JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IMPLEMENTATION OF GEOTECHNICAL &STRUCTURAL DYNAMICS ENGINEERING IN DESIGNING SEISMIC SHOCK WAVES (DURING BLASTING VIBRATION) ABSORBER SUPPORT SYSTEM FOR HARD ROCK UNDERGROUND EXCAVATION. (A HYBRID ENGINEERING MECHANISM— A HYPOTHETICAL APPROACH)

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1.Research objectives

In seismic excitation rock surrounding the excavation and existing support system along the periphery of the excavation vibrates in different mode as a result of which there developed a zone of differential movement which take a part to damage and crack in the static support system and there may be a permanent change of deformation of support which decrease load bearing capacity of the overlying rock mass.

During blasting underground various seismic waves produced. Apart from this when depth of mining increases phenomenon like rock burst is very common, which is not well defined. Blasting and excavation induced seismicity can not be prevented.

Blast induce seismic excitation deformed existing rock support near the zone of seismic excitation. In this particular situation we required shock absorber dynamic support system instead of static support system because such dynamic support system quickly reach in a dynamic equilibrium state to prevent any kind of deformation due to its flexibility where there is a differential movement in rock mass motion and support system.

While depth of mining increases the occurrence of seismic events due to depth of the mining and blast induce rock vibration increases.

In this paper a hybrid engineering mechanism for designing for rock support system is explained, which approaches towards development a ground support system under dynamic conditions.

The objective of such shock waves absorber support system is to increased support capacities during ground movement. Apart from the restoring its deformation during seismic excitation it also absorbed mechanical vibration and the energy released from rock burst prone zone.

2.Introduction and assumptions

In this paper the sub system models are chosen as simple mass system which are not intended to represent the model for an actual underground support structure in seismic excitation. However with this simple system we can understand how this selected procedure may be applied to a real problem when dynamical equilibrium is required.

Characterization of blast induce ground motion indicates that the shear strain and corresponding residual Excess Pore Pressure (EPPs) are associated with low frequency near — and far— field shear waves that are within the range of earthquake frequencies. Whereas the effect of high frequency P-wave are negligible. Various results show that rock joints have significant effects on the propagation characteristics of blast induce vibration.

In this paper rock mass is considered as elastic bodies. The explosion generated pulse in rock mass propagated parallel and perpendicular to columnar joints.

All discontinueties such as joints, faults, bedding planes and other surface of weakness exists in the surrounding of the rock excavation significantly affected by seismic excitation and it is the problem concern to the geotechnical engineering, geophysics and mining engineering.

The understanding of the interaction between rock joints and blast waves is very important as the velocities of seismic waves varies according to the geomining conditions. During rock breaking mechanism there is a outwards transmission of the strong stress wave which disturbed the existing support system. Therefore we have to think about the state of dynamic equilibrium of a single system instead of the combined system (support+ surrounding rock mass as a single one). To solve the problem in designing shock proof support system when dynamic stress passes through an anisotropic medium such as joint plans energy scattering occurs we apply laws of classical physics or Newtonian mechanics. In sedimentary rock strata dynamic states can not propagated along a straight line. It reflects in various direction of the bedding plans. Sobehaviour of interaction of seismic waves in different geomining parameters is considered.

During construction shock absorbing support system we have to consider the maximum principle stress that is transactional stress which is built up in the immediate skin of the excavation and other is, stored elastic strain energy surrounding the rock mass. Maximum principle stress remains constant but the rock strength degrades over the time due to loss of confinement and a condition of potentially unstable equilibrium situation developed in the zone of excavation. Which creates dynamic disturbance.

Rock burst may release large amount of seismic energy instantaneously because there is a relaxation of elastic strain stored in a large volume in a highly stressed rock surroundings. During excavation these destructive forces acting on the support and this highly stressed conditions existing static support can not regain its original shape when both seismic waves excitation and strata movement withdrawn.

Acoustic properties of rocks relate alternating stresses of varying frequencies and elastic strain. In hard rock blasting there are longitudinal and transversal waves propagation of which is described by the simple wave equation. Propagation velocities of elastic waves in rocks decrease with increasing temperature and increase with increasing pressure.

So describing the behaviour of mode of vibration the inner friction in rocks which in turn depends on temperature, pressure, porosity and pore saturation shall be studied. Rocks possess elastic intrinsic and extrinsic anisotropies. Therefore anisotropy behaviour of elastic waves shall be considered during construction of the support system. The characteristics impedance of a rock ,which is defined as a product of the sonic velocity and the density of the rock is a comprehensive physical property for an intact rock and it is closely related with strengths, fracture toughness, young modulus and poison ratio. Characteristics impedance for a given rock mass either increases markedly or may not be markedly with increasing depth. So behavioursof geomechanical disturbances shall be considered during designing dynamic rock support. Rock quality designation (RQD), rock mass index (RMI), rock mass rating (RMR) and protodyakonov index and other geological parameters which are significantly variable rock to rock are needed for making such support structure. Characteristics impedance of intact rock affects the proneness of rock burst.

3. Literature Review:

In designing and development vibration and seismic shock waves (which produces during underground blasting operation) absorber proof support structure for overlying and underlying strata or rock bed is a vital aspect.

Supporting hard rock excavation in mining is important because during blasting in hard rock various seismic waves of various amplitude and strength are produced according to different geomechanical and geomining parameters which may dislodge or decrease the efficiency of the existing static support system. When natural frequency and the frequency of seismic waves co-inside the phenomenon like resonance damage the support system exponentially in day-to-day blasting. In this case, such support system do not withstand the vibration and dynamic load come in contact in the peripheral body of the support structure. The various passive energies and elastic potential energies stored in the surrounding zones of the excavation play an active role for rock collapse. Due to geothermic gradient heat developes in deep mines and thermal conductivity of the rock therein distribute heat and seismic energies.

When seismic waves propagate through a rock mass, they encounter an increasing volume of rock mass, causing decrease in energy density. Such geometrical damping diminishing energy and seismic waves simultaneously affected by numerous inelastic effects that also cause energy loss during wave propagation.

In such situations amplitude is decreased. Although generally seismic waves do not have sufficient energy much beyond the zone of disturbance due to intrinsic attenuation.

Amplitude (A) of particle displacement due to blast induce vibration is proportional to the square root of the weight of the explosive charge(Q) and inversely proportional to the distance (D) from the blast. That is:

$$A=KQ^{0\cdot5}/D$$

:Morris (1950):

So during calculation of amplitude of seismic waves both should be considered, distance and weight of explosive charge.

Generally two groups of seismic waves activated by detonation of explosive charge. Body waves travel within rock mass and surface waves travel along free interfaces. At the moment of blasting rock near the hole shows a hydrodynamic behaviour.

This shock waves instantaneously moved from non-elastic state to quasi elastic zone in which the oscillatory wave motion propagated in sonic velocity and carries insufficient energy which is not destructive for surrounding rock mass.

The amount of energy transferred to a given rock mass is linear function of the product of the density and the rate of detonation, termed as characteristics impedance of explosive. Explosive which has the larger characteristics impedance or close to the characteristics impedance of rock, transfers more energy to the rock mass. So this is the most important variable for observation of intensity and strength of seismic waves.

Body waves consist of two discrete components— compressional (P-wave) and shear (S-wave). S-wave have two components— S-horizontal and S- vertical.

Two types of surface waves generated in mine blasting— Rayleigh (R-wave) and Love(L-wave). P-wave are faster than S-wave. Velocity of the Love waves remains less than the shear waves velocity. R-wave propagated at a velocity less than S-wave.

But most explosive are detonated as a series of smaller explosion which are delayed by milliseconds and differences in travel paths and delay times result in overlapping arrival of both wave fronts and wave types. (Pal Roy, 1995)

So we have to consider the overlapping waves phenomenon in seismic excitation.

The shock energy transmitted to the rock depends on detonation pressure of the explosive and the detonation pressure is a function of explosive density.

The most commonly used equation for the detonation pressure

$P(d)(N/m^2) = [V_e^2(m/s) * d_e(kg/m^3)]/3.8$

P (d)= detonation pressure

V_e= detonation velocity of the explosive

d_e= detonation density of the explosive.

As detonation pressure is maximum in the direction of shock waves. So velocity of shock waves depends on the above factors and taking a part during construction of s.eismic excitation phenomenon. All these parameters are taken to be consideration in calculating to choose the appropriate shock absorber system in support structure.

4. Behaviour of seismic excitation and its Interaction with rock during blasting:

As the pore pressure increases due to seismic excitation, site stiffness is found to gradually decreased. During the high pore pressure site behaviour is characterized by cycle of large shear strain and very small shear stress.

Elastic waves generated whenever a transient stress imbalance is produced within or in the surface of an elastic medium. Almost any sudden deformation or movement results in seismic sources.

The elastic rebound theory is an explanation for how energy is spreading during seismic excitation. As rock on opposite sides of any geological disturbance zones are subjected to force and shift, they accumulate energy and slowly deformed until there internal strength is exceed. At that time, a sudden movement occurs along the fault and other geological disturbances, releasing the accumulated energy and the rocks snap back to their original undeformed shap. It was considered before the development of elastic rebound theory that the ruptures of the surface were the result of strong ground shaking. In seismic excitation the accumulated strain is great enough to overcome the strength of rock. Like an elastic band, the more the rocks are strained the more elastic energy is stored and the greater potential for an rock burst or rock damage. The stored energy released during seismic event partially elastic waves.

The material properties of the material concerned are known as elastic moduli like rigidity modulus, bulk modulus, poison ratio, young modulus etc. when stress varies with time strain varies similarly and the balance between stress and strain results in seismic wave. These seismic waves travel at velocities that depend on the elastic moduli and are governed by equation of motion.

Strain is a measure of deformation that is variation of relative displacement as associated with a particular direction with the body of rock mass considered. For P-waves, the only displacement occurs in the direction of propagation. Such wave motion is termed " longitudinal". This P-waves introduce volume change in the materials therefore they are termed as " compressional" or " dilatational". P-waves involved shearing as well as compression. That is why P-velocity is sensetive to both the bulk and shear moduli. For S-waves the motion is perpendicular to the propagation direction. In S-wave particle motion we have seen that there are two components. The motion within a vertical plane through the propagation vector (SV waves) and the horizontal motion in the direction of perpendicular to this plane (SH waves). The motion is pure shear without any volume change. (Hence the name shear waves).

Like stress strain is decomposed into normal and shear components and seismic waves yield strains varying from 10^{-10} to 10^{-6} . And in such cases it has been proved by infinitesimal strain theory elementary strain and are its components during dilatational strain (relative volume change during deformation) shearing strain does not change the volume. In general Hooke's Law then describes the stress developed in deformed body (F= -kx). And mechanical work is required to deformed an elastic body is a result of elastic energy accumulated in the strain by stress field. When released this energy gives rise to seismic waves and uncompensated net force will result in acceleration as per Newton's law.(Reading — Telford et al, section 4.2, Introduction to seismology,Peter M Shearer, Institute of Geophysics and Planetary Physics, University of California).

As rock is considered as "elastic continuum " so it is deformed in response to stress and there shall be two types of deformation— one is change in volume and other is change in shape. But in above study it has been cleared that" shearing strain does not change the volume "

Web speed in a medium is primarily determined by the properties of the rock mass, specifically its elasticity and density. The speed of a wave is influenced by the characteristics of the rock mass medium through which it travels. This is because a wave is essentially a disturbance that propagate through a medium (both of rock mass and its support structure). More elastic medium allows the wave to travel faster because the particle of the medium can quickly return to their equilibrium position after being displaced by the wave and allowing the disturbance to move on to the next set of particles. Therefore velocity of propagation of waves depends on the rock properties and the properties of the materials of its support structure that is it depends on density and elasticity. Density is a measure of how much mass contain in a given volume. A denser medium tends to slow down the wave because there are more particles that the wave has to move through.

This means that seismic wave has to do more work to displace the particle, which slows down its speed. However it has been observed that the relationship between wave speed, elasticity and density is not always straight forward. Other factors such as temperature and pressure can also effect wave speed.

Understanding these relationships is very important for predicting and controlling seismic behaviours both of rock, surrounding the mine excavation and its support meterials.

Mechanical surface waves diminishing in amplitude as they get a farther paths of journey from the surface and propagate more slowly than seismic body waves (P and S).

Thus from above study we have seen that elastic waves are physically not different from seismic, sound or ulta sound waves, other than in their respective ranges of frequencies (as per example speed of light waves travel in more speed in space rather than water or any other denser medium).

According to elastic wave theory, P-wave velocity is a maximum, Rayleigh (R-wave) velocity is a minimum, and S-wave velocity is in between them. The theoretical upper limit of crack speed in an elastic, isotropic and homogeneous meterials is set the Rayleigh (R-wave) speed. Under normal conditions, cracks rarely run beyond 50% of the Rayleigh wave speed as they scattered.This is basically proved by the measurement of crack velocity in rocks or rock materials during blasting; that is, the maximum crack velocity measured is from 8% to 30% of the P-wave velocity in each corresponding materials.

5. A geomechanical study and some related parameters involves in seismic excitation by blasting:

Mining induce seismicity and the related phenomenon of rock burst have become more prevalent in hard rock mining. The development have been complimented by measures in excavation design and extraction sequencing which have done much to mitigate the serious operating problems which can occur in seismically active, rock burst prone mines. In large scale open stope mining, Canadian development based on pillerless stoping, formulation of extraction sequences which promote the evaluation and uniform displacement of a regular mine stress abutment, and the extensive use of cement — stabilised backfill, has been successful in managing an acute mining challenge. Notably, these measures have been based on sound conceptual and analytical models of the relation of damaging seismicity to induce stress, geological structure potential rock displacements and strain energy released during mining. Many mining rock mechanics problem effectively depends on the evaluation of the state of stress over the time scale of the mining life of the orebody which needs to be interpreted in terms of the probable modes of the response of the host rock mass. The computational efficiency of tools for three dimensional stress analysis now permit modelling of key stages of an extraction sequence. The engineering mechanics problem posed in all structural design in the prediction of the performance of the structure under the loads imposed on it during its prescribed functional operation.

The effect of open cast blasting deformed the underground rock mass that is load come from surface. When some amount of explosive is detonated at certain depth in single or multiple drill holes, very rapid decomposition of the charge takes place, forming gases at very high temperature and pressure. A true shock wave is formed only when the initial explosive pressure far exceeds the strength of the rock in compression, so much so that any plastic state by- passed and then it can be said to behave hydrodynamically. Such an unstable shock wave rapidly passes through the non elastic state, due to its instability and decreasing velocity, and settles into a stable quasi - elastic zone in which the oscillatory wave motion propagating at sonic velocity carries insufficient energy to permanently disturb the material in its path. This zone is known as the elastic or semi elastic wave zone (Ghosh 1983). The intensity of the shock wave attenuates very rapidly as a large amount of energy is consumed in crushing and producing cracks. Thus in elastic or semi elastic zones located away from the source, the intensity drops significantly and this produces no parmanent deformation. The remaining energy goes directly into the surrounding rock as seismic waves and these waves propagate elastically. The seismic waves propagate away from its source. This remains till there is no other source of energy. The decay in the amplitude of vibration that is geometrical damping in an ideal elastic rock mass, the attenuation of amplitude for different types of waves given by Rinehart et al. 1961 as follows…

a) Body waves propagating along the surface, amplitude is proportional to R^{-2}
b) Body waves propagating through the medium, amplitude is proportional to R^{-1}
c) Rayleigh waves, amplitude is proportional to $R^{-0.5}$; R being the distance from the source.

The actual decay in amplitude of vibration with respect to distance is more than what has been explained due to geometrical spreading. The extra attenuation is due to inelastic nature of the rock (Bath, 1979).

In a multiple grained rock mass, the available surface area for dissipation of energy is more than that of a single crystal. Frictional forces are developed due to possible relative motion of grains during wave propagation (Walsh 1966).

The above mechanism, including dissipation due to relative motion at grain boundaries and accross surfaces is termed as matrix in elasticity.

In this concern the study of Dr. Pijush Pal Roy ,Scientist CSIR- CIMFR ,India,1991 has given a potential observation in which different parameters may be a strong tool to give a real model to construct the shock absorber support system the hypothesis made in this paper. In the study of the Dr. Pal Roy it has been found describes below —

There are several causes for inelastic attenuation some of which are

1. Attenuation due to fluid flow, including relaxation, because of shear motions at pore- fluid boundaries.
2. Partial saturation effects such as gas pockets squeezing.
3. Enhanced inter crack flow.
4. Energy absorbed in a system under going phase changes.
5. Large catagory of geometrical effects, including geological discontinueties, scattering of small pores, large irregularities and selective reflection from thin beds.

Ghosh and Daemen (1983) reformulated the propagation equation of USBM and Ambraseys and Hendron(1968) by incorporating the inelastic attenuation factor $e^{-\alpha D}$. The modified equations are

$$V=K(D/Q^{0.5})^{-B}e^{-\alpha D}$$

and

$$V=K(D/Q^{1/3})^{-B}e^{-\alpha D}$$

Where K,B,and α are empirical constants, α is called the inelastic attenuation factor.

The effect of the inelastic attenuation factor of the Langefors et al. (1958) and Indian Standard (1973) equations has been reported in the work of Pal Roy (1991).

To the standardize the values of site constants for various rock masses and to assess the validity of a particular empirical model, the blasting research group of the CSIR -CIMFR , India conducted investigations on different types of exposed rock masses, which included lime stone (fissured and highly jointed), granite (hard and fresh), iron ore, coal, dolomite, basalt, sandstone (weathered) and sandstone - alluvium (Pal Roy,1991).

It is important that if no assumptions are made about the joint distribution of the concerned random variables, the validity of the prediction and of the estimate of the site constants can not be judged.

In the case of normal distribution,the square of the coefficient will determine the strength of the regression equation. If there are more than one independent variables in the model as in above equations then in the calculation of correlation coefficient between two variables, there will be an effect of the third variable. This effects can be avoided if the partial correlation coefficient are considered. The partial correlation coefficient measure only the effect of the specified variables while ignoring the influence of the other variables. There may be possibility for a positive simple correlation coefficient to be transformed into a negetive partial correlation coefficient.

Inelastic attenuation of elastic waves is a characteristic that could be applied for the study of the geotechnical properties of rocks and to predict the change in the shape of a plane stress wave while passing through a rock mass.

CSIR -CIMFR India predictor equation model assuming special significance because of its simplified form and the consideration of the zone of disturbance due to blasting (Pal Roy, 93). The equation is valid only in the zone of disturbance. At the boundary of this zone and outside this boundary, V is obviously zero everywhere. This equation consideres two distinct categories of parameters n and K, where n is related to the category of parameters that are influenced by rock properties and geometrical discontinueties and K is related to design parameters including charge weight, distance from the source, charge diameter, burden spacing, sub- grade drilling, stemming length and delay interval. The equation is

$$V= n+K(D/Q^{0.5})^{-1}$$

As n is categories as a damping parameter that is influenced by rock properties and geometrical discontinueties, in practical solutions the value is always negative. Thus from this equation we can reach in a conclusion how open cast blasting disturbed the underground rock mass.

Using the concept of rock breakage and the theory of reflection of seismic waves at a free surface CSIR-CIMFR has developed a mixed analytical - empirical model for the prediction of blast induce ground vibration (Pal Roy and Dhar, 1992). The model accounts for the characteristics of the explosive, rock mass properties and charge loading parameters. The equations are

$$V_v = \{2K_1P_Dr_1^2l(r_1+r_2)^{-\tau\alpha}\}/\rho_1c_1(l^2+x^2)^{3/2}$$

$$K_1 = V_D\rho_2/\rho_1c_1$$

$$P_D = \tfrac{1}{2}\,\sigma_t[10^3(Q/K_3)^{1/3}]^2/(k_2r_2)^2$$

Above equations are dimensionally balance. When the blast hole contains more than one explosive then V_D and ρ_2 may be taken as the simple average of their respective values.

V_V= peak particle velocity (mm/s)

K_1=(characteristic impedance of explosive)/(characteristics impedance of rock)

ρ_1= density of rock (gm/cm^3)

c_1= P-wave velocity in rock (m/s)

ρ_2= density of explosive (g/cm^3)

V_D = velocity of detonation of explosive (m/s)

P_D = peak charge pressure (MPa)

r_1= radius of the charge (mm)

l= depth of centre of explosive column from the surface (m)

x= distance of the measuring transducer from the blast hole (m)

Q= weight of explosive in blast hole (kg)

σ_1= tensile strength of rock (MPa)

K_2= proportionality constant=1.0 for most rock

K_3= factor relating to the lifting of one m^3 rock mass by 0.8kg/m^3 explosive (for most rock)

τ= charge symmetry parameter (2 for cylindrical charge and 3 for spherical charge)

α= an explosive constant of parametric value lying between 1.2 and 1.5.

Excessively high ground vibration from underground production blasting alone or coupled with the increase stress due to openings created by extraction of minerals or coal may cause damage to the roof rock and may affect the stability of roof bolts and mine supports and cause ventilation stoppage. The area of underground workings affected by such vibration needs to be assessed and proper supports ensured. Based on the studies conducted by CSIR -CIMFR in conventional methods of blasting in mining and construction projects, a peak particle velocity (PPV) of 100 mm/s was found safe for the stability of coal mine roof and pillars from underground blasting. Thus the area of underground workings experiencing a vibration of 100 mm/s or more should be treated as a zone of disturbance. Blasting vibration may induce substantial dynamic loading on mine openings, which is difficult to assess and generalize in respect of the effect on the over stability of workings. General observation of Siskind(2000) shown there can be an effective guidance to prevent roof collapse and pillar failure and it has been seen from his studies that there is a strong influence of geotechnical properties on the velocity and frequency content in the wave motions. Therefore, there is a need with specific attention for determining the damage threshold values on underground working.

Apart from seismic load on structure and mine pillar the mechanics of vartical loading of pillar due to depth of cover and other geological parameters is very complex to give a exact mathematical analysis. In order to compute the pressure acting on the pillar the following assumptions are made

1. Any element of the ground at a depth **d** below the surface is subjected to a pressure P_0, which depends on the weight of the superincumbent rock so that **P_0=W*d (** w= weight per unit volume of the superincumbent rock.
2. Each pillar support the volume of the rock over an area which is the sum of the cross sectional area of the pillar plus a portion of the bord area, the latter being equally shared by all the pillars. The load is vertical only and is uniformly distributed over the cross sectional area of the pillar. Then Pressure (P) can be written as **P= P_0*1/1-R**.(R= percentage of extraction).

The determination of coal pillars is difficult. The strength of coal pillars S was found to have as $S=R*K*W^{0.46}/h^{0.66}$ ld/in²(CSIR -CIMFR, Sheorey et al , 1982, after Salamon and Munro, 1967).

Here, S= strength of pillar in ld/in²

K= a constant= 1320 ld/in², which is the strength of one ft³ of coal.

W= width of pillar

h= height of the pillar

Load bearing capacity of supports has a function is to limit the convergence so that the roof fractures are low enough to have no adverse effects on mining activity. Certain amount of convergence is unavoidable and is desirable upto some extend as the value being different roof situation or the geomechanical parameters. Thus the desired load bearing capacity of the support may be defined as that which will not permit the convergence to be in excess of the threshold value at which roof deterioration accelerates. It should be noted that no universal formula can be given which will be applicable to all situations. Every situation will need detailed study and analysis of the lithology of the nature of the rock mass.

For details study of symbols used in the above equations are elastrated in the book Rock Blasting Effects and Operation (special Indian edition, Oxford and IBH publishing Co. Pvt. Ltd, New Delhi by Dr. Pijush Pal Roy, ISBN 81-204-1660-0) and Rock Mechanics for underground mining by B. H. G. Brady and E. T. Brown, 3rd edition, Kluwer Academic Publishers, New York)

All these parameters have a strong influence to categorised the strength of the seismic excitation during open cast blasting which in turn results the underground rock movement. So to give the real model of the hypothesis in this paper of shock absorber underground support systems have an great importancy.

6.Operational hypothesis and application of Newtonian mechanics:

When a wave travels in a absorbing medium it losses energy as it propagates through the medium. It has been found experimentally the amplitude of the wave decays by a constant fraction of its value when the wave progresses through a certain distance. This means that the amplitude falls exponentially with distance and we can write the amplitude at a distance x which respect to the origin at x=0 as,

$$A(x)=A_0e^{-\alpha x}$$

where A_o is the amplitude at x=0 . The constant α is called the attenuation constant. From above equation we find that

$$\alpha= - 1/A(x)dA(x)/dx$$

Thus α is the decrease in amplitude per unit amplitude per unit length. Therefore α is the fractional amplitude attenuation of amplitude A(x) per unit length. So during construction of shock wave absorber support system above equation must be considered.

In an elastic meterials at least two types of waves can be propagated— pressure waves and shear waves. Whereas in an acoustic meterials only pressure waves are propagating. Both shear waves and pressure waves are governed with the same equation. The elastic wave equation described the propagation of elastic disturbances produced by seismic waves in blasting. The acoustic wave equation governes the propagation of sound.

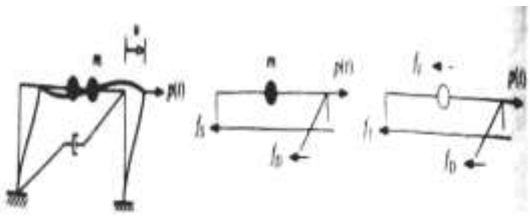
Using the stress and strain theory we can solve the seismic wave equation for elastic wave propagation. The equation of wave propagation in elastic solids are described by using Hooke's law and Newton's second law of motion. Solid bodies such as rock mass are capable of propagating forces that acting upon them.

Seismic wave velocities p-wave(V_p) for unconsolidated materials 1.5—2 km/s, for sedimentary rock bed it is 2—6 km/s, for igneous rocks 5.5—8.5 km/s, for steel it is 6.1 km/s.

In the aseismic approach we can prevent the support from seismic hazard by mechanism which reduces the transmission of horizontal acceleration into the support system. The fundamental concept of base isolation is to reduce frequency of a structural vibration to a minimum value then the predominant energy contain frequencies of blast hole explosion responsible for strata movement or ground motion.

During blast hole explosion isolation technique actually uncoupled the support system from the ground which is in motion.

In designing shock absorbing support system we consider the forces acting on the mass of the support system for instantaneous time period.



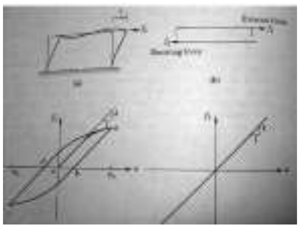


FIGURE -1

(Applied Dynamic force)-(Elastic resistance force) – (Damping Force)

$P(t)— f_S—f_D$

Here external forces P(t). The forces due to elastic resistance f_S and damping forces f_D acting on the structure of the support. The elastic and damping forces at the moment of explosion work in the opposite direction because these forces resist the deformation and velocity (during blasting induce vibration) of the support structure and we get resultant force as

(Applied dynamic force)-(elastic resistance force)-(damping force)

e.i,

P(t) — f_s-f_D(as shown in the figure1.)

Which is equal to produce of the mass of the support system and its acceleration (according to Newton's second law of motion)

We know that,

force= mass*acceleration

P=m*a

Therefore, from Newton's second law of motion we get,

$P(t) - f_s - f_D = m\ddot{U}$.

Finally we get the equation governing dynamical equilibrium system in seismic excitation.

$M\ddot{u} + C\dot{u} + Ku = p(t)$

[As the force is acting on the mass of the support for very short time therefore it may be considered as Impulse.

Therefore,

$_i\int^f dP = {}_{ti}\int^{t_f} Fdt$

$P_f - P_i = {}_{ti}\int^{t_f} Fdt$

P_i= initial momentum of the support system at time t_i

P_f= final momentum of the support system at time t_f

$P_f - P_t = \nabla P$=change in momentum of the support system during time interval $t_f - t_i = \nabla t$

The integral $_{ti}\int^{t_f} Fdt = J$ is called the impulse — **so it may be an another approach in designing seismic shock waves absorber support system].**

Taking external forces as positive in X axis the displacement U(t), velocity U'(t) and acceleration U''(t) are also positive in the direction of X axis and then we get the above equation as

$md^2U/dt^2 + f_D + f_s = P(t)$ (as per convention)

$\mathbf{M\ddot{u} + C\dot{u} + Ku = p(t)}$

K = stiffness resistance

U= resulting displacement

We k**now that** dynamic load is time varying ,

$m\ddot{U}(t)$= inertia force

$C\acute{U}$= damping force

KU= restoring force (Lateral dynamic force)

$\ddot{U}(t)$= acceleration

This acceleration generated inertial force ($m\ddot{U}$) (mass* acceleration)

Inertial forces are proportional to the acceleration of the mass, and acts opposite to the ground motion.

This inertial forces **$m\ddot{U}(t)$** depends upon two important things.

1. Characteristics of the ground motion.
2. Structural characteristics of the structures.

The damping force **$c\acute{U}(t)$** as we understand that the ground motion if produces energy in the structure, which is needed. In other words we can say it is essential to dissipate this energy through inertial friction within the structure and its members. This dissipation energy is called damping. Damping force is proportional to the velocity induced in the structure and c is actually the damping coefficient and denote percentage of critical damping or degree of damping. Fundamental period of structure and fundamental period of ground is very close and there is a chance of probability to exist quasi resonance.

KU(t) = Restoring force. It is actually proportional to the deformation induced in the structure during seismic excitation and the constant of proportionality is referred as stiffness of the structure. This stiffness is greatly affects the structure during seismic excitation. K implies the cracking in the structure and the quality of materials of the structure as it is influenced by externally applied force.

Now we can conclude **P(t)**= inertial forces+ damping forces+ restoring forces

Some of all resisting forces that is due to inertia, damping and stiffness is equal to the external forces.

It is the second order differential equation which needs to be solved for the displacement **U(t).**

This dynamic equilibrium equation is referred to as an equation of motion of single degree of freedom (SDOF) system under a lateral force **P(t)**.

A system that is damped is a system which is in motion, and a moving system is mathematically described by the above equation. This differential equation contains derivatives. If the equation can be set equal to zero then it is considered homogeneous. For understanding this moving system a mass attached spring given in the figure. When spring is compressed and released, the mass moves and there are three related qualities which has been described above. The velocity **Ú(t)** is time derivative and can be written in the traditional form as **dU(t)/dt**. The acceleration of the mass is the second time derivative of displacement **U(t)**. And can be written as $\mathbf{d^2U(t)/dt^2}$**.** These three variables control the motion of the mass on the spring.

In oscillation back and forth motion arround a point of equilibrium is mathematically represent sin or cosin waves. A normal sin wave is an undamped oscillation because it's amplitude remains constant and a damped oscillation is a wave whose amplitude decreases to zero. Damping is a restraining vibrations and how quickly the vibrations of a damped wave sease depend on the damping ratio or the damping coefficient. Damping ratio increases with higher damping coefficient. Damping also depends on the spring constant of the material. Higher spring constant values will increase the natural frequency of a spring will oscillate at.

The damping coefficient formula only involves the mass of the object and the actual damping of the system. The unit of damping coefficient is **Ns/m**.

- A system can be **over damped** if the damping ratio is greater than 1, and this system will slowly return to equilibrium without oscillating.
- The system is **under damped** and it will oscillate quickly to rest.
- If the ratio is equal to 1, the system is critically damped and the system will quickly return to rest without oscillating.

There is no "good" damping ratio but above three points give the selection of required dampers. The highest natural frequency is always decrease by damping but the lower natural frequencies may either increase or decrease depending on the form of the damping matrix.

Damping is of primary importance in controlling vibration response amplitudes under conditions of steady-state resonance and stationary random excitation. Damping also plays a crucial role in fixing the border line between stability and instability in a dynamical system.

Solution to equation of motion gives four common cases —

Free vibration:P(t)=0

Undamped: c=0

Damped: c is not equal to zero

Forced vibration: P(t) is not equal to zero

Undamped c=0

Damped c is not equal to zero

Displacement of the structure is governed by this equation of motion and we can reach to designing a shock proof vibration absorber support system where dynamical equilibrium is required. The region which is very prone to rock burst or sensetive to seismic waves the principal problem is induce motion of the base of the support structure U_g and support movement U_s their relative displacement due to total ground motion U may be related at each instance of time of the disturbance by the laws of classical physics as bellows.

equation of motion (base motion)

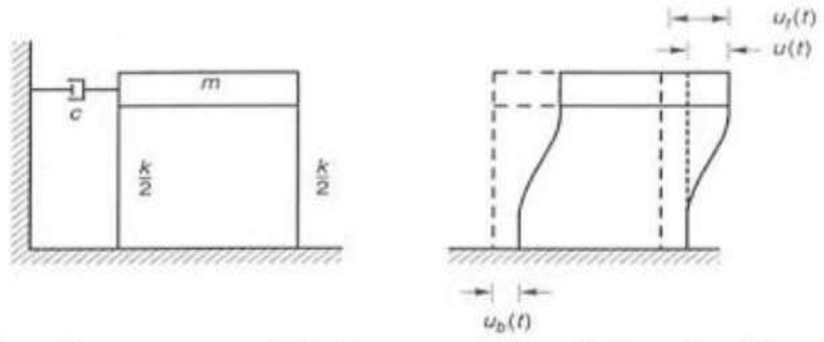


FIGURE -2

Newton's law is expressed in terms of absolute velocity and acceleration. The spring and dashpot forces depends on the relative motion.

$$U_s(t) = U(t) + U_g(t)$$

U_s and U_g refer to the internal frame of reference and positive direction co-inside. Ultimately from figure 1(b) we can write an equation for dynamic equilibrium in the state of seismic excitation and blasting vibration as

$$f_I + f_D + f_s = 0$$

Thus from above study it may be recommended that external blast induce vibration and seismic excitation can be minimise by introducing the elastic dampers in the support system to reduce the amplitude of vibration in support frame.

It is well known thar If

vibration frequency (resonance frequency) 'f' ,

mass of the vibrating support system ' m' ,

cold/ hot movement 'mm' in ambient temperature (maximum/ minimum) and

temperature of the vibrating support system then a damping of 40% is consider necessary to provide an initial selection of elastic dampers. The well known formula for Damping parameter =40% m 2π f/1000

Temperature taken in centigrade

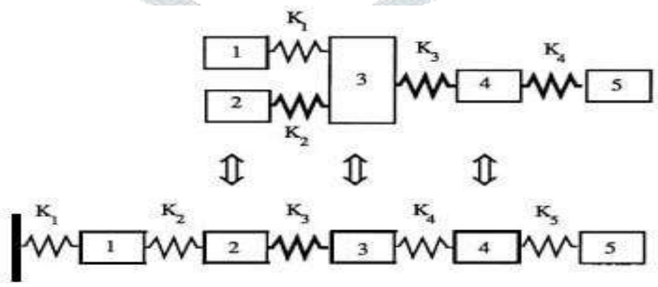
Frequency taken in Hartz

Amplitude taken in millimetre

Mass taken in kilogram

Ambient temperature varies from (-30°C)—(+ 110°C)

As well as the most demanding mine environmental conditions.



Coupled Structure

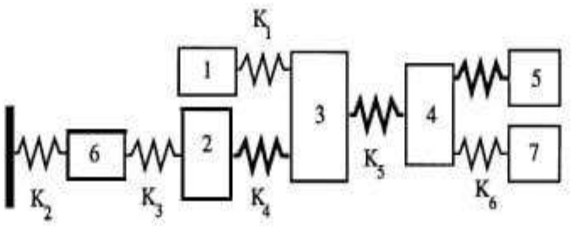


Figure 3.

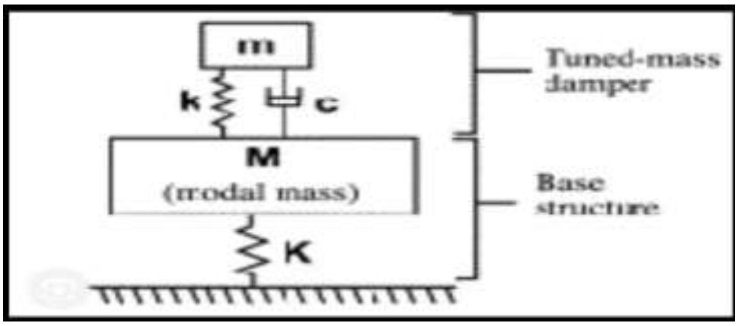
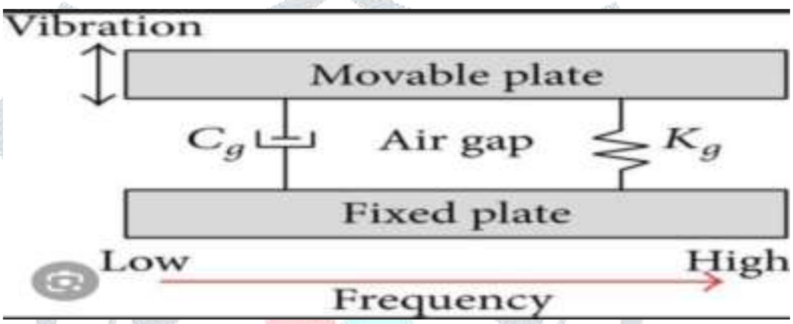


Figure 4.



Air damping analysis by microaccelerometer

(Figure 5)

7.Research Design and Methodology:

High strength steel support covered by Fibre Reinforced Polymers(FRPs) significantly enhanced the toughness and ductility provide an increased resistance to seismic forces and it offers excellent corrosion resistance for a large life.

Seperation or a little isolation from the surrounding rocks by introducing polymer matrix and Led Rubber bearing or by incorporating flexible materials such as visco elastic dampers effectively reduced damage during vibration as such support system enhancing their seismic resilience.

Energy generated by seismic forces absorbed by such support system and may exhibits durability and resistance to cracking.

The design of the isolated (through viscoelastic dampers) structure consume target displacement from its mean position.

Because vibrational amplitude demands to regain its shape and dimension which is self adjusted according to the geomechanical and geomining condition after absorbing seismic excitation.

The vibration and friction occuring along the surface of the periphery of the excavation support system enables the structure to stay in the elastic range without having any structural damage. Also it supplies a significant amounts of damping to the structure due to incorporation of

1. polymer matrix,

2.led rubber bearing,

3.viscoelastic dampers etc as shown in the adjoining figures inbetween support and rock that is interface of support and surrounding rock mass.

Introduction of such dampers give a model of dynamic behaviour of the structure.

And then Oscillatory motion of the support structure dissipate energy for (for internal momentary deformation) , friction,rubbing, cracking, permanent deformation etc.

Because of the larger the energy dissipation capacity the smaller the amplitude of vibration.

In such support structure passive energy control devices impart forces that are developed in response to the motion of the structure. Because the energy is passively controlled as system itself is of dynamic character. In state of dynamic equilibrium through transformation of the kinetic energy (which produced during blasting) to heat energy when it is in vibrating mode.

Energy input during explosion to the support structure can't reached intensely in metallic body as it is covered by Fibre Reinforced Polymer Matrix (FRPM) and protect it from permanent inelastic deformation.

Such fibre polymer matrix shows stable hysteretic behaviour, low cycle fatigue property, long term reliability and relative insensitivity to a temperature and heat produced in mines.

Such support system shall be consist of Passive energy dissipation device.

Passive energy dissipation device when installed to the support system then it actually works as a seismic isolation as a means of protecting both support structure and underground excavation during blast hole explosion.

The basic function of passive energy dissipation (PED)device in a support is to absorb or consume a portion of the blast induce input energy. The means by which the energy dissipation is adopted by following methods—

1. Metallic Yield Dampers
2. Friction Dampers
3. Visco elastic dampers
4. Viscous Fluid dampers
5. Tuned liquid dampers
6. Tuned mass dampers
7. Base isolation
8. Laminated Rubber bearing
9. Fibre reinforced polymer matrix

We can achieve a design of vibration proof and shock absorber underground support system.

Property of tuned spring and damping elements providing a frequency dependent hysteresis that increases required oscillations in the support. The first and foremost factor during installation of such dampers we have to consider the amount of rock mass in overlying rock bed.

Laminated Rubber bearing (LRB): LRB exhibits high damping capacity both in horizontal and vertical direction. The high damping rubber bearing is made from natural rubber.

As absorption coefficient hardness factors of rock are frequency dependent therefore during incorporation of shock absorbing meterials in the support system this frequency dependent parameter to be considered.

A base isolator predominantly provides a way to prevent a structure having to move and follow the ground as the ground shakes during a seismic excitation. While seismic dampers absorbs energy when the structure moves. Sometimes base isolation is combined with seismic dampers, which provide an additional form of energy dissipation to prevent the structure moving too far relative to the ground.

By adding a damper into the structure with base isolator, seismic energy can be farther absorbed as the structure moves, which will help to established a farther dynamic equilibrium in between rock and support system.

For controlling seismic damage in support structure, dampening is provided by a lead- based device that looks very similar to a car damper (shock absorber).

Ground movement forces the lead to pass through a narrow gap. When the direction of movement changes, the flow of lead is reversed. The principle is still the same as the lead rubber bearing, with kinetic energy being converted into heat energy, thereby preventing the support structure in absorbing the kinetic energy.

Base isolation has limitations and is subjected to special conditions, such as the need for utilities to accommodate large lateral movement where they enter into the support system below ground. In general base isolation reduces, but does not eliminate the effects of horizontal motions.

Metallic Yield Dampers are usually made from steel. They are designed to deforme so much when the structure vibrates during a seismic excitation that they can not return to their original shape.

Metallic dampers can effectively dissipates huge amount of seismic energy through inelastic mechanism of steel materials. The key use of these devices is to reduce structural damage by vibration in prearranged or replaceable elements, subsequently prevent irrecoverable damages to primary structure.

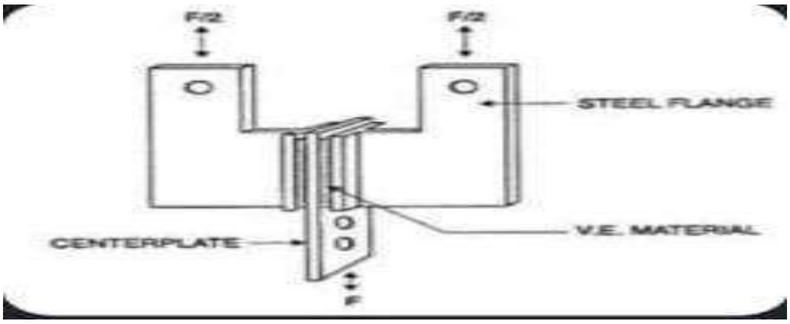
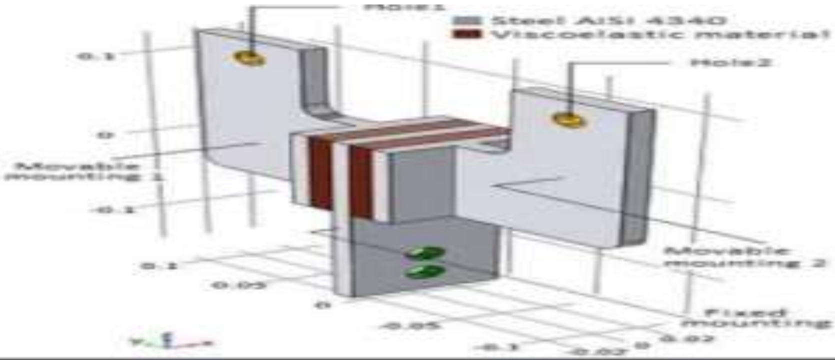


FIGURE -6

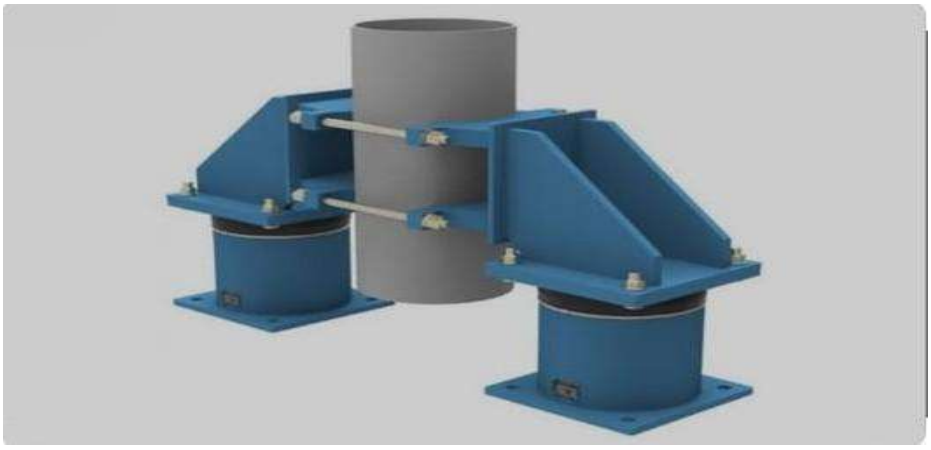


Design of Viscoelastic Structural Dampers

FIGURE -7

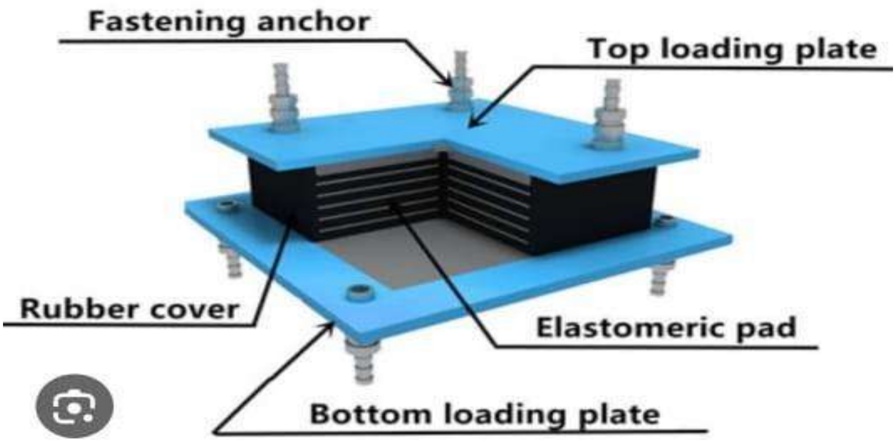
Tuning Spring Devices Viscoelastic Dampers

FIGURE -8



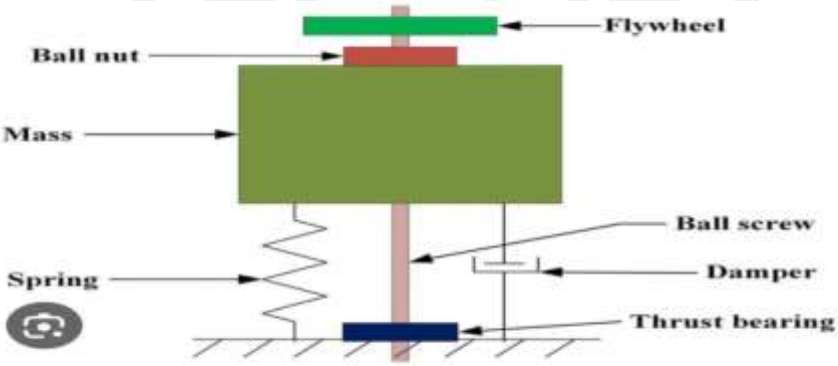
Viscoelastic Dampers

FIGURE -9



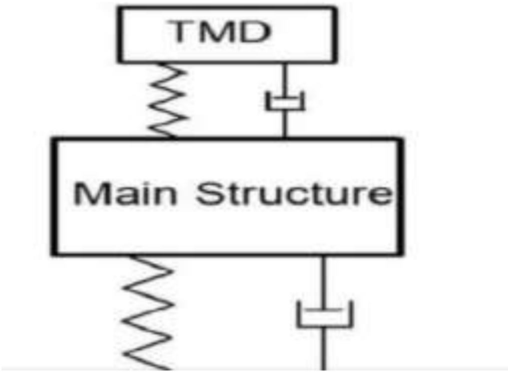
High Damping Rubber Bearing for Seismic Isolation

FIGURE -10



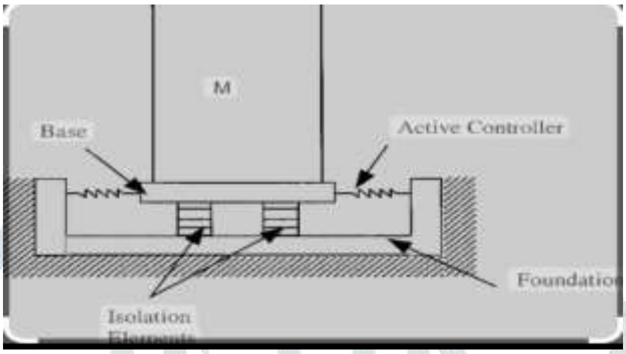
Schematic diagram of a vartical tuned mass dampers (VTMD)

FIGURE -11



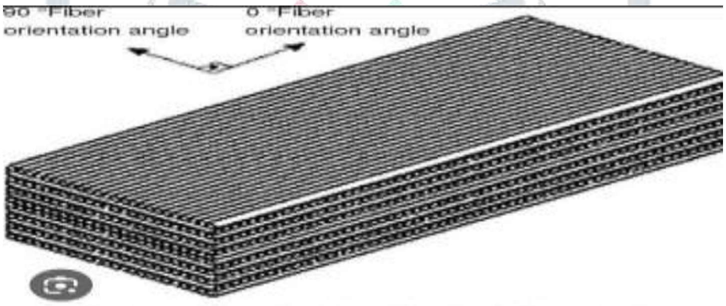
Tuned mass dampers

FIGURE -12



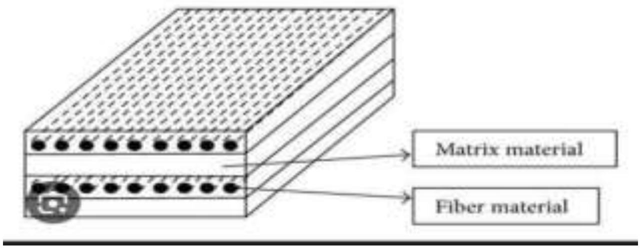
Base isolator

FIGURE -13



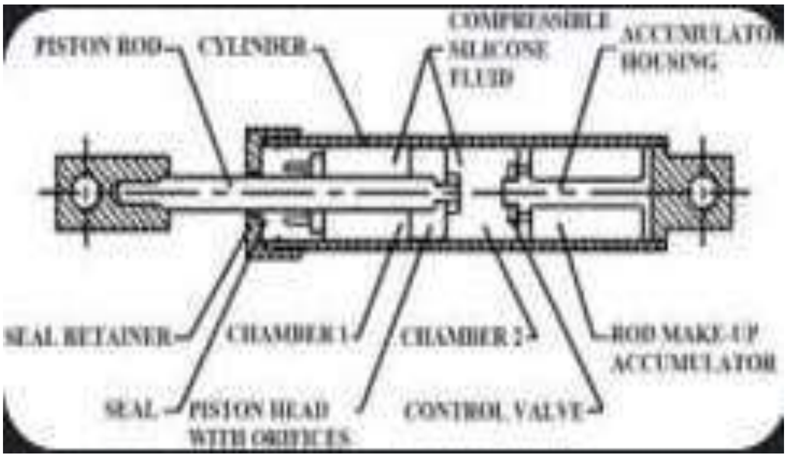
Carbon -Fiber Reinforced Polymer Matrix

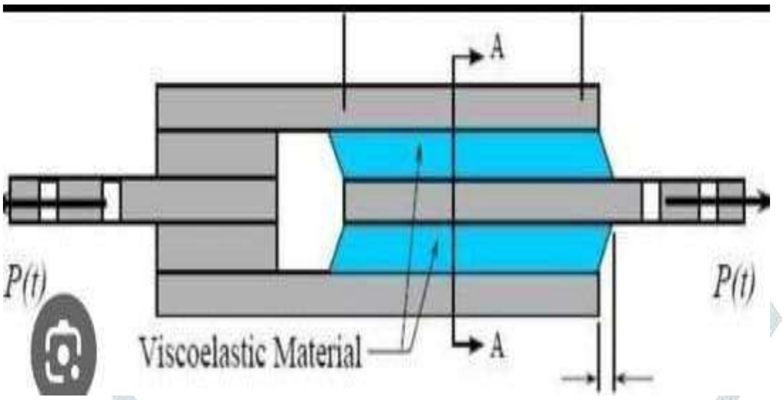
FIGURE -14



Carbon -Fiber Reinforced Polymer Matrix Composites

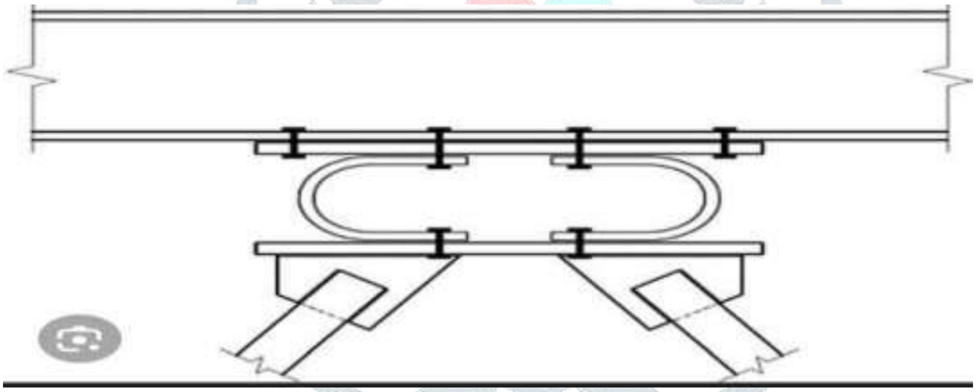
FIGURE -15



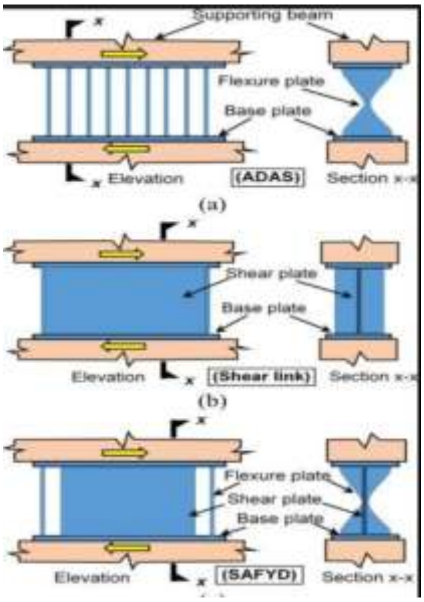


Typical View of a Viscoelastic Dampers

FIGURE -16

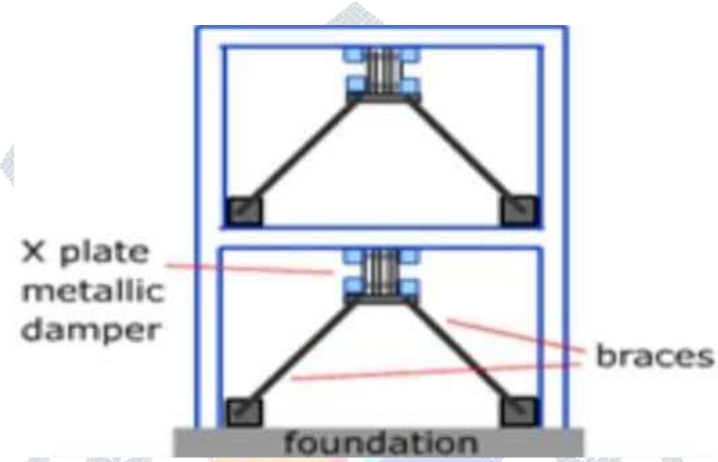


Testing of seismic Dampers with replaceable U shaped
FIGURE -17



Cyclic behaviour of shear and flexural yielding metallic damper

FIGURE -18



Storey still frame with metallic dampers in position

FIGURE -19

1.Preparation of glass fibre reinforced polymer matrix composites
2. Mechanical properties of glass fibre reinforced polymer matrix composites
3. Vibration behaviours of glass fibre reinforced polymer matrix composites
4. Environmental properties of glass fibre reinforced polymer matrix composites
5. Thermal properties of glass fibre reinforced polymer
6. Tribological behaviours of glass fibre reinforced polymer matrix composites
7. Application of glass fibre reinforced polymer matrix composites

A review of glass fibre reinforced polymer composites. All these dampers and seismic isolator systems are being implemented successfully in civil engineering construction in structural dynamics Engineering to protect the structures from any kind of seismic excitation. Now we have to manipulate such systems in such a manner that those modified dampers (under this hypothesis) shall be implemented to construct shock absorber support system which can be installed in underground excavation and tunnel where dynamic equilibrium is required during seismic excitation like blasting underground.

8.Science and Mechanism of Dampers

By combining Newton's second law, the acceleration of Simple Harmonic Motion (SHM), and Hooke's Law, we can derive the equation relating the angular frequency (ω) to the mass(m) and the spring constant (k). We shall the convention of using "a" for acceleration:

Newton's second law: $F=m*a$

Simple Harmonic Motion: $\alpha=-\omega^{2x}$

Hooke's Law: $F=-kx$

$F=-m\omega^2x=-kx$

$k=m\omega^2$

$\omega=\sqrt{(k/m)}$

We can then find the period (T) associated with this oscillating mass-spring (as shown in figure) by the definitions of period and angular frequency. We shall use "f" to indicate the frequency (not the angular frequency, they're different)

$T=1/f$

$\omega=2\pi f$

so $T=2\pi/\omega= 2\pi\sqrt{(m/k)}$

Simple Harmonic Motion is periodic motion, motion that repeats itself over consistent intervals, that is assumed to ignore damping.

The spring constant (k) is a quality of the spring that describes how "strong" the spring is.

Spring with a higher spring constant are more difficult to compress and extend than springs with a lower spring constant.

The seismic behaviour of support structure with added visco elastic dampers is studied experimentally. The experimental results show that significant improvement of structural performance under seismic conditions. It has been seen that effectiveness of dampers is strongly dependent upon mine temperature and highly stressed conditions.

The visco elastic damper is a well known passive control device in mitigating peripheral vibration of the support structure induced by long period seismic excitation also it is actively effective during strong air blast when wind stressed try to deformed the support system. Since its dynamic properties are dependent on several factors such as— overlying load of rock mass, loading frequency and temperature, the increases of its temperature from dissipating kinetic energy significantly affects its behaviour, perticularly for long duration loading.

Analysis models incorporating such effect is being proposed by focusing on heat generation and trasfer.

In nonlinear hysteresis models based on visco elastic (EV) constitutive rule using fractional time derivatives of shear stress and strain. Moreover their accuracy are inherently limited to the appropriate estimation of convective heat transfer parameters. However in practice, a certain degree of deviation due to some uncertainties can be tolerable. This paper proposes an evaluation Methodology for practical application to the shock absorber support system for a dynamic equilibrium.

Visco elastic meterials (VEM) that can resist deformation that is regain its shape, size and dimension as soon as external forces attenuated is practically useful in the underground mine support structure technology. By sandwiching thins slabs of VEM between steel plates, a visco elastic dampers is made and is used as a passive control device to mitigate vibrations of the support structure. VEM dampers effectively reduced the induced stress and strain while strong wind due to heavy air blast passing through it. Also it capable to absorb seismic excitation during blasting and earthquake which deformed the rock texture when installed properly.

Commonly VE damper properties are evaluated by considering its steady states response to harmonic loading and the hysteretic relationship between the force and the deformation or between the shear stress and shear strain.

Fluid viscous dampers work based on the principle of dissipation of energy due to fluid flowing through orifices.

The damper consist of a stainless steel piston, a steel cylinder divided into two champers by the piston head— a compressible hydraulic fluid (silicone oil) and an accumulator for smooth fluid circulation. In fluid viscous dampers as the piston moves(left to right or right to left), fluid flows from one chamber to another chember through the orifice. This movement of fluid from a large area (cylinder chamber) to a smaller area orifice and from a smaller orifice to a larger area (cylinder chamber) results in the dissipation of energy because of head loss. Fluid viscous dampers can operate in an ambient temperature ranging from -40°C to 70°C.

The damping force of the damper is proportional to the pressure difference across the piston head and is expressed as a function of velocity of piston.

Polymer matrix : polymer matrix composites (PMCs) are comprised of a variety of short or continuous fibres bound together by an organic polymer matrix. Reinforcement in a polymer matrix composites (PMCs) provides high strength and stiffness. The PMCs designed so that the mechanical load, seismic excitation, air blast wind pressure to which the support structure is subjected in service are supported by the reinforcement. The function of the matrix is to bond the fibres together and to transfer loads between them.

Polymer matrix composites (PMCs) devided into two categories — reinforced plastic and advanced composites. The distinction is based on the level of mechanical properties (usually strength and stiffness).

High damping rubber bearing is similar with LED rubber bearing, belongs to seismic isolation bearing. It is composed of special rubber with excellent damping attribute, sandwich together with layer of steel of the support structure. Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations. Thus high damping rubber has excellent vibration reduction ability. Due to excellent flexibility and high restoring ability (HDR) can absorb some input energy of the seismic excitation before the energy is transmitted to the support structure. High damping rubber bearing features highly vartical loading capacity, recovery ability. Full of hysteretic behaviour HDRB can produced seismic isolation effect due to blast induce vibration. HDRB itself producing the seismic isolation function, doesn't need install other devices. Thus the cost of maintenance and repair is reduced.

Temperature influences on the flexibility and damping performance of the high damping rubber bearing HDRB is extremely small. Thus HDRB has a wide range of applied field. High damping rubber bearing are commonly used in base isolation system which can protect the support structure from heavy seismic excitation due to heavy blasting in metal mines by elongating natural vibration period of the support structure and improving the energy dissipation capacity of the system.

9.Limitation and applicability of the study:

1. Such support system shall not be installed near the blasting face underground.

2. In the mine permanent roadway it shall be effective.

3. In the four way junction of the underground mine it is very effective rather than the temporary road way.

4. Displacement of such support system from one place to another is a factor of time consuming.

5. As it is permanent nature of support so it shall be installed where permanent roadways are necessary both in traveling and haulage road.

6. If it is not cost effective then it shall be installed in some strategic places , where zone is prone to seismic excitation or the areas of geological disturbances.

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