DINAMIK YUKLAR TA’SIRIDA IKKI VA UCH O‘LCHAMLI MODELLASHTIRISH NATIJALARINING TAQQOSLASH

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Annotatsiya. Ushbu maqolada PLAXIS 2D va PLAXIS 3D dasturlarida bajarilgan hisob natijalari tahlil qilinib, tekis va hajmiy masalalarni modellashtirishda statik va dinamik yuklar ta’siri ostidagi farqlari o‘rganilgan. Tadqiqot davomida grunt parametrlari, chegaraviy shartlar hamda yuklanish holatlari bir xil sharoitda solishtirildi. Statik yuklar ta’sirida 3D model natijalari aniqroq va real holatga yaqin ekani aniqlangan. Dinamik yuklar esa 3D model real seysmik yozuvlar asosida tahlil qilganda tebranish amplitudalarining aniqroq baholanishini grunt hamda inshoot o‘zaro ta’sirining fazoviy xarakterini to‘liqroq aks ettirishi kuzatildi. Olingan natijalar asosida 2D va 3D modellarni qo‘llash bo‘yicha ilmiy va amaliy xulosa va tavsiyalar ishlab chiqilgan.

Kalit so‘zlar: Tekis va hajmiy masala, chekli elementlar usuli (ChEU), statik yuk, dinamik yuk, seysmik tahlil, deformatsiya, kuchlanish, grunt modeli.

So‘nggi yillarda qurilish muhandisligi, ayniqsa, seysmik barqarorlikni ta’minlashga yo‘naltirilgan inshootlarni loyihalashda raqamli modellashtirish usullarining roli ortib bormoqda. Zamonaviy hisoblash texnologiyalari yordamida murakkab geometrik shaklga ega bo`lgan konstruksiyalar, turli grunt qatlamlari vaqtga bog‘liq yuklanish holatlari uchun aniq tahlil qilinmoqda. Bunda, ayniqsa, 2D (ikki o‘lchamli) va 3D (uch o‘lchamli) modellashtirish usullarini to‘g‘ri tanlash masalasi muhim ahamiyat kasb etadi.

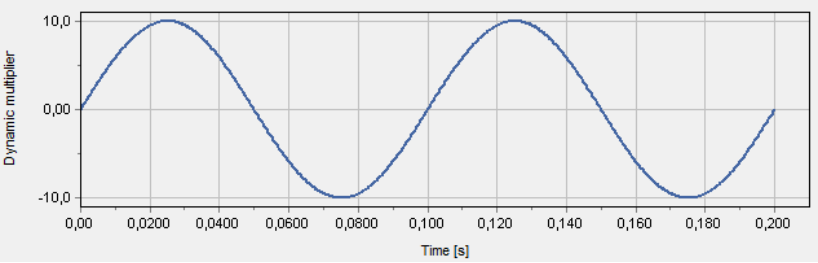
Ko‘p hollarda soddalashtirish maqsadida inshoot elementlari **tekis (2D)** model asosida tahlil qilinadi. Biroq bunday yondashuvda yuklarning **fazoviy tarqalishi**, **to‘lqinlarning tarqalishi**, va **chekka zonalardagi kuchlanish konsentratsiyasi** to‘liq

hisobga olinmaydi. **3D modellashtirish**da esa inshoot fazoviy shaklda ko‘rib chiqilib, har bir nuqtadagi deformatsiya va kuchlanish o‘zaro bog‘liqlikda tahlil qilinadi[3].

Ayniqsa, dinamik yuklanishlar (zilzila, transport vibratsiyasi, shamol bosimi va hokazo) ta’sirida 3D modellarning afzalligi yaqqol namoyon bo‘ladi. Shuning uchun, 2D va 3D modellar uchun olingan natijalarni solishtirish, ularning statik hamda dinamik yuklanishlardagi farqlarini tahlil qilish - nafaqat ilmiy jihatdan, balki amaliy loyihalashda ham muhimdir.

Mazkur masalani hal etish uchun Plaxis 2D va Plaxis 3D kompleks dasturidan foydalangan holda, tekis va hajmiy masalalar natijalari dinamik yuklar ta’sirida o‘zaro solishtirilib, ularning kushlanish, deformatsiya, va tebranish amplitudalaridagi tafovutlari tahlil qilinadi.

Tekis masala sifatida uzunligi 40 m, chuqurligi 10 m bo‘lgan grunt massiviga to‘plangan kuch (P=10 kN), hajmiy masala uchun uzunligi va chuqurligi tekis masalanikidek, eni esa 20 m bo‘lgan grunt massivi ustiga yoyilgan kuch (intensivligi q=10kN/m) qo‘yilgan modellar dinamik yuklar ta’sirida taqqoslandi. Dinamik yuk modelga garmonik (amplitudasi 10 ga, chastotasi 10 Hz ga teng) ta’sir qiladi(1-rasm).



1-rasm. Dinamik yukning garmonik ko‘rinishi

Modellar Plaxis 2D va Plaxis 3D dasturlarida qurildi. Har ikkala model uchun ham grunt parametrlari chiziqli elastik model asosida qabul qilinib, grunt zichligi $\rho = 20\ kN/m^3$, $E = 50000\ kN/m^2$ va Puasson koeffitsiyenti $\nu = 0{,}3$ deb qabul qilingan.

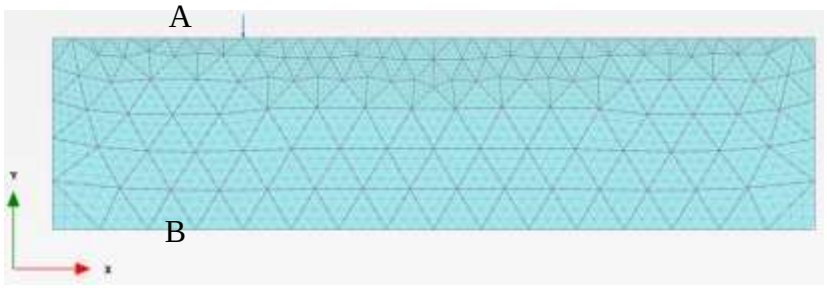
Masalani yechish uchun chekli elementlar usulidan foydalanamiz.

Chekli elementlarning shakllari uchburchk (2D uchun) va tartibsiz tetraedr (3D uchun) sifatida tanlandi.

Masalani elastiklik nazariyasining masalasiga keltirilib yechiladi.

Ushbu masalada cheksiz tekislikni chekli soha bilan almashtirildi. Bunda chegaralarda to‘lqinlarning cheksizlikka intilishini ta’minlovchi quyidagi shartlar qo‘yilgan.

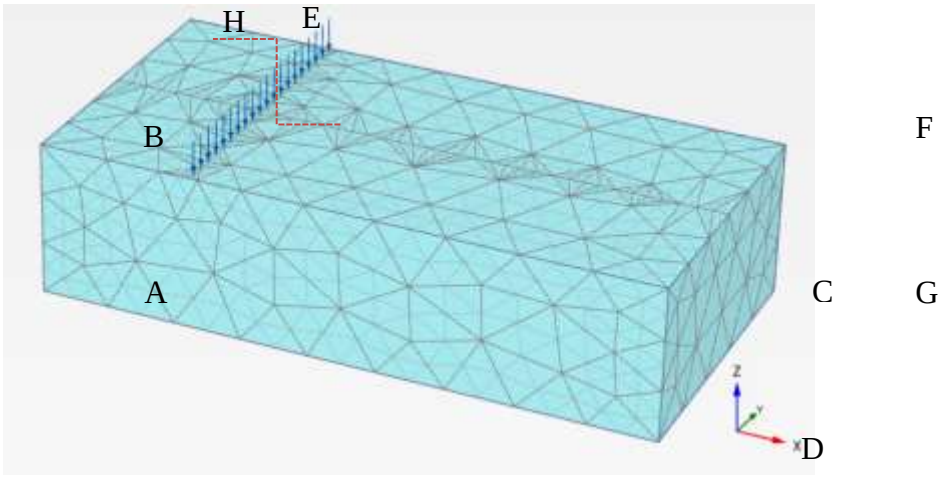
Tekis masala uchun:



AB da $\left.\begin{matrix}\sigma_x = a\cdot\rho\cdot V_P\cdot\dot{v}\\ \tau_y = b\cdot\rho\cdot V_S\cdot\dot{u}\end{matrix}\right\}$, CD da $\left.\begin{matrix}\sigma_x = -a\cdot\rho\cdot V_P\cdot\dot{v}\\ \tau_y = -b\cdot\rho\cdot V_S\cdot\dot{u}\end{matrix}\right\}$,

BC da $\left.\begin{matrix}\sigma_y = a\cdot\rho\cdot V_P\cdot\dot{v}\\ \tau_x = -b\cdot\rho\cdot V_S\cdot\dot{u}\end{matrix}\right\}$ (1)

Hajmiy masala uchun:



ABEH da $\left.\begin{matrix}\sigma_x = a\rho V_p\dot{u}\\ \tau_{xy} = b\rho V_s\dot{v}\\ \tau_{xz} = b\rho V_s\dot{w}\end{matrix}\right\}$, DCFG da $\left.\begin{matrix}\sigma_x = -a\rho V_p\dot{u}\\ \tau_{xy} = -b\rho V_s\dot{v}\\ \tau_{xz} = -b\rho V_s\dot{w}\end{matrix}\right\}$,

ABCD da $\left.\begin{matrix}\sigma_y = a\rho V_p\dot{v}\\ \tau_{yz} = b\rho V_s\dot{w}\\ \tau_{yx} = b\rho V_s\dot{u}\end{matrix}\right\}$, EFGH da $\left.\begin{matrix}\sigma_y = -a\rho V_p\dot{v}\\ \tau_{yz} = -b\rho V_s\dot{w}\\ \tau_{yx} = -b\rho V_s\dot{u}\end{matrix}\right\}$,

$$\left.\begin{array}{l}\sigma_z = a\rho V_p \dot{w} \\ \text{ADHG da } \tau_{zy} = b\rho V_s \dot{u} \\ \tau_{zy} = b\rho V_s \dot{v}\end{array}\right\}. \qquad (2)$$

Bu yerda $\boldsymbol{\sigma}$ va $\boldsymbol{\tau}$ – normal va urinma kuchlanishlar; $\dot{\boldsymbol{u}}, \dot{\boldsymbol{v}}$ va $\dot{\boldsymbol{w}}$ – chegaraviy nuqtalar tezliklarini o‘qlardagi proyeksiyalari; $\boldsymbol{V_p}$ va $\boldsymbol{V_s}$ – P va S to‘lqinlarning tezliklari; $\boldsymbol{a}$ va $\boldsymbol{b}$ – o‘lchamsiz parametrlar; $\boldsymbol{\rho}$ – materialning zichligi [5,6,7,8,9].

Kinematik munosabatni quyidagicha shakllantirish mumkin:

$$\boldsymbol{\varepsilon = Lu} \qquad (3)$$

L^T - transponirlangan differensial operator

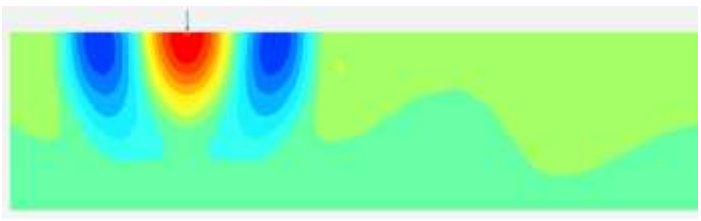
$$\mathbf{L^T} = \begin{bmatrix} \frac{\partial}{\partial x} & 0 & 0 & \frac{\partial}{\partial y} & 0 & \frac{\partial}{\partial z} \\ 0 & \frac{\partial}{\partial y} & 0 & \frac{\partial}{\partial x} & \frac{\partial}{\partial z} & 0 \\ 0 & 0 & \frac{\partial}{\partial z} & 0 & \frac{\partial}{\partial y} & \frac{\partial}{\partial x} \end{bmatrix} \qquad (4)$$

Dinamik yuk ta’sirida modelga chekli elementlar usulini qo‘llash orqali hosil qilingan diskret sistemaning vaqtga bog‘liq harakat differensial tenglamalar sistemasi quyidagicha ifodalanadi:

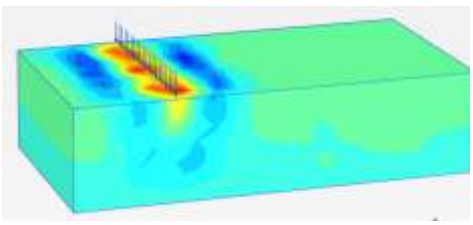
$$[\boldsymbol{M}]\{\ddot{\boldsymbol{u}}(\boldsymbol{t})\} + [\boldsymbol{C}]\{\dot{\boldsymbol{u}}(\boldsymbol{t})\} + [\boldsymbol{K}]\{\boldsymbol{u}(\boldsymbol{t})\} = \{\boldsymbol{F}(\boldsymbol{t})\} \qquad (5)$$

Bu yerda $[\boldsymbol{M}]$ – massalar matrisasi, $[\boldsymbol{C}]$ – so‘ndirish matrisasi, $[\boldsymbol{K}]$ – bikrlik matrisasi va $\{\boldsymbol{F}(\boldsymbol{t})\}$ – dinamik yuk vektori. $\{\boldsymbol{u}(\boldsymbol{t})\}$ – ko‘chish, $\{\dot{\boldsymbol{u}}(\boldsymbol{t})\}$ – tezlik va $\{\ddot{\boldsymbol{u}}(\boldsymbol{t})\}$ – tezlanishlar vaqtning uzuluksiz funksiyalari. Bu yerda nazariya chiziqli elastiklik nazariysi asoslarida tavsiflanadi. $[\boldsymbol{M}]$ –matrisasida materiallarning massasi (grunt + suv + har qanday konstruksiya) hisobga olinadi[10,11].

Dinamik yuk ta’sirida quyidagi natijalarga erishildi:

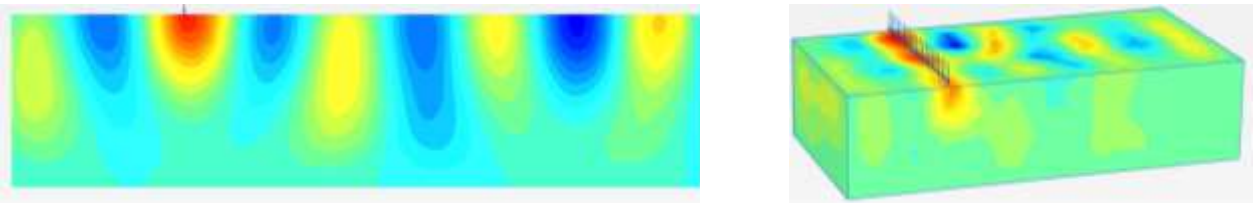


2D



3D

2-rasm. Dinamik yuk ta’siridan hosil bo‘lgan to‘lqin ko‘chishi (0,1 sek. uchun)



2D 3D

3-rasm. Dinamik yuk ta’siridan hosil bo‘lgan to‘lqin ko‘chishi (1 sek. uchun).

Dinamik tahlillar natijalariga asosan dinamik to‘lqin parametrlari (ko‘chish, tezlik va tezlanish) quyidagi jadvalda o‘z aksini topgan.

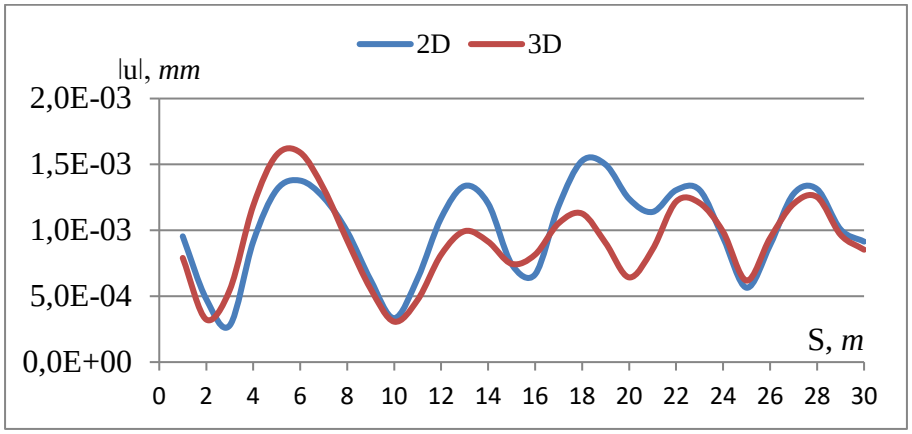
1-jadval

№	Dinamik to‘lqin ko‘chishi, *u[mm]*	To‘lqin tezligi, *v[sm/s]*	To‘lqin tezlanishi, $a[sm/s^2]$	Kuchlanish, $\sigma_z[kN/m^2]$
2D	**1,53**	**3,1**	**27,86**	**216**
3D	**1,6**	**3,3**	**28,23**	**219**
Orasidagi farq, % da	**4,5 %**	**6 %**	**2,2 %**	**1,5 %**

2D model faqat bitta tekislikdagi tebranishlarni hisobga olgani uchun amplitudalar nisbatan kichik bo‘ldi. 3D modelda esa tebranishlar uch yo‘nalishda bir vaqtning o‘zida kechganligi sababli **fazoviy rezonans** kuzatiladi va maksimal kuchlanishlar nisbatan yuqoriroq chichishi mumkin.

Shuningdek, 3D modellashtirishda tebranishlarning **fazoviy tarqalishi** va **chekka zonalarda kuchlanish to‘planishi** aniq ko‘rinadi. Bu holat ayniqsa zilzila tebranishlarida muhim ahamiyat kasb etadi.

Quyidagi grafikda esa har ikkala modellar uchun vaqtning ma’lum onida yuk qo‘yilgan joydan 1 m dan 30 m masofagacha bo‘lgan oraliq uchun to‘lqin ko‘chishlari tasvirlangan.



4-rasm. 1-sekund vaqt oni uchun dinamik yuk ta'siridan hosil bo'lgan ko'chish grafiklari.

Natijalar shuni ko'rsatdiki, dinamik yuklanishlar holatida 3D modellar o'z afzalligini yaqqol namoyon etdi. Chunki 3D modellashtirishda tebranishlar uch yo'nalishda bir vaqtda tarqalishi, energiyaning tabiiy taqsimlanishi va rezonans zonalarining aniqlanishi imkonini beradi. Shu bilan birga, 3D model real seysmik yozuvlar asosida tahlil qilganda tebranish amplitudalarining aniqroq baholanishini va grunt hamda inshoot o'zaro ta'sirining fazoviy xarakterini to'liqroq aks ettiradi.Shu bois, seysmik xavfsiz inshootlarni loyihalashda 3D modellashtirishni asosiy tahlil vositasi sifatida qo'llash eng maqbul va ilmiy jihatdan to'g'ri yondashuv ekanligi tasdiqlandi.

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