see fig. 3.13.
40 kN downward	4404 kgf	1520 kgf	25 kN downward	63 kN anticlockwise at 1 m

VI. CONCLUSION

There are various equipments foundations in modular design of cold rolling mill like mill housing, base frame at strip preparation station, base frame of reversing reel no.1 & 2, guard frame, chimney for fume exhaust system etc. We have found out the effect of these equipments on the foundation, and we have designed the foundation bolts so that the cold rolling mill foundation can easily withstand that static, dynamic and heaviest load, and the civil engineers can easily design the foundation with the help of these foundation loads.

REFERENCES

[1] Tselikov, A.I., “Theory of calculation of forces in Rolling Mills” 1962, Chpt. 5, pp.120-122.
[2] Roberts, W., “Cold Rolling of Steel”, Marcel Dekker, 1978, Chpt. 3, pp. 68-70.
[3] Tselikov, A. I., “Effect of external friction and tension on the pressure of the metal on the rolls in rolling”, vol. 6, 1939, pp. 61-76.
[4] William L.Roberts “Manufacturing engineering and materials processing/2”, Cold Rolling of Steel.1938.
[5] A.G.Davenport, “The application of statistical concept to the wind loading of structure”, proc.Inst.Civil Engg. London, vol.19, 1961, pp. 449-472.
[6] Ginzburg Vladimir B.,”High-Quality Steel Rolling Theory and practice”, Newyork, USA, Marcel Deker Inc.1993.
[7] Maria Pia Repetto, Giovanni Solari, “Wind Engineering and Industrial Aerodynamics” Equivalent static wind action on vertical structures, 2004, vol. 92, pp. 335-357.
[8] D.Stirling and S.Sevin, “Combined simulation and knowledge- based control of a stainless steel rolling mill”, 1991, pp. 353-366.
[9] Bland, D. R. and Ford, H., “The calculation of roll force and torque in cold strip rolling with tensions,” Proc. Inst. Mech. Eng., 1948, Vol. 159, pp. 144-153.
[10] Basavanna, B.M., Joshi, V.H. and Prakash, S., “Dynamic bearing capacity of soils under transient loading.” Bull. Indian Soc. Earthquake Tech., 1974, Vol.2, No. 3, pp. 67-84.

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