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“QURILISHDA YASHIL IQTISODIYOT, SUV VA ATROF-MUHITNI ASRASH TENDENSIYALARI, EKOLOGIK MUAMMOLAR VA INNOVATSION YECHIMLAR” MAVZUSIDAGI RESPUBLIKA MIQYOSIDAGI ILMIY-AMALIY KONFERENSIYA TASHKILIY QO‘MITASI

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Propagation of spherical shock waves in a contiguous elastic-plastic environment

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Abstract: This article studies the propagation of one-dimensional spherical shock waves in a homogeneous medium, represented by soil or ground, modeled as a continuous elastic-plastic medium. The research assumes that the loading shock waves in the elastic-plastic medium filling the surrounding space propagate at a constant velocity. Furthermore, the effective use of directional blasting technology in construction, mining-geological industries, and other technical fields requires determining the relevant mechanical parameters of continuous elastic-plastic media subjected to shock loads. Within the theory of small elastic-plastic deformations, the relationship between the components of the stress and strain tensors in a spherical coordinate system is taken into account.

Keywords: elasto-plastic medium, underground capacity, soil, explosion, shock wave, elastic potential, tensor, intensity, deformation, stresses.

Tutash elastik-plastik muhitda sferik zarbali to‘lqinlarning tarqalishi

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Annotatsiya: Mazkur maqolada uzluksiz elastik-plastik muhit tarzida modellashtirilgan va kuchlanish-deformatsiyalanishi tabiiy holatdagi bir jinsli zamin yoki tuproq (grunt)dan iborat muhitlarda bir o‘lchovli sferik zarbali to‘lqinlarning tarqalishi o‘rganilgan. Tadqiqot jarayonida atrof fazoni qoplagan elastik-plastik muhitlarda yuklanish zarbiy to‘lqinlari o‘zgarmas tezlik bilan tarqaladi, deb qaraladi. Shuningdek, Qurilish sohasida, tog’- geologiya sanoati va texnikaning turli tarmoqlarida yo’naltirilgan portlash texnologiyasidan unumli foydalanish, zarbga duchor bo‘lgan yuklanish zarbiy to‘lqinlari ortidagi uzluksiz elastik-plastik muhitlarning tegishli mexanik parametrlarini aniqlash, Kichik elastik-plastik deformatsiyalar nazariyasiga ko‘ra, sferik koordinatalar tizimida kuchlanish va deformatsiya tenzorlari komponentlari orasidagi bog‘liqlik ko‘zda tutilgan.

Kalit so‘zlar: elastik-plastik muhit, yer osti sig‘imi, tuproq, portlash, zarba to‘lqini, elastik potensial, tenzor, intensivlik, deformatsiya, kuchlanishlar.

1. Kirish

Qurilish sohasida, tog’- geologiya sanoati va texnikaning turli tarmoqlarida yo’naltirilgan portlash texnologiyasidan unumli foydalaniladi. Ushbu texnologiyalarni rivojlantirish fan va texnikaning dolzarb masalalaridan bo’lib, iqtisodiyotning resurs va mablag’larini tejashga imkon beradi. Maqolada ko’rilayotgan masalaning dolzarbligi shu bilan asoslanadi. Taraqqiy etgan mamlakatlarda portlash nazariyasiga bag’ishlangan ko’plab tadqiqotlar o’tkazilgan. Portlash natijasida hosil bo‘lgan sferik zarba to‘lqinlarining tarqalishi haqidagi mavjud adabiyotlarni sharhlash shuni ko‘rsatadiki, tuproq massivlari (ayniqsa, turli muhandislik kommunikatsiyalari, masalan, gaz va neft saqlash idishlari, shaxta quduqlari, kanallar va boshqa gidrotexnika inshootlari bilan real aloqada bo‘lgan modellar) ko‘plab tadqiq qilingan. Shu bilan bog‘liq holda, portlashning sferik zarba to‘lqinlarining buzilmagan elastik-plastik muhitda tarqalishini modellashtirish va yechish usullarini ishlab chiqish jarayonida ilmiy tahlil qilish muammolari dolzarb hisoblanadi.

2. Sferik simmetrik elastik-plastik muhitlarning avtomodel harakati tadqiqi

Kichik elastik-plastik deformatsiyalar nazariyasiga ko‘ra, sferik koordinatalar tizimida kuchlanish va deformatsiya tenzorlari komponentlari orasidagi bog‘liqlik quyidagi ko‘rinishda ifodalanadi:

$$\sigma_r = \lambda\,\varepsilon + 2\,G\frac{\partial u}{\partial x}, \qquad \sigma_\varphi = \lambda\,\varepsilon + 2\,G\frac{u}{r} \quad (1)$$

Sferik simmetriya sharoitida, mos ravishda hajmiy deformatsiya va sirpanma deformatsiya intensivligi quyidagi ko‘rinishga ega bo‘ladi:

$$\varepsilon = \frac{\partial u}{\partial x} + 2\frac{u}{r}\ ; \qquad \varepsilon_i = \frac{2}{3}\left(\frac{u}{r} - \frac{\partial u}{\partial x}\right) \quad (2)$$

O'tkazilgan tajribalar shuni ko'rsatadiki, o'zgaruvchan koordinatalar $\lambda(\varepsilon, \varepsilon_i)$ va $G(\varepsilon, \varepsilon_i)$ to'liq deformatsiya tenzori komponentlarining funksiyalari sifatida aniqlanadi va elastik potensial $U(\varepsilon, \varepsilon_i)$ orqali quyidagicha ifodalanadi.

$$\lambda(\varepsilon, \varepsilon_i) = \frac{1}{\varepsilon}\cdot\frac{\partial U}{\partial \varepsilon} - \frac{2}{9}\cdot\frac{1}{\varepsilon_i}\cdot\frac{\partial U}{\partial \varepsilon_i}\ ; \quad G(\varepsilon, \varepsilon_i) = \frac{1}{3\,\varepsilon_i}\cdot\frac{\partial U}{\partial \varepsilon_i}$$

$U(\varepsilon, \varepsilon_i)$ ni aniqlash uchun, odatda, eksperimental tadqiqotlar natijalaridan foydalaniladi. Tajribalar kuchlanishlar intensivligi σ_i ning deformatsiya intensivligi ε_i va o'rtacha normal kuchlanish (yoki aynan shu ma'noda, hajmiy deformatsiy)ε bilan invariant bog'liqligi mavjudligini tasdiqlaydi:

$$\frac{\partial U}{\partial \varepsilon} = \sigma(\varepsilon) \qquad \frac{\partial U}{\partial \varepsilon_i} = \sigma_i(\varepsilon, \varepsilon_i) \quad (4)$$

Shu bilan bog'liq holda, umumlashtirilgan modullar $\lambda(\varepsilon, \varepsilon_i)$ va $G(\varepsilon, \varepsilon_i)$ ni aniqlash uchun, mazkur maqolada birinchi marta eksperimental tadqiqotlar natijalari qo'llanilgan. Bu tadqiqotlar gruntlar va tog' jinslarining mexanik xususiyatlarini aniqlash bo'yicha olib borilgan va [2-4] ilmiy ishlarda bayon etilgan:

$$\lambda(\varepsilon, \varepsilon_i) = k_1 + k_2\varepsilon + k_3\varepsilon^2 -$$

$$\frac{2\ G_0\ tg\psi}{9}\cdot[H_0 + (k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)]\cdot\cdot(tg\psi + G_0\varepsilon_i)^{-1}$$

$$G(\varepsilon, \varepsilon_i) = \frac{G_0\ tg\psi}{3}[H_0 + (k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)]\cdot$$

$$\cdot(tg\psi + G_0\varepsilon_i)^{-1} \quad (5)$$

Bu yerda , $k_1, k_2, k_3, H_0, tg\psi, G_0$ - eksperimental konstantalar.

Eksperimental tadqiqotlar natijalarini hisobga olgan holda, ko'rib chiqilayotgan muhitning dinamik harakat tenglamalari tegishli o'zgartirishlardan so'ng ushbu masalaga tatbiq qilingan holda quyidagicha ifodalanadi (6)

$$\frac{\partial^2 u}{\partial t^2} = \frac{1}{\rho_0}(1+\varepsilon_\varphi)^2\cdot\left[m_\varepsilon + \frac{4}{9}\cdot n_\varepsilon\left(q_{\varepsilon_i}^{-1} + G_0 q_{\varepsilon_i}^{-2}\right)\right]\cdot$$
$$\frac{\partial^2 u}{\partial r^2} - \frac{2}{\rho_0}\cdot\frac{\varepsilon_\varphi}{r}(1+\varepsilon_\varphi)^2\cdot\left\{m_\varepsilon - \frac{2}{3}\cdot n_\varepsilon\left(q_{\varepsilon_i}^{-1} + G_0 q_{\varepsilon_i}^{-2}\right) + n_\varepsilon q_{\varepsilon_i}^{-1}(1+\varepsilon_r)\left[\varepsilon_\varphi(1+\varepsilon_\varphi)^{-1}\right]\cdot\varepsilon_i\right\} \quad (6)$$

Bu yerda

$$m_\varepsilon = k_1 + 2k_2\varepsilon + 3k_3\varepsilon^2$$

$$n_\varepsilon = G_0\ tg\psi\ [H_0 + (k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)] \quad (7)$$

$$q_{\varepsilon_i} = tg\psi + G_0\varepsilon_i$$

Mexanikadagi o'lchamliklar nazariyasi (yoki π nazariyasi) dan foydalanib ko'rsatish mumkinki, zarba to'lqinidan keyingi gruntning aniqlovchi parametrlaridan faqat quyidagi bitta o'lchamsiz kombinatsiyani tuzish mumkin:

$$\eta = \frac{r}{b_0 t} \quad (8)$$

va shu sababli, masala **avtomodel** bo'ladi [5-7]. Grunt harakatining tenglamasi yechimi quyidagi ko'rinishda qidiriladi

$$u = b_0 t\cdot f(\eta) \quad (9)$$

Bu yerda , $f(\eta)$ - izlanayotgan funktsiya.

$$\frac{\partial^2 u}{\partial t^2} = b_0\frac{\eta^2}{t}\cdot f''(\eta)\ ;\ \frac{\partial^2 u}{\partial r^2} = \frac{\eta}{t}\cdot f''(\eta) \quad (10)$$

Shunday qilib, yuqorida bayon etilganlarni hisobga olib, ba'zi o'zgartirishlardan so'ng, grunt harakatining tenglamalari ikkinchi tartibli oddiy differensial tenglama ko'rinishida olinadi:

$$f''(\eta) - Q(\eta, f, f')\cdot\{\eta[\eta^2 - L(\eta, f, f')]\}^{-1} = 0 \quad (11)$$

Bu yerda, $L(\eta, f, f') = \frac{1}{\rho_0 b_0}\left[1 + \frac{f(\eta)}{\eta}\right]^2\cdot$

$$(k_1 + 2k_2\varepsilon + 3k_3\varepsilon^2 + \frac{4}{9}\ G_0\ tg\psi\ )\cdot$$
$$\cdot[H_0 + (k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)]\cdot$$
$$\cdot[(tg\psi + G_0\varepsilon_i)^{-1} + G_0(tg\psi + G_0\varepsilon_i)^{-2}]$$

$$Q(\eta, f, f') = \frac{1}{\rho_0 b_0^2}\frac{f(\eta)}{\eta}\left[1 + \frac{f(\eta)}{\eta}\right]^2\left\{\frac{2}{3}(H_0 + k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)\cdot[(tg\psi + G_0\varepsilon_i)^{-1} + G_0(tg\psi + G_0\varepsilon_i)^{-2}] - (k_1 + 2k_2\varepsilon + 3k_3\varepsilon^2) - (H_0 + k_1\varepsilon + k_2\varepsilon^2 + k_3\varepsilon^3)\cdot(tg\psi + G_0\varepsilon_i)^{-1}\cdot[1 + f'(\eta)]\left[\frac{f(\eta)}{\eta}\left(1 + \frac{f(\eta)}{\eta}\right)\right]^{-1}\cdot\varepsilon_i\right\}$$

$$\varepsilon = \frac{2\ f(\eta) + \eta\ f'(\eta)}{\eta}\ ; \quad \varepsilon_i = \frac{2}{3}\cdot\left[\frac{f(\eta) - \eta\ f'(\eta)}{\eta}\right] \quad (12)$$

Shuni ta'kidlash kerakki, (11) tenglamani sonli usullar yordamida yechish uchun zarba to'lqinidagi shartlar asosida aniqlanadigan η^*, f^*, f'^* parametrlaridan foydalanish zarur.

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