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TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
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Articles are published in Uzbek, Russian, and English, ensuring a wide-reaching audience and fostering cross-cultural academic exchange. As a beacon of academic excellence, the "Journal of Transport" continues to serve as a vital conduit for knowledge dissemination, collaboration, and innovation in the transport sector and related fields.

Modeling of fluid leakage processes from channels

A.J. Obidjonov[1][a], A. Ibadullaev[1][b], A.R. Babaev[1][c], U.R. Chorshanbiev[1][d]
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Abstract: Liquid leakage through channels is one of the urgent problems of hydraulics and hydraulic engineering, modeling this process is important for determining the liquid flow, optimizing the coating of the channel walls, reducing environmental and economic losses. This review analyzes studies based on various approaches and methods. Modern studies suggest analyzing these factors through mathematical and numerical modeling. In particular, creating equations that accurately reflect filtration processes and solving them using numerical methods opens up new opportunities in this area. This article discusses the main aspects of modeling the processes of liquid outflow from channels.

Keywords: Channel, hydraulics, hydraulic engineering, Darcy, liquid seepage, filtration, filtration rate in soils

Kanallardan suyuqlikni sizib chiqish jarayonlarini modellashtirish

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[1]Toshkent davlat transport universiteti, Toshkent, O‘zbekiston

Annotatsiya: Suyuqlikning kanal devorlar orqali sizib chiqishi gidravlik va gidrotexnikaning dolzarb muammolaridan biri bo‘lib, bu jarayonni model qilish suyuqlikning harakatini aniqlash, kanal devorlarining qoplamalarini optimallashtirish, hamda ekologik va iqtisodiy yo‘qotishlarni kamaytirish uchun muhim ahamiyatga ega. Ushbu sharhda turli yondashuvlar va usullar asosida olib borilgan tadqiqotlar tahlil qilindi. Zamonaviy tadqiqotlar ushbu omillarni matematik va raqamli modellash orqali tahlil qilishni taklif etmoqda. Ayniqsa, filtratsion jarayonlarni aniq ifodalovchi tenglamalarni tuzish va ularni sonli usullar yordamida yechish bu sohada yangi imkoniyatlarni ochmoqda. Mazkur maqola kanal devorlaridan suyuqlikning sizib chiqish jarayonlarini modellashtirishning asosiy jihatlarini ko‘rib chiqadi.

Kalit so‘zlar: Kanal, gidravlika, gidrotexnika, Darsi, suyuqlikni sizishi, filtratsiya, filtratsiya tezligi

1. Kirish

Jahonda aholi soninig o‘sib borishi, sanoatning barcha sohalarini jadal suratlarda rivojlanishi, iqlim o‘zgarishi kabi omillar suvga bo‘lgan talabni keskin ortishiga va ayni paytda mavjud suv resurslaridan oqilona foydalanish masalalarini o‘rtaga qo‘yadi. Qishloq xo‘jaligida suv resurslaridan oqilona foydalanish va yo‘qotishlarni kamaytirish bugungi kunda dunyo hamjamiyati va mamlakatimizda muhim vazifalar qilib belgilangan.

Bugungi kunda mamlakatimizda suv xo‘jaligida yuzaga kelishi mumkin bo‘lgan suv tanqisligining oldini olish, suvdan oqilona foydalanish maqsadida turli xil qonunlar, farmonlar va chora tadbirlar ishlab chiqilmoqda [1, 2]. Masalan, O‘zbekiston Respublikasining “Suv va suvdan foydalanish to‘g‘risida”gi qonuni, quyi bo‘g‘inda suv resurslarini boshqarish tizimini takomillashtirish hamda suv resurslaridan foydalanish samaradorligini oshirish chora-tadbirlari prezident qarori, “O‘zbekiston-2030” strategiyasi prezidenti farmonida suv xo‘jaligiga katta e’tibor berilgan [1, 2].

“O‘zbekiston-2030” strategiyasida 18,7 ming km yoki 66 % tuproq o‘zanli bo‘lgan magistral va xo‘jaliklararo kanallarning beton qoplamali ulushini 13,1 ming kmga yoki 46 % ga yetkazish ko‘zda tutilgan. Suvning behuda yo‘qolishini oldini olish maqsadida turli xil usullar mavjud: beton, temir-beton, geomembrana, tuproq zichlash, tosh yotqizish, polimer plyonkalar va boshqalar [2, 3].

Dunyo tajribasida an’anaviy usllarni o‘rniga inavatsiyon usulardan foydalanish keng ko‘lamda rivojlanib bormoqda chunki ular kanallarining samaradorligini 0,97-0,98 gacha oshirishni ta’minlaydi. Zamonaviy innovatsiyon materiallarni fizik mexanik xossalaridan kelib chiqib kanallarda qoplama sifadida foydalanishda suvning gidravlik parametrlari natijasida vujudga keladigan normal va urinma kuchlanishlarni aniqlash metodlarini yanada chuquroq o‘rganish zarurati dolzarb masalalar hisoblanadi [4, 5, 6].

Kanallardan suyuqlikning sizib chiqishi muhandislik gidravlikasi va gidrotexnik inshootlar sohasida muhim muammolardan biri hisoblanadi [6, 7]. Ushbu jarayon, bir tomondan, suv resurslarining yo‘qotilishiga, boshqa tomondan esa, kanal devorlarining buzilishiga va tuproqning sho‘rlanishiga olib keladi. Bu salbiy oqibatlar nafaqat iqtisodiy yo‘qotishlar, balki ekologik muvozanatga ham jiddiy zarar yetkazadi. Shu sababli, sizib chiqish jarayonlarini to‘g‘ri modellash va nazorat qilish gidrotexnik inshootlarning samaradorligini oshirishda dolzarb vazifa hisoblanadi[2, 3].

Kanallar devorlarida polimer qoplamalardan foydalanish so‘nggi yillarda samarali usul sifatida keng e’tirof etilmoqda. Ushbu qoplamalar gidravlik yo‘qotishlarni

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[c] https://orcid.org/0000-0001-5045-8288
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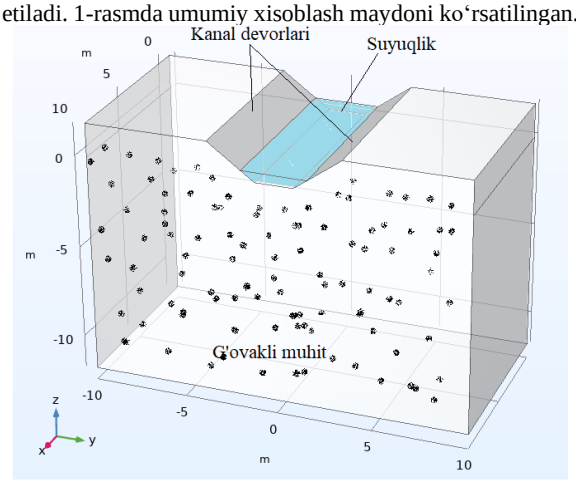
kamaytirish va suyuqlikning sizib chiqishiga qarshi chidamliligini oshirish orqali iqtisodiy va ekologik foyda keltiradi. Shu bilan birga, filtratsiya jarayonlarini sonli simulyatsiya qilish va laboratoriya sharoitida eksperimental tahlil qilish usullari bu muammoni o‘rganishda yangi yondashuvlarni taklif qilmoqda.

2. Tadqiqot metodikasi

Suyuqlikning kanal devorlari orqali sizib chiqishi turli omillarga bog‘liq bo‘lib, bular orasida kanal devorlarining materiali, geometriyasi, gidravlik parametrlar va tashqi sharoitlar muhim ahamiyatga ega.

Tadqiqotda filtratsiya jarayonlarini matematik modellashtirish, polimer qoplamalarning samaradorligini baholash va raqamli simulyatsiya natijalari o‘rtasidagi bog‘liqlik tahlil qilinadi. Shu orqali sizib chiqishni kamaytirish uchun yangi texnologik yondashuvlar taklif etiladi. 1-rasmda umumiy xisoblash maydoni ko‘rsatilingan.



1-rasm. Hisoblash maydoni

Birinchi bo‘lib oddiy turpoqdan suvni sizib chiqishishini o‘rganamiz (1-rasm). Kanaldagi filtratsiya masalasini o‘rganish uchun Darsi qonunidan foydalanamiz.

Darsi qonuni - bu g‘ovak muhit orqali suyuqlikning harakatini tavsiflovchi fundamental qonun bo‘lib, u 1856-yilda fransuz muhandisi Anri Darsi tomonidan kashf etilgan [8, 9]. Ushbu qonun g‘ovak materiallardan suyuqlik oqimi tezligini (yoki filtratsiya tezligini) aniqlash uchun ishlatiladi va gidrologiya, gidrogeologiya, neft qazib olish va boshqa ko‘plab sohalarda keng qo‘llaniladi.

Darsi qonunining matematik ifodasi. Darsi qonuni suyuqlik oqimining tezligi va gidravlik gradienti o‘rtasidagi bog‘liqlikni quyidagicha ifodalaydi [8, 9]:

$$\boldsymbol{u} = -\frac{\kappa}{\mu}(\nabla p - \rho g) \qquad (1)$$

Bu yerda:

u - filtratsion tezlik (m/s yoki boshqa birliklarda), ya’ni birlik yuzadan oqib o‘tuvchi suyuqlik tezligi;

k – g‘ovak muhitning o‘tkazuvchanlik koeffitsienti (m/s);

μ - suyuqlikning dinamik qovushqoqligi.

p - bosim gradienti,

ρ - suyuqlikning zichligi,

g - erkin tushish tezlanishi.

Darsi qonunining asosiy xususiyati shundaki, u suyuqlikning laminar (tartibli) harakatiga tegishli va Reynolds soni kichik bo‘lgan holatlarda qo‘llanadi.

3. Tadqiqot natijalari

Kanal gidravlik parametrlarini aniqlash uchun mavjud kanalda dala tadqiqotlar olib borildi. Tadqiqot davomida asosiy kattaliklar o‘rganildi.

Geometriya. Kanalning balandligi: H_{kanal}=2 m, Suv chuqurligi: H_{suv}=0.5 m, Kanal ostki kengligi: B_{ostki}=2 m, Suvning ustki kengligi: B_{ustki}=3.4 m. Tuproq devorlarini va kanal tubini ham geometrik soha sifatida belgilandi, chunki filtratsiya tuproq orqali sodir bo‘ladi.

Material xossalari. Tuproqning filtratsiya xossalarini hisobga olish uchun kerakli parametrlarni kiritildi: O‘tkazuvchanlik (Permeability): k (masalan, qumoq tuproq uchun $k=10^{-5}$ m^2, gil tuproq uchun $k=10^{-6}$ m^2). Suvning zichligi: ρ=1000 kg/m^3, Suvning dinamik qovushqoqligi: μ=0.001 Pa/s.

Chegaraviy shartlar. Filtratsiyani modellashtirish uchun quyidagi chegaraviy shartlar qo‘yildi:

a) Kanal ichidagi suv yuzasi: Suvning bosimi erkin yuzadan pastga tuproq orqali o‘tadi. Suv yuzasida bosim sharti sifatida: $p=\rho g h$, bu yerda: h - suvning chuqurligi (h=0.5 m), Bu qiymat suv yuzasi bilan aloqa qiluvchi tuproq chegaralariga bosim sharti sifatida o‘rnatildi.

b) Tuproqning tashqi chegaralari: Tuproqning tashqi chegaralari uchun suv oqishi yo‘qligi shartini qo‘yildi: un=0, bu yerda n - tashqi chegara uchun normal vektor.

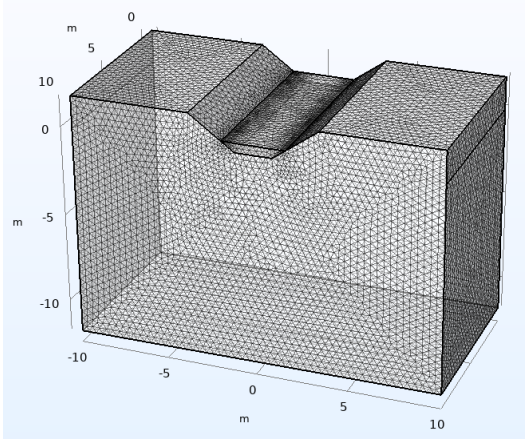
c) Kanalning tub qismi: Tuproqning filtratsiya qismi kanalning tubida ham ishlaydi. Bosim sharti kanal tubidagi suv bosimi balandligi asosida belgilandi: $p=\rho g h_{\text{tub}}$

d) Tuproq ichidagi filtratsiya: Filtratsiya tuproqning g‘ovakli muhitida sodir bo‘ladi. Bu hodisa (Darsi Law) orqali tavsiflanadi:

$$\boldsymbol{u} = -\frac{\kappa}{\mu}(\nabla p) \qquad (2)$$

bu yerda: ∇p - bosim gradienti, u - tuproq ichidagi filtratsiya tezligi.

Boshlang‘ich shartlar. Filtratsiya masalasi uchun boshlang‘ich shart sifatida tuproq ichida boshlang‘ich bosimni nol sifatida belgilash mumkin: p=0 tuproqning hamma joyida.

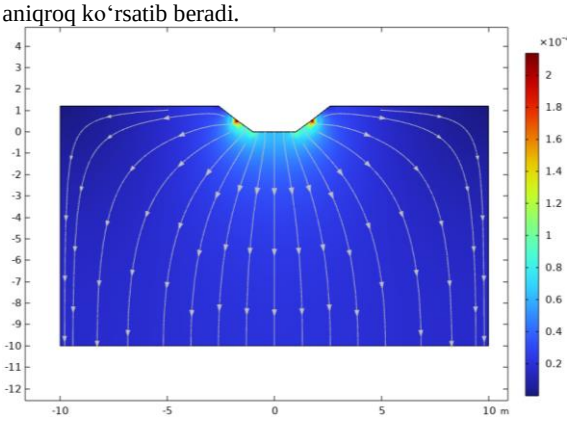


2-rasm. Hisoblash to‘ri 716 425 ta tugun

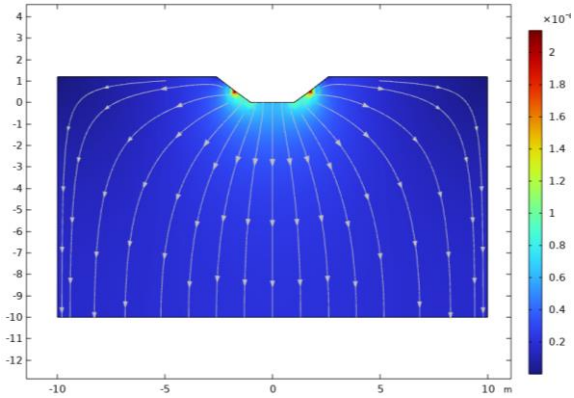
Hisoblash to‘ri. 2-rasmda hisoblash to‘ri tasvirlangan bo‘lib, u modellashtirish jarayonida qo‘llaniladigan asosiy elementlardan biridir. Hisoblash to‘ri sonli simulyatsiyalarda geometrik modelni mayda elementlarga bo‘lish orqali fizikaviy jarayonlarni aniqroq va batafsil tahlil qilish imkonini beradi [8, 9]. Ushbu to‘rning tuzilishi va sifat darajasi hisoblash natijalarining aniqligi va ishonchliligiga bevosita ta’sir ko‘rsatadi. Shu sababli, hisoblash to‘rini loyihalashda uning tuzilishi, o‘lchami va shakllari ehtiyotkorlik bilan tanlanadi, chunki noto‘g‘ri qurilgan to‘r

hisoblash xatoliklariga yoki ortiqcha vaqt sarflanishiga olib kelishi mumkin.

Kanal oddiy turpoq bo‘lgan xolda olingan natijalar tahlili. 3a,b-rasmda qumoq tuproq va gil tuproq orqali suvning sizib chiqish tezligining o‘zgarishi izoliniyalari tasvirlangan. Ushbu rasmda suvning filtratsiya jarayoni har xil tuproq turlari uchun qanday farqlanishi vizual ravishda ko‘rsatilgan. Qumoq tuproqning yuqori o‘tkazuvchanligi tufayli suvning sizib chiqish tezligi yuqori bo‘lib, bu tuproqning nisbatan katta g‘ovakligi va kamroq zichligi bilan bog‘liq. Aksincha, gil tuproq juda past o‘tkazuvchanlikka ega bo‘lib, suvning sizib chiqish tezligi sezilarli darajada cheklangan. Rasmda izoliniyalar har bir tuproq turidagi suv oqimining yo‘nalishi va intensivligini aniqroq ko‘rsatib beradi.



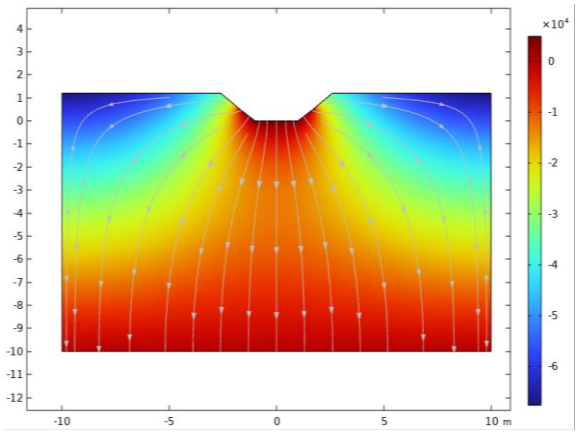
a) Qumoq tuproq



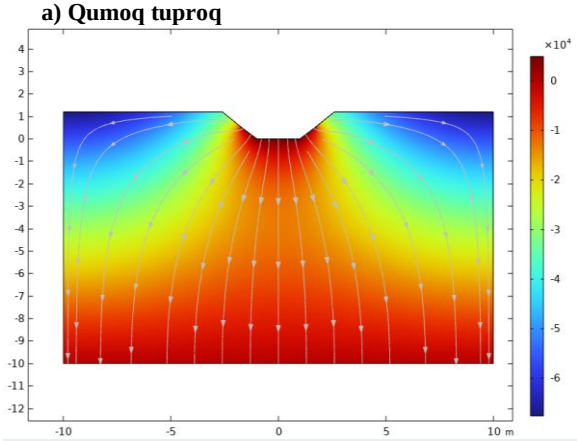
b) Gil tuproq

3-rasm. Qumoq tuproq va gil tuproq orqali suvning sizib chiqish tezligi

Ushbu natijalar suvning filtratsiya jarayoniga tuproqning tuzilishi va fizik xususiyatlari qanday ta’sir ko‘rsatishini tahlil qilish imkonini beradi. 4-rasmda qumoq tuproq va gil tuproq orqali suvning sizib chiqish bosimining o‘zgarishi izoliniyalari tasvirlangan.



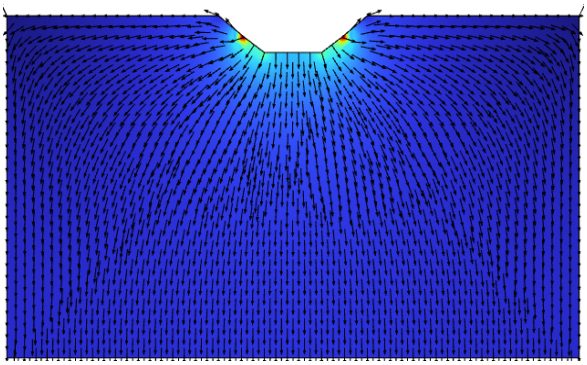
a) Qumoq tuproq



b) Gil tuproq

4-rasm. Qumoq tuproq va gil tuproq orqali suvning sizib chiqish bosimining o‘zgarishi

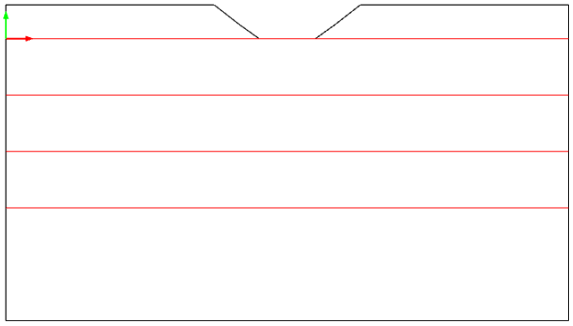
5-rasmda suyuqlikning harakati davomida tezlik vektorlarining yo‘nalishlari tasvirlangan. Ushbu tasvirda tezlik vektorlarining kattaligi va yo‘nalishlari harakat jarayonining turli sohalarida qanday o‘zgarishini vizualizatsiya qilish mumkin. Tezlik vektorlarining yo‘nalishi harakatning asosiy yo‘nalishini ko‘rsatadi, vektor uzunligi esa harakat tezligining kattaligiga mos keladi.



5-rasm. Suyuqlikning harakati davomida tezlik vektorlarining yo‘nalishlari

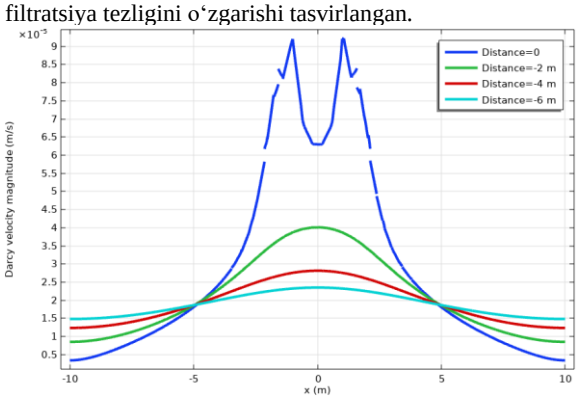
5-rasmda oqimning turbulent yoki laminar harakatiga xos xususiyatlar, oqimning turli chegaraviy shartlar yoki to‘siqlar ta’sirida qanday burilishi yoki yo‘nalishi o‘zgarishi aniq ko‘rsatilgan. Bu ma’lumot suyuqlikning kinetik xususiyatlarini, jumladan, harakat yo‘nalishini tahlil qilish va oqimni boshqarish uchun muhim ahamiyatga ega. Rasm yordamida tezlik maydonining muhim hududlari, masalan, oqimning tezlashish yoki sekinlashish zonalari aniqlanadi.

Turli xil turpoqlarda filtratsiya tezligini kesimlarda farqini bilish uchun 6-rasmda gorizontal 4 ta kesmani ajratib olingan. Bu kesmalarni birinchisi kanalning tubidan boshlab xar 2 metr chuqurlikda olingan.

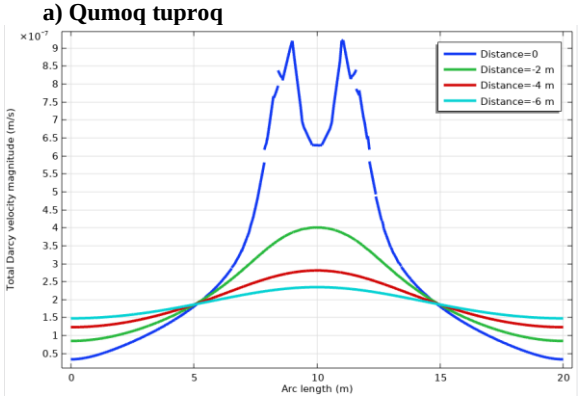


6-rasm. Ajratib olingan kesmalar

7-rasmda yuqoridagi kesmalardagi turlixil tuproqlarda filtratsiya tezligini o‘zgarishi tasvirlangan.



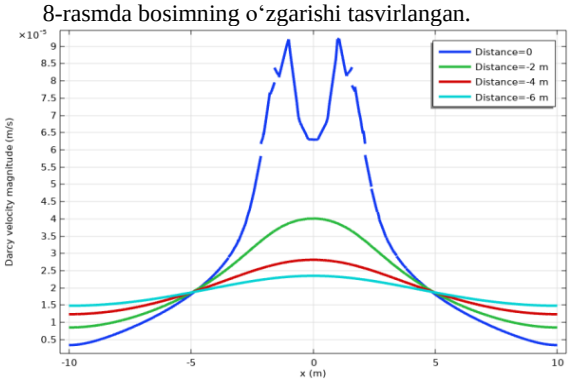
a) Qumoq tuproq



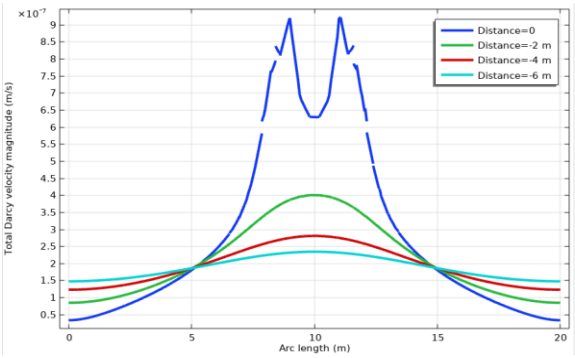
b) Gil tuproq

7-rasm. Qumoq tuproq va gil tuproq orqali suvning sizib chiqish tezligi

8-rasmda bosimning o‘zgarishi tasvirlangan.



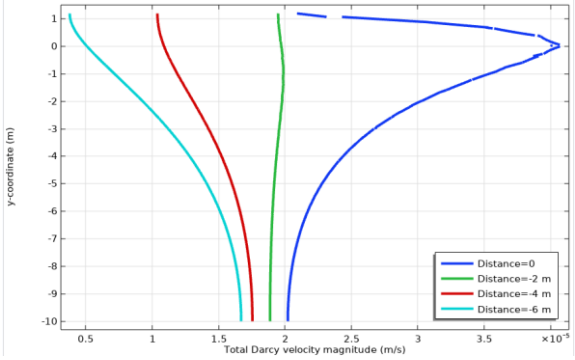
a) Qumoq tuproq



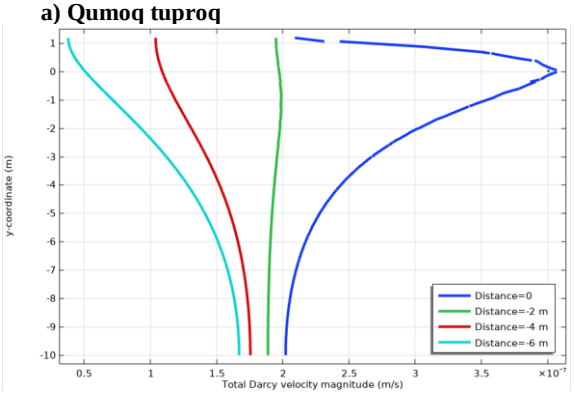
b) Gil tuproq

8-rasm. Bosimning turli kesimlarda o‘zgarishi

9-rasmda yuqoridagi 4 ta vertikal kesmalardagi turlixil tuproqlarda filtratsiya tezligini o‘zgarishi tasvirlangan.



a) Qumoq tuproq



b) Gil tuproq

9-rasm. 4ta vertikal kesmalardagi turlixil tuproqlarda filtratsiya tezligini o‘zgarishi

Yuqoridagi rasmlardan ko‘rinib turibdiki filtratsiya tezligi muxitning o‘tkazuvchanligiga bog‘liq o‘zgarar ekan.

4. Xulosa

O‘lchov natijalarida kanal sizib chiqish jarayonlari modellashtirilgan. Tadqiqotda filtratsiya jarayonlarini matematik modellashtirish, qoplamalarning samaradorligini baholash va raqamli simulyatsiya natijalari o‘rtasidagi bog‘liqlik tahlil qilindi. Shu bilan birga, filtratsiya jarayonlarini sonli simulyatsiya qilish va laboratoriya sharoitida eksperimental tahlil qilish usullari bu muammoni o‘rganishda yangi yondashuvlarni taklif qilindi.

Filtratsiyani modellashtirish uchun quyidagi chegaraviy shartlar aniqlandi. Suyuqlik harakatining tezlik vektorlarini tahlil qilish oqimning yo‘nalishi va intensivligini aniqlashga yordam berdi. Bu oqimning turli hududlarida tezlashish va

sekinlashish zonalarini ko‘rsatib, suyuqlikning dinamikasini chuqurroq tushunish imkonini berdi.

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