American Journal of Mining and Metallurgy, 2013, Vol. 1, No. 1, 11-14
Available online at http://pubs.sciepub.com/ajmm/1/1/3

DOI:10.12691/ajmm-1-1-3

Seismic Effect Prognosis for Objects with Different Geometric Configuration of Fundament in Close Blasting

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Received November 21, 2013; Revised November 25, 2013; Accepted December 05, 2013

Abstract Seismic wave influence in near field from millisecond delay blast to buildings with different foundation configuration was researched. Three main type of base (square, tree-corner and elliptical shape) were described. Recommendation for charges disposition and orientation in blasting scheme were given.

Keywords: *blasting, building foundation, near field, seismic wave, base configuration, seismic effect*

Cite This Article: Viktor Boiko, “Seismic Effect Prognosis for Objects with Different Geometric Configuration of Fundament in Close Blasting.” *American Journal of Mining and Metallurgy* 1, no. 1 (2013): 11-14. doi: 10.12691/ajmm-1-1-3.

1. Introduction

During blasting practice problems to forecast objects’ seismic stability by building foundation’s contour appears very often. The main mistake is determining boundary allowable charges in near field for guarded objects’ seismic stability with different geometric configuration of foundation, when we use the same calculation as for remote zone. In this case, we keep invalid data with relation to practice. Really, if value of breakdown speed 3 cm/s is putted in Eq.(1) and coefficient K, which is depended on blast charge loading, accept as 300, Eq. (2) would be got. As rules, coefficient K value is bigger for hard rocks than for soft rock, because blast charges are more loaded.

$$v = K\rho^2 \quad (1)$$

$$Q_{\max} = (0.1r)^3 \quad (2)$$

For example, from preceding follows that even on distance 10 m from building foundation it possible to blast charge with mass 0.01 kg. [1] But blasting practice shows, it could be blast charge in 30-50 times greater.

2. Materials and Methods

The mechanism of seismic affecting on a building in a short-range zone and in long-range are different, and it is the reason of such divergence. Local character of explosion act in a short-range zone and dominant composition of volume waves show up. Last gives oscillation with high frequency and small slowness to a subgrade. If velocity of particles displacement takes on criterion of seismic safety, it should be velocity of particles displacement in building’s base by all plane. It is quantitative characteristics for energy, which transmits through foundation to whole building. This criterion does not depend on geometrical configuration of building foundation and type of construction design, but it depends on blast conditions, distance and geological conditions along way of seismic wave’s distribution.

As regards remote zone, displacement particles velocity and displacement foundation velocity have small difference (1,5 times), that is why, evenly, displacement particles velocity in house footing takes on criterion of seismic safety [1].

In near field, displacement foundation velocity is much less than displacement particles velocity under foundation. It is bound up with short waves from close blasting comes to different parts of foundation with dissimilar amplitudes, inasmuch as last damps inversely proportional to distant, which, for example, independent of foundation’s configuration, is bigger for back wall than to nearby wall. (Figure 1).

If square house footing is under consideration, ground keep almost motionless under separate part (in corners) of foundation. Inasmuch as all base parts and walls are connected with each other, most of construction’s elements oppose to engaging of fabric in the oscillating process, which fits velocity of particles displacement in the closest zone to the blast charge. In case, when construction parts are disconnected (for example, dam), majority of elements will response independently of one another to sway, and accordingly displacement particles velocity will change in different points with certain distances from charge. It leads to substantial increase of seismic demonstration from blasting through ground base in determinate unsafe junctions, for concrete foundation configuration. That is why the task to develop method of stress field (oscillation velocity) calculation near ground base, where foundation with elements' configuration is located and seismic waves from blasting have influence, springs up. Especially it applies to near field. Concerning far zone, calculation methods for seismic safety of buildings and other guarded objects are based on determining ground oscillation velocity only in a ground base. In this case, particles oscillation velocity measuring in any spots of ground base near foundation is enough for seismic stability calculation. Seismic stability estimation, according to this methodic, does not account oscillation pattern along all boundary of ground-building contacts and it could be used for any configuration objects. Scilicet existing design procedures of seismic stability by soil particles oscillation velocity do not allow different durability of construction elements depend on waves' distribution changing along all boundary of massif and building contacts. It is explained absence theoretical and experimental data of dynamic stress fields distribution (soil particles' oscillation velocity) through medium to construction elements of different building's configuration.

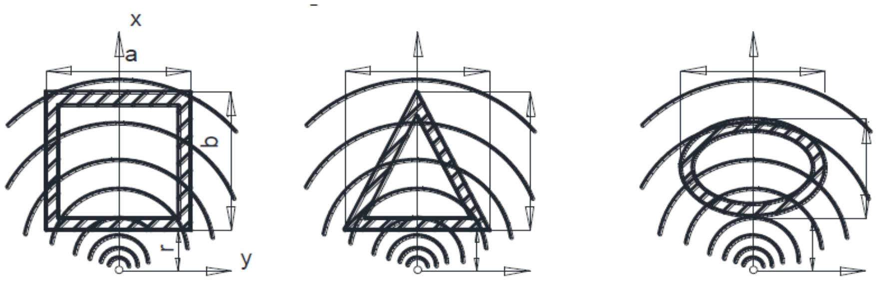

Figure 1. Seismic-wave motion scheme in near field through ground base to objects with square, three-angled and oval foundation

In adjacent scientific fields with geomechanics, task of loading distribution for different types elastic inclusions is has been decided [2]. Let us handle a task about plane-polarized three-dimensional wave's distribution in elastic medium, which hold non-circular cylindrical foundation (object) with dissimilar mechanical properties from medium properties. Diffraction phenomenon role in dynamic load's distribution become formed on such facility, if non- circular cylindrical coordinate system (ρ,θ,z) with axis coincide with inclusion axis will introduce. Variables ρ,θ,z are connected with Cartesian coordinates (x,y,z) and circular cylindrical coordinates (ρ,φ,z) correlation.

$$x + yi = re^{i\varphi} = R\left(\rho e^{i\theta} - \varepsilon\rho^{-N} e^{-iN\theta}\right) \qquad (3)$$

Guides of cylindrical surface $\rho = 1$ by different dimensions have elliptic form or regular (N + 1)-gon with truncated corner.

Let polarized longitudinal wave with potential distribute in elastic medium

$$\Phi^* = A_0 \exp ik_p\left(n_{px}x + n_{py}y\right), \qquad (4)$$

Where A_o – amplitude of incident wave;

n_{px} = cosφ_p, n_{py} = sinφ_p – guides cone of normal to waves' surface of longitudinal waves.

Solution of Helmholtz equation

$$\Delta\Phi + \alpha^2\Phi = 0, \Delta\Psi + \beta^2\Psi = 0, \qquad (5)$$

(Where Φ, Ψ – scalar potentials accordingly longitudinal and transverse waves; α, β – wave numbers) for elastic medium ρ > 1, which characterize depictured waves in coordinates (r, φ, z) (their potentials satisfy propagation term when $r = \infty$. Expression Eq. (5) could be written as

$$\Phi = \sum_n A_n H_n^{(1)}(\alpha r)e^{in\varphi}$$
$$\Psi = \sum_n B_n H_n^{(1)}(\beta r)e^{in\varphi} \qquad (6)$$

Where A_n, B_n – non-defined coefficients;

$H_n^{(1)}(\xi)$ – 1st rood of Hankel function.

Confines of summing from –∞ till +∞ are omitted here and further. Total wave field in medium defines as sum Φ + Φ*, Ψ.

Potentials for inclusion $\rho < 1$ are chosen similar:

$$\Phi_f = \sum_n A_{f,n} J_n(\alpha_f r)e^{\mathrm{inf}};$$
$$\Psi_f = \sum_n B_{f,n} J_n(\beta_f r)e^{\mathrm{inf}}, \qquad (7)$$

де $A_{f,n}$, $B_{f,n}$ – non-defined coefficients;

α_f, β_f – wave numbers of longitudinal and transverse waves for foundation materials;

$J_n(\xi)$ – Bessel function (index f to meet an object).

Potential of incident wave Eq. (5) in circular cylindrical coordinates (r,φ, z) could be written as

$$\Phi^* = A_0 \sum_n a_n J_n(\alpha r)e^{in\phi} \qquad (8)$$

де $a_n = i^n e^{-in\phi_p}$.

Continuity conditions of movements and tensions have to comply on surface of discontinuity $\rho = 1$.

$$U_p^f(1,\theta) = U_p(1,\theta) + U^*_p(1,\theta);$$
$$U_\theta^f(1,\theta) = U_\theta(1,\theta) + U^*_\theta(1,\theta);$$
$$\sigma_{\rho\rho}^f(1,\theta) = \sigma_{\rho\rho}(1,\theta) + \sigma^*_{\rho\rho}(1,\theta);$$
$$\sigma_{\rho\theta}^f(1,\theta) = \sigma_{\rho\theta}(1,\theta) + \sigma^*_{\rho\theta}(1,\theta). \qquad (9)$$

For observance continuity conditions Eq. (9), let pass on to expressions Eq. (6)-(8) and coordinates (ρ, z, θ) using solutions of Helmholtz equation in curvilinear coordinates [3]:

$$\Phi(\rho,\theta)=\sum_n e^{in\theta}\sum_p A_{n-(N+1)p}J_p(\alpha\varepsilon\rho^{-N})H^{(1)}_{n-Np}(\alpha\rho);$$

$$\Psi(\rho,\theta)=\sum_n e^{in\theta}\sum_p B_{n-(N+1)p}J_p(\beta\varepsilon\rho^{-N})H^{(1)}_{n-Np}(\alpha\rho);$$

$$\Phi_f(\rho,\theta)=\sum_n e^{in\theta}\sum_p A_{f,n-(N+1)p}J_p\left(\alpha_f\varepsilon\rho^{-N}\right)J_{n-Np}\left(\alpha_f\rho\right);$$

$$\Psi_f(\rho,\theta)=\sum_n e^{in\theta}\sum_p B_{f,n-(N+1)p}J_p\left(\beta_f\varepsilon\rho^{-N}\right)J_{n-Np}\left(\beta_f\rho\right);$$

$$\Phi^*(\rho,\theta)=\sum_n e^{in\theta}\sum_p A_0 a_{n-(N+1)p}J_p\left(\alpha\varepsilon\rho^{-N}\right)J_{n-Np}\left(\alpha\rho\right) \quad (10)$$

Expression Eq. (10) puts in contact conditions Eq. (9) then infinite system of algebraic equalizations be received for constants A_n, B_n, $A_{f,n}$ and $B_{f,n}$ (n=0,±1,...). This equalization system was worked with using computer.

Finite number of equalizations hold in the system for determination the nearest answers. The calculations accuracy checked through result comparison for different approximation. Maximum relative difference of results was not bigger then 5% for tensions.

When tensions analysis for massif with object was doing, computation made for most common configuration of elliptical (N = l; ε = ±0,4; a + b = 2R), three-cornered (N = 2; ε = ±0,25; d = 3/4R) and square (N = 3; ε = +1/6; d = 5/6R) sections (dam, building base, etc.). These stress amplitudes $\sigma_{\rho\rho}$, $\sigma_{\rho\theta}$ and $\sigma_{\theta\theta}$ were charged to $\left|\sigma_{yy}^{(\infty)}\right|=(\lambda+2\mu)\alpha^2$.

Calculation made for points of contour $0 \le \theta \le \pi$ in increments of $\Delta\theta=\pi/18$ for elliptical and three-cornered inclusion and of $\Delta\theta=\pi/12$ for square one. Poisson's ratio for massif was 0,35 and 0,2 for object when ratio of density and hardness was $\rho_f/\rho_m=2$ and $\mu_f/\mu_m=20$ respectively.

Relationship of stress amplitudes σ_{pp}, $\sigma_{p\theta}$, $\sigma_{\theta\theta}$ in matrix when $\rho=1$ from angle θ with fixed frequency (Value α is numbers near graph) are depicted on Figure. 2. Block curve meets to stress $\left|\sigma_{\theta\theta}\right|$, dashed-line curve meets to $\left|\sigma_{\rho\rho}\right|$, chain line meets to $\left|\sigma_{\rho\rho}\right|$ on the graphs.

3. Results and Discussion

In case of inclusions elliptical intersection, maximum tensions originate in boundaries points of the smallest crookedness radius θ = π/2 for ε = 0,4 (waves distribute along short axis of ellipse) and θ = 0, θ = π for ε = –0,4 (waves distribute lengthwise long axis of ellipse). The biggest is $\sigma_{\theta\theta}$. In area of the biggest crookedness radius points maximum tension originate θ = π, θ = 0. Tension σ_{pp} dominate in front face and shady side of contour when ε = 0,4, as in case circular inclusion.

Maximum tension σ_{pp} arise in corner points' areas θ = π, θ = π/3 for objects with three-corner section. In case of ε = 0,25, θ = 2/3π and θ = 0 for ε = 0,25 the largest stress are $\sigma_{\theta\theta}$, as for elliptical objects. Efforts σ_{pp} have the biggest value in black side points of contour θ = 0 for ε = 0,25 and θ = π front side of contour for ε = –0,25

In case of object with square section for ε = 1/6 stress σ_{pp} has peak value in corner points region θ = 3/4π and θ = π, but tension $\sigma_{\theta\theta}$ has maximum in corner points area θ = π, θ = π/2 and θ = 0.

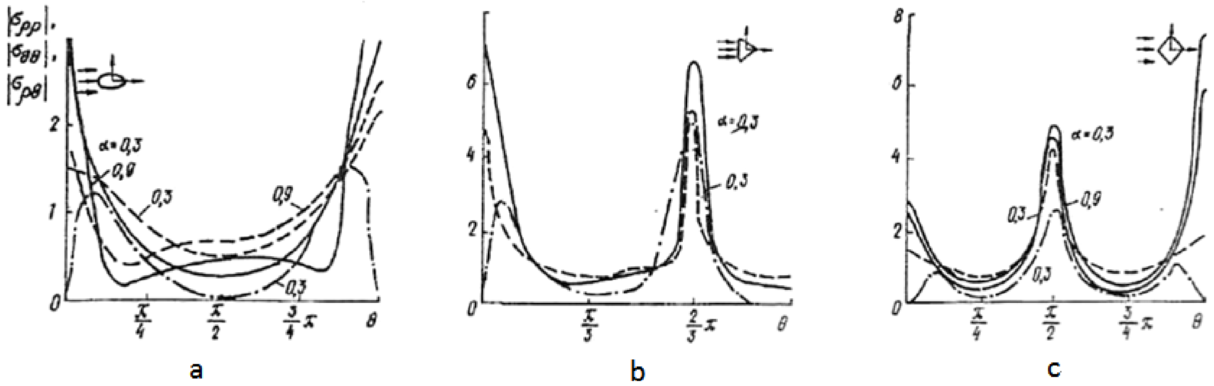

Figure 2. Plot of tension amplitude from θ angle when fixed frequencies by foundation contour of safe object with elliptical (a), three-corner (b) and square (c) configuration

It is worthwhile noting that strong stress concentration arise in the smallest radius of curvature for object with different cross-section shape, which are in three-eight times excess over tensions of incident wave. Maximum effort in incident wave σ_{pp} is achieved in points of minimum curvature radius. Other contour points could have big value as σ_{pp} so $\sigma_{\theta\theta}$. These theoretical calculations have found practical evidence when the largest cracks from blasting concussion have been locked in building corners with square and right-angled base (Figure 2) [4].

4. Conclusion

The foregoing allows affirming that take-off data of body wave's oscillation velocity, which were obtained on the corner points, should be assumed for forecasting of blasting concussion for facilities with different base configuration. Borehole charges, which blast instantly, should be oriented concurrently to flank walls (Figure 3) during drilling and blasting operations. It is not permissible when waves come from side of corner point.

In this articles just a few configuration of building base have been taken, but here are a lot building with other regular or irregular shape. It gives wide field of future research Seismic safety of engineering and nature objects could be obligatory or preventive, for example by psychological factors affecting people. Industrial implementation sphere of seismic safe methods during special and engineering blasting will appear always.

Figure 3. Typical crack (place of maximum stress) formed under the impact of seismic waves from large-scale blast on mines

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