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GRUNT O‘ZANLI KANALLARDA URINMA KUCHLANISHNI ANIQLASH VA YUVILMASLIK SHARTLARINI BAHOLASH

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Annotatsiya. *Ushbu maqolada grunt o‘zanli kanallarda oqimning urinma kuchlanishini aniqlash va o‘zan tubining yuvilmaslik shartlarini baholash masalasi tadqiq etilgan. Grunt o‘zanli kanallarda oqim ta’sirida yuzaga keladigan urinma kuchlanish o‘zan tubi va yon qiyaliklarining deformatsiyasi, yuvilishi hamda kanalning gidravlik barqarorligini belgilovchi asosiy omillardan biri hisoblanadi. Maqolada oqim sarfi, o‘rtacha tezlik, suv chuqurligi, gidravlik qiyalik, gidravlik radius, gruntning granulometrik tarkibi, zichligi va zarrachalar o‘lchamining urinma kuchlanish shakllanishiga ta’siri tahlil qilindi. Amaldagi urinma kuchlanish qiymatlarini kritik urinma kuchlanish bilan taqqoslash asosida grunt o‘zanining yuvilish yoki yuvilmaslik holatini baholash mezonlari ko‘rib chiqildi. Shuningdek, oqimning gidravlik parametrlari va gruntning fizik-mexanik xususiyatlarini hisobga oluvchi yondashuv asosida yuvilmaslik shartlarini aniqlash imkoniyati baholandi. Tadqiqot natijalari grunt o‘zanli kanallarda o‘zan barqarorligini prognozlash, yuvilish xavfini kamaytirish hamda kanalning ishonchli va samarali ishlashini ta’minlash uchun qo‘llanishi mumkin. Taklif etilgan yondashuv sug‘orish va melioratsiya kanallarining gidravlik hisoblarini takomillashtirish hamda o‘zanlarni mustahkamlash zaruriyatini ilmiy asoslashga xizmat qiladi.*

Kalit so‘zlar: *grunt o‘zan, ochiq kanal, urinma kuchlanish, kritik urinma kuchlanish, yuvilmaslik sharti, o‘zan barqarorligi, oqim tezligi, suv chuqurligi, gidravlik qiyalik, gidravlik radius, granulometrik tarkib, o‘zan yuvilishi, kanal deformatsiyasi.*

УДК 627.841

ОПРЕДЕЛЕНИЕ КАСАТЕЛЬНЫХ НАПРЯЖЕНИЙ В КАНАЛАХ С ГРУНТОВЫМ РУСЛОМ И ОЦЕНКА УСЛОВИЙ НЕРАЗМЫВАЕМОСТИ

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Аннотация. *В статье исследованы вопросы определения касательных напряжений потока в каналах с грунтовым руслом и оценки условий неразмываемости дна русла. Касательные напряжения, возникающие под воздействием потока в каналах с грунтовым руслом, являются одним из основных факторов, определяющих деформацию и размыв дна и боковых откосов, а также гидравлическую устойчивость канала. Проанализировано влияние расхода воды, средней скорости течения, глубины потока, гидравлического уклона,*

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гидравлического радиуса, гранулометрического состава грунта, его плотности и размеров частиц на формирование касательных напряжений. На основе сопоставления фактических значений касательных напряжений с критическими касательными напряжениями рассмотрены критерии оценки размываемого или неразмываемого состояния грунтового русла. Кроме того, оценена возможность определения условий неразмываемости на основе подхода, учитывающего гидравлические параметры потока и физико-механические свойства грунта. Результаты исследования могут быть использованы для прогнозирования устойчивости грунтовых русел каналов, снижения риска размыва, а также обеспечения надёжной и эффективной эксплуатации каналов. Предложенный подход способствует совершенствованию гидравлических расчётов оросительных и мелиоративных каналов и научному обоснованию необходимости укрепления русел.

Ключевые слова: *грунтовое русло, открытый канал, касательное напряжение, критическое касательное напряжение, условие неразмываемости, устойчивость русла, скорость течения, глубина потока, гидравлический уклон, гидравлический радиус, гранулометрический состав, размыв русла, деформация канала.*

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DETERMINATION OF SHEAR STRESSES IN UNLINED EARTH CHANNELS AND EVALUATION OF NON-ERODIBILITY CONDITIONS

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Abstract. *This article investigates the determination of flow-induced shear stress in earthen channels and the assessment of non-scouring conditions of the channel bed. Shear stress generated by flowing water in earthen channels is one of the principal factors governing the deformation and erosion of the channel bed and side slopes, as well as the hydraulic stability of the channel. The effects of discharge, mean flow velocity, flow depth, hydraulic slope, hydraulic radius, soil particle-size distribution, soil density, and particle size on the development of shear stress are analyzed. By comparing the actual shear stress values with the critical shear stress, criteria for assessing the scouring or non-scouring condition of the earthen channel bed are examined. Furthermore, the feasibility of determining non-scouring conditions using an approach that accounts for the hydraulic parameters of the flow and the physical and mechanical properties of the soil is evaluated. The research findings can be applied to predict the stability of earthen channels, reduce the risk of bed erosion, and ensure reliable and efficient channel operation. The proposed approach contributes to improving hydraulic calculations for irrigation and land reclamation canals and provides a scientific basis for determining the need for channel bed and bank protection.*

Keywords: *earthen channel, open channel, shear stress, critical shear stress, non-scouring condition, channel stability, flow velocity, flow depth, hydraulic slope, hydraulic radius, particle-size distribution, channel bed erosion, channel deformation.*

Kirish

Grunt o‘zanli kanallarda oqimning o‘zan tubi va yon qiyaliklariga ta’siri natijasida yuzaga keladigan urinma kuchlanish o‘zan barqarorligini belgilovchi asosiy gidravlik omillardan biridir. Ushbu kuchlanishning kritik qiymatdan oshishi grunt zarrachalarining harakatlanishi, o‘zan tubining yuvilishi va kanal kesimining deformatsiyasiga olib keladi. Shu sababli urinma kuchlanishni aniq baholash kanallarning gidravlik barqarorligini ta’minlashda muhim ahamiyatga ega.

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Mavjud hisoblash usullarida urinma kuchlanish asosan oqimning gidravlik parametrlari orqali aniqlanadi, biroq gruntning granulometrik tarkibi va fizik-mexanik xususiyatlari yetarli darajada hisobga olinmasligi mumkin. Bu esa yuvilmaslik shartlarini baholashda ma’lum xatoliklarga olib keladi.

Mazkur tadqiqotning maqsadi grunt o‘zanli kanallarda urinma kuchlanishni aniqlash va yuvilmaslik shartlarini baholashning takomillashtirilgan yondashuvini asoslashdan iborat. Tadqiqotda oqim tezligi, suv chuqurligi, gidravlik qiyalik, gruntning granulometrik tarkibi va kritik urinma kuchlanish o‘rtasidagi bog‘liqlik tahlil qilinadi.

Gruntli o‘zanlarda oqimning gidravlik ta’siri, urinma kuchlanish, mahalliy yuvilish, o‘zan deformatsiyasi va oqiziqlar harakati masalalari ko‘plab mahalliy va xorijiy olimlar tomonidan o‘rganilgan. Xususan, S.T. Altunin, V.S. Borovkov, V.K. Debolskiy, I.F. Karasev, H. Einstein, R. Engelund, P. Ackers, L. Van Rijn, J. Kennedy, W.H. Graf, W.H. Yalin, P.Y. Julien, V.T. Chow, C.T. Yang va boshqa tadqiqotchilar oqim va grunt o‘rtasidagi o‘zaro ta’sir, kritik urinma kuchlanish, zarrachalar harakatining boshlanishi hamda o‘zan barqarorligi bo‘yicha ilmiy tadqiqotlar olib borgan. [1–11, 12–15].

O‘zbekiston olimlaridan Q.Sh. Latipov, A.M. Arifjanov, M.R. Bakiyev, D.R. Bazarov, S.S. Eshev va boshqa tadqiqotchilar ochiq o‘zanlarda oqim va oqiziqlar harakati, grunt o‘zanlarining yuvilishi, o‘zan deformatsiyasi va gidravlik barqarorlik masalalarini tadqiq etgan. Ushbu tadqiqotlar oqim tezligi, suv chuqurligi, gidravlik qiyalik, gruntning granulometrik tarkibi va urinma kuchlanish o‘rtasidagi bog‘liqliklarni aniqlash uchun muhim nazariy asos yaratgan.

Shunga qaramay, grunt o‘zanli kanallarda urinma kuchlanishni aniqlash va yuvilmaslik shartlarini birgalikda baholash masalasi qo‘shimcha tadqiqotlarni talab etadi. Shu sababli oqimning gidravlik parametrlari va gruntning fizik-mexanik xususiyatlarini kompleks hisobga oluvchi yondashuvni ishlab chiqish ushbu tadqiqotning asosiy yo‘nalishini tashkil etadi [12-15].

Materiallar va uslublar

Ochiq o‘zanlarda oqim ta’sirida tub va yonbag‘irlarda urinma kuchlanish hosil bo‘ladi. Agar uning qiymati gruntning ruxsat etiladigan (kritik) urinma kuchlanishidan oshsa, grunt zarrachalari siljishi, o‘zan tubining yuvilishi va deformatsiyasi boshlanadi. Shuning uchun o‘zan mustahkamligining asosiy sharti [3, 8, 11, 12, 15]:

$$\tau \le \tau_{\partial on} \ , \qquad (1)$$

bunda: τ – oqimning haqiqiy urinma kuchlanishi (siljituvchi kuchi), N/m²; $\tau_{\partial on}$ – grunt turi uchun ruxsat etiladigan urinma kuchlanish, N/m².

Urinma kuchlanish oqim tezligi, suv chuqurligi, gidravlik qiyalik, gidravlik radius va o‘zan g‘adir-budurligiga bog‘liq. τ va $\tau_{\partial on}$ ni taqqoslash grunt o‘zanlarining yuvilmaslik va gidravlik barqarorligini baholashning asosiy mezonidir.

Urinma kuchlanish yuza birligiga to‘g‘ri keladigan ishqalanish kuchi sifatida aniqlanadi:

$$\tau = \frac{F}{\omega} \ , \qquad (2)$$

bu yerda: τ – urinma kuchlanish, N/m², F – ishqalanish kuchi; ω – jonli kesim yuzasi.

Urinma kuchlanishlar taqsimotini nazariy jihatdan asoslash uchun ochiq o‘zanda joylashgan L uzunlikdagi oqim uchastkasini ko‘rib chiqamiz. Oqimning ushbu elementiga quyidagi kuchlar ta’sir ko‘rsatadi [5, 8, 12–15]:

1. Nishablik bo‘yicha og‘irlik kuchi

$$Fg = \rho g \omega L \sin\alpha \ , \qquad (3)$$

bu yerda α – nishablik burchagi.

Kichik burchaklar uchun $\sin\alpha \approx I$, bunda I – gidravlik nishablik. Buni inobatga olib (4) ifodani quyidagicha yozamiz:

$$F_g = \rho g \omega L I \ . \qquad (4)$$

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2. O‘zan qarshilik kuchi bo‘lib, bunda urinma kuchlar bilan ho‘llanish perimetri bo‘yicha qarshilik sodir bo‘ladi, ya’ni

$$F_{\tau} = \tau \chi L , \quad (5)$$

bunda τ – o‘rtacha urinma kuchlanish; χ – ho‘llanish perimetri.

Ochiq o‘zandagi suvning tekis harakatida kuchlar muvozanatda bo‘ladi, ya’ni

$$\rho g \omega L I = \tau \chi L . \quad (6)$$

(6) tenglikni qisqartirib, quyidagi tenglikka ega bo‘lamiz:

$$g \omega I = \tau \chi . \quad (7)$$

$R = \omega / \chi$ ekanligini nazarga olib, (6) tenglikdan τ siljituvchi kuchni topamiz:

$$\tau = \rho g R I \quad (8)$$

yoki

$$\tau = \gamma R I , \quad (9)$$

bunda $\gamma = \rho g$ suvning solishtirma og‘irligi.

(7) – (8) ifodalar urinma kuchlanish qiymati oqimning energetik nishabligi hamda o‘zanning geometrik xususiyatlari bilan belgilanishini ko‘rsatadi [4, 6, 11, 12, 15].

(9) formula siljitish kuchining oqim chuqurligi (gidravlik radius R orqali, I o‘zan nishabligi va ρ suv zichligiga bog‘liqligini ko‘rsatadi. Bundan agar oqim qanchalik chuqur bo‘lsa, yuvish kuchi shunchalik katta bo‘ladi; shuningdek, nishablik qanchalik tik bo‘lsa, urinma kuchlanish ham shunchalik kuchayadi.

Ochiq o‘zanlarda urinma kuchlanishlar ho‘llangan perimetr bo‘yicha notekis taqsimlanadi. Ularning maksimal qiymati, odatda, o‘zan tubida, yonbag‘irlarda esa kamayib boradi; erkin sirtda esa deyarli nolga teng.

Taqsimlanish xarakteri o‘zan kesimining shakli, oqim tezliklarining notekisligi va ikkilamchi sirkulyatsion oqimlar bilan belgilanadi. Tabiiy o‘zanlarda ikkilamchi oqimlar ta’sirida maksimal urinma kuchlanish nuqtasi ko‘pincha o‘zan markazidan siljigan holda joylashadi.

Ruxsat etiladigan sidiruvchi kuch o‘zan gruntining turiga qarab aniqlanadi va tajriba ma’lumotlariga asosan belgilanadi. O‘zan barqarorligi shartidan foydalanib, maksimal ruxsat etiladigan gidravlik radiusni aniqlash mumkin:

$$R_{\partial on} = \frac{\tau_{\partial on}}{\gamma i} . \quad (10)$$

Natijalar va muhokama

Olingan qiymat kanalning geometrik o‘lchamlarini tanlashda muhim parametr hisoblanadi. Ochiq o‘zanli kanalning umumiy mustahkamligini baholashda uning yon tomon qiyaliklarining mustahkamligini ham ta’minlash kerak bo‘ladi.

Kanal yon tomon qiyaliklaridagi urinma kuchlanishlar kanal tubidagi kuchlanishlardan farq qiladi, chunki tezliklarning ko‘ndalang kesim bo‘yicha taqsimlanishi notekisdir. Yon tomon qiyaliklaridagi urinma kuchlanishlarni baholash uchun quyidagi bog‘liqlikdan foydalaniladi:

$$\tau_{omk} = k \tau , \quad (11)$$

bunda k – urinma kuchlanishlarning taqsimlanish koeffitsiyenti (odatda 0,75 – 0,90 oralig‘ida qabul qilinadi).

Yon tomon qiyaliklarining mustahkamlik sharti quyidagicha yoziladi:

$$\tau_{omk} \le \tau_{\partial on} . \quad (11)$$

Yon nishabliklarning ta’sirini qaraymiz. Kanal gorizontal o‘zanining barqarorligi (1) yoki (2) tenglamasi bilan aniqlanadi. Biroq qirg‘oq nishabliklarida yana bir siljituvchi kuch, ya’ni zarracha og‘irligining tashkil etuvchisi ham ta’sir qiladi. Qirg‘oq nishabligida tinch holatda turgan, og‘irligi W ga teng bo‘lgan zarrachani ko‘rib chiqamiz. Bu zarrachaga quyidagi kuchlar ta’sir qiladi:

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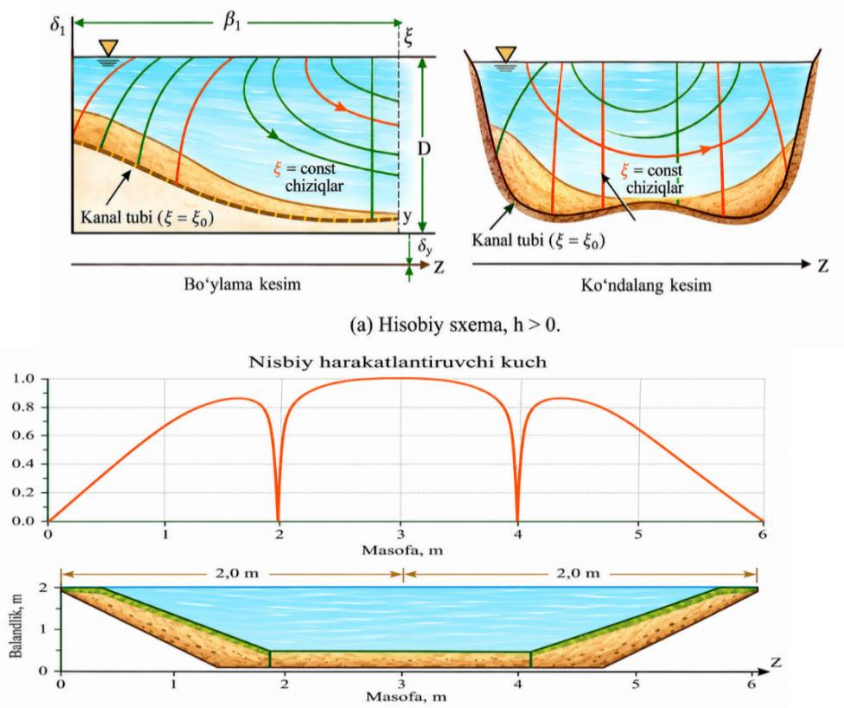
$$\tau = \gamma IR; \quad (12)$$

– qirg‘oq nishabligi bo‘ylab yo‘nalgan W ning tashkil etuvchisi: $w\sin\theta$;
– qirg‘oq nishabligiga normal bo‘lgan W ning tashkil etuvchisi: $R\tan\theta$;

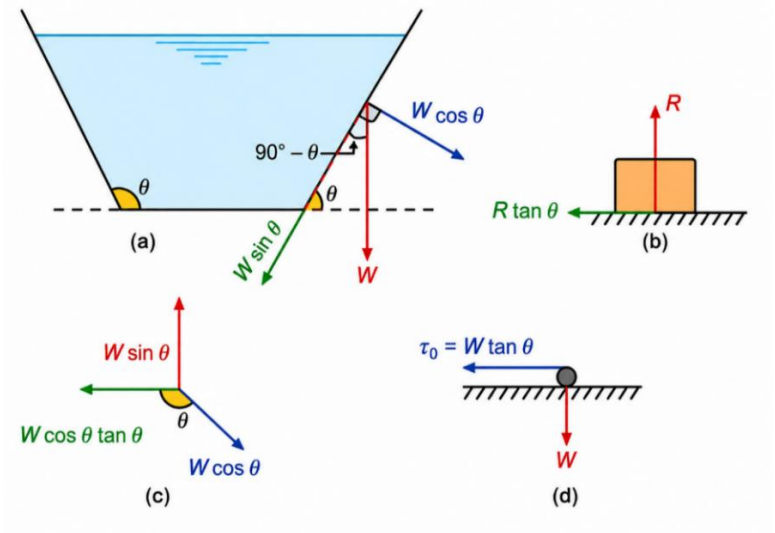
bunda: θ – qirg‘oq nishabligining gorizontalga nisbatan qiyalik burchagi; φ – tabiiy qiyalik burchagi. 1-rasmda zarrachaga ta’sir qiluvchi turli kuchlar va ularning kuch diagrammasi ko‘rsatilgan.

$$\tau_c = w\mu = w\tan\varphi, \quad (13)$$

bunda τ_c – o‘xshash zarrani gorizontal qatlam bo‘ylab siljitish uchun zarur bo‘lgan kritik urinma kuchlanish.



1-rasm. Zarrachaga ta’sir qiluvchi turli kuchlar va ularning kuch diagrammasi.



2-rasm. Kanal qiyaliklarida ta’sir etuvchi kuchlar.

Jismga ta’sir etuvchi kuchlar diagrammasini ko‘rib chiqaylik (2-rasm).

$$(\tau_0)^2 + (\omega\sin\theta)^2 = (\tau_c\cos\theta)^2 = (W\tan\phi\cos\theta)^2$$

$$(\tau_0)^2 + \left(\frac{\tau_c}{\tan\phi}\sin\theta\right)^2 = \left(\frac{\tau_c}{\tan\phi}\cos\theta\tan\phi\right)^2$$

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$$(\tau_0)^2 + \frac{\tau_c^2}{\tan^2\phi}\sin^2\theta = \tau_c^2\cos^2\theta$$

$$\tau_0^2 = \tau_c^2\left[\cos^2\theta - \frac{\sin^2\theta}{\tan^2\phi}\right]$$

$$\frac{(\tau_0)^2}{(\tau_c)^2} = \cos^2\theta - \frac{\sin^2\theta}{\tan^2\phi} = \cos^2\theta\left[1 - \frac{\tan^2\theta}{\tan^2\phi}\right] \quad (14)$$

$$\left(\frac{\tau_0}{\tau_c}\right) = \left[\cos^2\theta + \sin^2\theta - \sin^2\theta - \frac{\sin^2\theta}{\tan^2\phi}\right]$$

$$= \left[1 - \sin^2\theta - \frac{\sin^2\theta}{\tan^2\phi}\right]$$

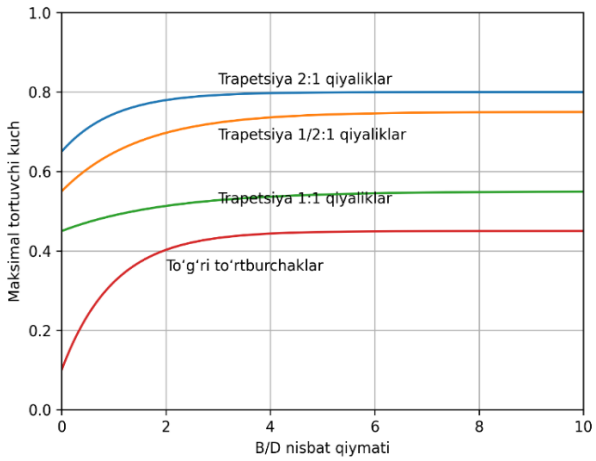
$$= \left[1 - \sin^2\theta\left(1 + \frac{1}{\tan^2\phi}\right)\right]$$

$$= \left[1 - \sin^2\theta\left(\frac{1+\tan^2\phi}{\tan^2\phi}\right)\right]$$

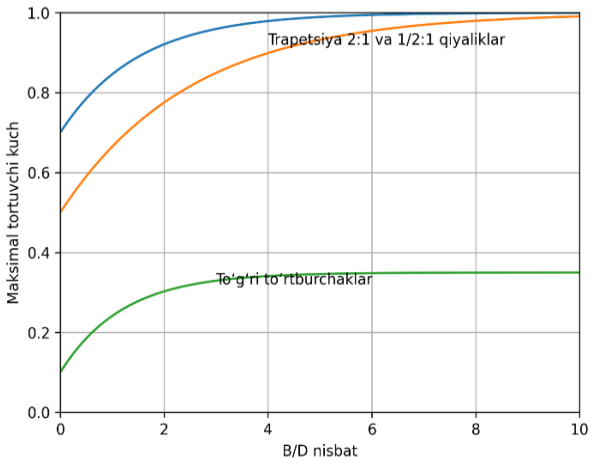
$$= \left[1 - \sin^2\theta\frac{\sec^2\phi}{\tan^2\phi}\right]$$

$$= 1 - \frac{\sin^2\theta}{\sin^2\phi}$$

$$\left(\frac{\tau_0}{\tau_c}\right) = 1 - \frac{\sin^2\theta}{\sin^2\phi}\ . \quad (15)$$



3-rasm. Yon tomon qiyalik uchun.



4-rasm. Tub uchun.

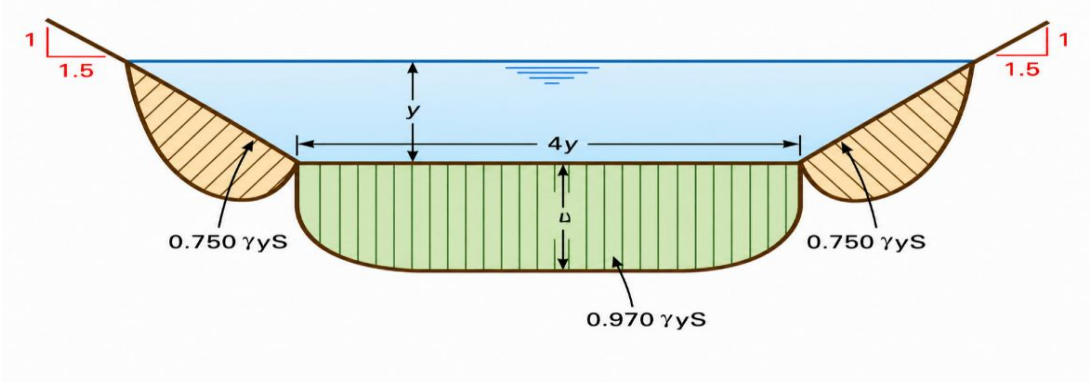
Ushbu tenglama $\tau_c > \tau_0$ ekanligini ko‘rsatadi. Bu esa zarrachani nishablik bo‘ylab siljitish uchun zarur bo‘lgan ishqalanish kuchi yoki urinma kuchlanish donni gorizontal qatlam bo‘ylab siljitish uchun zarur bo‘lgan ishqalanish kuchidan kichikroq ekanligini anglatadi.

Gorizontal o‘zanda oqayotgan suv hosil qiladigan urinma kuchlanish yoki siljitish kuchining o‘rtacha qiymati $\tau_0 = \gamma IR$ formulasi bilan aniqlanadi, yon qiyaliklarda (devorlarda) esa uning qiymati $\tau_c = 0,75\tau_0 = 0,75\gamma IR$ teng ekanligi aniqlangan (3-, 4-rasmlar).

Urinma kuchlanish yoki siljitish kuchining taqsimlanishi 5-rasmda ko‘rsatilgan.

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5-rasmda ko‘rsatilganidek, birlik siljitish kuchi yoki urinma kuchlanishning taqsimlanishi o‘zan tubi uchun to‘g‘ri to‘rtburchak, qiyaliklar uchun esa parabolik shaklda bo‘ladi. Birlik siljitish kuchining (urinma kuchlanishning) qiymati kanalning egriligiga ham bog‘liqdir.



5-rasm. Siljituvchi kuchning taqsimlanishi.

1-jadval. Egri va to‘g‘ri kanallar uchun ruxsat etilgan siljitish kuchi quyidagicha berilgan:

Egrilik darajasi	**Nisbiy kritik tortilish kuchi (%)**
To‘g‘ri kanal	100%
Biroz egri kanallar	90%
O‘rtacha egri kanallar	75%
Keskin egri kanallar	60%

Yirik allyuviydagi kanal o‘zani Shildsning oqiziqlarni harakatga keltirish usuli bo‘yicha loyihalanadi.

Bu usul quyida tushuntirilgan:

Unga ko‘ra, oqim tubidagi zarrachaning harakati quyidagi o‘zgaruvchilarga bog‘liq:

τ_0 - asosning urinma kuchlanishi yoki birlik siljitish kuchi;

ρ_s - zarrachaning zichligi;

ρ_f - Suyuqlik zichligi;

d - Zarracha diametri;

μ - Suyuqlikning dinamik qovushqoqligi.

Bu o‘zgaruvchilarning barchasi ichida urinma kuchlanish (τ_0) eng muhim omil hisoblanadi, chunki u cho‘kindilarni joyidan qo‘zg‘atuvchi oqim quvvatini o‘lchaydi. Bu omil oqim tezligiga (υ) bog‘liq.

Oqim tubidagi zarracha harakatini o‘rganish uchun o‘lchamsiz tahlil usuli qo‘llaniladi.

Yuqorida sanab o‘tilgan barcha oltita o‘zgaruvchini guruhlab, uchta o‘lchamsiz son hosil qilish mumkin. Bu sonlar quyidagilar:

$$\frac{\tau_0}{P_f g d'}\frac{P_s}{P_f'}\frac{d\sqrt{P_f\tau_0}}{\mu}. \qquad (16)$$

Garchi tezlik atamasi shart bo‘lmasa-da, tezlik o‘lchamiga ega parametrning mavjudligi qulaydir. Shu sababli, biz sirpanish ishqalanish tezligi deb ataluvchi yangi atamani kiritamiz va uni υ' bilan belgilaymiz.

$$\upsilon' = \sqrt{\frac{\tau_0}{P_f}} \qquad (17)$$

yoki

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$$\tau_0 = (\upsilon')^2 P_f \ . \tag{18}$$

Birinchi o‘lchamsiz son, $\frac{\tau_0}{P_f g d}$ ga teng bo‘ladi.

$$\frac{\upsilon'^2 P_f}{P_f g d} = \frac{\upsilon'^2}{g d} \tag{19}$$

Uchta o‘lchamsiz son quyidagilar:

$$\frac{\upsilon'^2}{g d}, \tag{20}$$

$$\frac{P_s}{P_f}, \tag{21}$$

$$\frac{\sqrt{P_f \tau_0}}{\mu} = \frac{\sqrt[d]{P_f (\upsilon')^2 P_f}}{\mu} = \frac{d\upsilon' P_f}{\mu} = \frac{d\upsilon'}{\frac{\mu}{P_f}} = \frac{d\upsilon'}{\upsilon} \ . \tag{22}$$

(20) va (21) o‘lchamsiz sonlarni birlashtirib, $\upsilon_2' / g d(S_s - 1)$ ko‘rinishidagi yana bir o‘lchamsiz sonni hosil qilamiz.

Buni quyidagicha yanada soddalashtirish mumkin:

$\omega = 1$

$\tau_0 = \omega RS$

$$\frac{\upsilon'^2}{g d(S_s - 1)} = \frac{\tau_0}{\frac{P_f}{g d(S_s - 1)}} = \frac{\tau_0}{P_f g d(S_s - 1)} = \frac{\tau_0}{\omega d(S_s - 1)}, \tag{23}$$

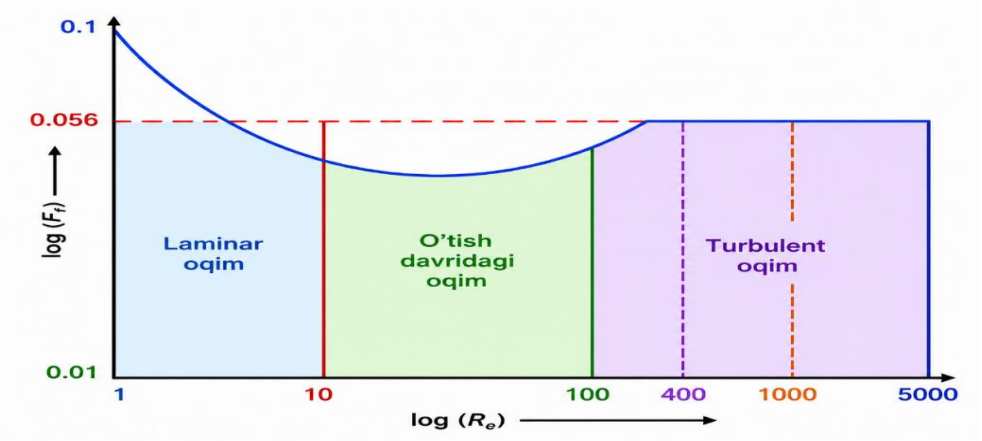
bu yerda $P_f g = \gamma$ – suvning solishtirma og‘irligi; S_s – zarraning solishtirma og‘irligi.

Bu son Shildsning parametri deb ataladi va F_c bilan belgilanadi.

$d\upsilon' / \upsilon$ ga teng uchinchi o‘lchamsiz son Reynolds soni (Re) deb nomlanadi, bunda υ kinematik qovushqoqlikdir.

Endi zarrachaning harakati shu ikki songa, ya’ni F_c va Re ga bog‘liqligini aytishimiz mumkin.

F_c va Re orasidagi bog‘liqlik grafiklari 6-rasmda ko‘rsatilganidek chizilishi mumkin. Hosil bo‘lgan egri chiziq o‘zan tubi zarrachalarining harakatlanishini oldini olish yoki uni minimal darajada saqlash talab etiladigan kanallarni loyihalash uchun asos bo‘lib xizmat qiladi. Reynolds soni 400 va undan yuqori bo‘lganda Re qiymati o‘zgarmas bo‘lib qoladi, natijada bu jihatni qo‘llash ancha soddalashadi va 0,056 ga teng bo‘ladi. Zarracha o‘lchami diametri 6 mm dan oshganda Zarra Reynolds soni 400 dan yuqori bo‘lishi kuzatilgan.



6-rasm. F_s va R_C **orasidagi bog‘liqlik.**

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Shu sababli, yirik donali allyuviydagi (6 mm dan katta) o‘zan uchun

$$\frac{\tau_0}{wd(S_s-1)}=0,056, \tag{3.24}$$

Suv uchun

$$\gamma=1;$$
$$\tau_0=\gamma RI;$$

$$\frac{\gamma RI}{\gamma d(S_s-1)}=0,056, \tag{3.25}$$

$$\frac{RI}{d(2,65-1)}=0,056. \tag{3.26}$$

Yechishda, $d=11RS$.

Ushbu tenglama R va I ko‘rsatkichlari ma’lum bo‘lgan kanalda tinch holatda qoladigan zarrachaning eng katta o‘lchamini ifodalaydi. Agar d qiymati bundan kichik bo‘lsa, zarracha harakatga keladi.

Vaqt o‘tishi bilan yirik toshlar bilan qoplangan sirt ustidan mayda zarrachalar yuvilib ketganligi sababli, amalda olinadigan o‘lcham $d=11RI$ tenglamasi bo‘yicha hisoblangan qiymatdan biroz kattaroq bo‘lishi kerak.

Xulosa

1. Ochiq yer o‘zanli kanallarda oqiziqlar harakatining boshlanishi suv oqimining gidravlik xususiyatlari va zarrachalarning fizik parametrlariga bevosita bog‘liq. Oqimning urinma kuchlanishi ma’lum kritik qiymatga yetganda, zarrachalar harakatga keladi va shu orqali kanal tubidagi deformatsiya jarayonlari boshlanadi.

2. Mazkur jarayonni to‘g‘ri baholash va hisoblash kanallarni loyihalash, ulardan samarali foydalanish hamda tub yuvilish yoki cho‘kish kabi noxush holatlarning oldini olishda muhim ahamiyatga ega. Nazariy va amaliy tadqiqotlar shuni ko‘rsatadiki, oqiziqlar harakatini aniqlashda ilmiy asoslangan usullardan foydalanish gidrotexnik inshootlarning ishonchliligi va barqarorligini ta’minlaydi.

3. Shu sababli, ochiq kanallarda oqim va oqiziqlar o‘rtasidagi o‘zaro ta’sirni chuqur o‘rganish va hisobga olish suv xo‘jaligi tizimlarining samaradorligini oshirishda muhim omil hisoblanadi.

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