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Approximation of the general model of bridge supports to finite elements taking into account the specified loads. Analysis of the capabilities provided by the "Lira-Sapr" software complex to solve the tasks set

F.E. Abdukadirov[1][a], T.M. Khasanov[1][b]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This paper considers the finite element method for approximating the general model of bridge supports taking into account various loads, such as static and dynamic effects, as well as temperature deformations. To solve this problem, the modern software package "Lira-SAPR" is used, which provides extensive capabilities for modeling and analyzing structures taking into account various physical effects. The software allows you to create accurate models of bridge supports, which take into account not only the mechanical properties of materials, but also geometric features, such as the shape and size of elements.Features of the application of "Lira-SAPR" consist in the ability to fine-tune the load parameters and take into account the influence of external effects on the structure, including seismic, wind and operational loads. The package also supports various types of tasks, including static and dynamic analysis, as well as checking the strength and stability of structural elements.The use of finite elements allows you to break down complex geometry into simple elements, which significantly simplifies the calculation and optimization of the structure. As a result, the use of Lira-SAPR for modeling bridge supports ensures high accuracy of analysis, increasing the safety and durability of bridge structures.

Keywords: foundation, mathematical model, Lira-sapr, finite elements, spatial-rod, spatial-block, structural optimization, strength, stability, static analysis, dynamic analysis

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Belgilangan yuklarni hisobga olgan holda ko'prik tayanchlarning umumiy modelining chekli elementlarga yaqinlashtirish. Qo'yilgan vazifalarni hal qilish uchun "Lira-Sapr" dasturiy ta'minot majmuasi tomonidan taqdim etilgan imkoniyatlarni tahlil qilish

Abduqadirov F.E.[1][a], Xasanov T.M.[1][b]
[1]Tashkent davlat transport universiteti, Toshkent, O'zbekiston

Annotatsiya: Ushbu maqola statik va dinamik ta'sirlar, shuningdek, harorat deformatsiyalari kabi turli xil yuklarni hisobga olgan holda ko'prik tayanchlarining umumiy modelini yaqinlashtirish uchun chekli elementlar usulini o'rganadi. Ushbu muammoni hal qilish uchun biz turli xil jismoniy ta'sirlarni hisobga olgan holda tuzilmalarni modellashtirish va tahlil qilish uchun keng imkoniyatlarni taqdim etadigan "Lira-SAPR" zamonaviy dasturiy paketidan foydalanamiz. Dasturiy ta'minot nafaqat materiallarning mexanik xususiyatlarini, balki elementlarning shakli va hajmi kabi geometrik xususiyatlarni ham hisobga olgan holda ko'prik tayanchlarining aniq modellarini yaratishga imkon beradi.Lira-SAPRni qo'llashning o'ziga xos xususiyatlari yuk parametrlarini aniq sozlash va tashqi omillarning strukturaga ta'sirini, shu jumladan seysmik, shamol va operatsion yuklarni hisobga olish qobiliyatini o'z ichiga oladi. Paket shuningdek, statik va dinamik tahlilni o'z ichiga olgan har xil turdagi vazifalarni, shuningdek, strukturaviy elementlarning mustahkamligi va barqarorligini tekshirishni qo'llab-quvvatlaydi.Cheklangan elementlardan foydalanish murakkab geometriyani oddiy elementlarga bo'lish imkonini beradi, bu esa dizaynni hisoblash va optimallashtirishni sezilarli darajada osonlashtiradi. Natijada, ko'prik tayanchlarini modellashtirish uchun Lira-SAPR dan foydalanish tahlilning yuqori aniqligini ta'minlaydi, ko'prik konstruktsiyalarining xavfsizligi va mustahkamligini oshiradi.

Kalit so'zlar: tayanch, matematik model, Lira-sapr, chekli elementlar, fazoviy-sterjen,fazoviy-blok, konstruksiyani optimallashtish, mustahkamlik, barqarorlik, statik tahlil, dinamik tahlil

1. Kirish

Transport oqimi va tashqi yuklarning ta'sirini hisobga olgan holda transport ko'priklari tayanchlarining umumiy modelini baholash uchun chekli elementlar usulidan foydalanish, turli omillar ta'siri ostida konstruksiya elementlarning ishlashi to'g'risida batafsil ma'lumotlarni olish imkonini beradi. Ushbu jarayon tayanchlarning fizik-

[a] https://orcid.org/0000-0003-2271-3768
[b] https://orcid.org/0009-0007-8137-853x

mexanik xususiyatlarini, shuningdek, uning atrof-muhit bilan o‘zaro ta’sirini aniq aks ettiruvchi batafsil geometrik modelni yaratishni o‘z ichiga oladi. Harakatlanuvchi transport vositalari bilan bog‘liq dinamik va statik yuklarni to‘g‘ri belgilash, shuningdek, iqlim va ish sharoitlarini hisobga olish muhim [1]. Asosiy jihati esa tenglamalar tizimini yechishda matematik modellashtirish usulini qo‘llash, bu konstruksiyaning turli yuklanishlarda kuchlanish va deformatsiyalarning taqsimlanishini ko‘rish imkonini beradi. Bu konstruksiyaning mustahkamligi va barqarorlik xususiyatlarini baholash, turli omillarning uning ishlash parametrlariga ta’sirini tahlil qilish, chegaraviy holatlarga uchragan hududlarni aniqlash va mustahkamligini ta’minlashga qaratilgan chora-tadbirlarni ishlab chiqish [3].

2. Tadqiqot metodologiyasi

Lira-SAPR dasturiy ta’minot to‘plami – bino va inshootlarni me’moriy loyihalash va hisoblash sxemalarini yaratish uchun mo‘ljallangan parametrik 3D modellashtirish tizimi bo‘lib, bu quruvchi va muhandislarga turli xil obyektlarni loyihalash imkonini beradi: sun’iy inshootdan tortib, turli xil maqsaddagi ko‘p qavatli binolar va inshootlargacha [2].

Kompleks dastur chiziqli bo‘lmagan, maxsus hisoblashlarga asoslangan bo‘lib, unda ko‘priklar va transport inshootlarini loyihalash uchun mo‘ljallangan to‘liq integratsiyalashgan tizim mavjud. Dasturiy ta’minot temirbetondan yasalgan konstruktsiyalarni, shu jumladan ko‘prik konstruktsiyalarining oraliqlari va tayanchlarini hisoblashni ta’minlaydi. Dasturiy ta’minot chekli elementlar usuli asosida amalga oshiriladi.

Lira-Saprni qo‘llash orqali blok elementlari uchun chekli elementlar usulini qo‘llash murakkab tuzilmalarda, masalan, turli hil tayanchlarning uchlarida, oldindan zo‘riqtirilgan armatura ankerlarida kuchlanish va deformatsiyalarni aniqlash muammolarini hal qilishga imkon beradi [4].

Dastur umumiy holda quyidagi amaliy muammolarni hal qilishga imkon beradi:

• har qanday konstruksiyalarning statik va dinamik hisoblarini bajarish;

• nochiziqlilikni hisobga olgan holda ustuvorlik hisoblarini bajarish;

• beton va armatura orasidagi aloqa hisoblarini bajarish;

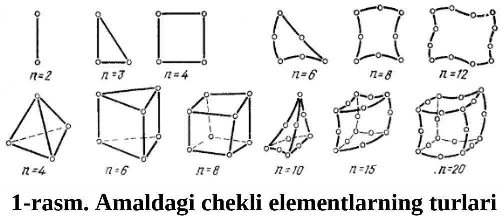
• po‘lat, beton va armaturaning o‘zaro ta’sirining uch o‘lchovli batafsil hisoblarini amalga oshirish;

• uzoq muddatli ta’sirlarda (masalan, betonning qisqarishi)

konstruksiyaning batafsil hisobini amalga oshirish;

• betonda yoriqlar paydo bo‘lishi va rivojlanishi bo‘yicha hisoblarini bajarish va boshqalar.

Dasturiy ta’minot chekli elementlarning faqat kichik qismi ishlatilgan [7]: tekis va hajmli, to‘g‘ri chiziqli oddiy va turli xil miqdordagi egri yuzli izoparametrik tugunlar (1-rasm).



1-rasm. Amaldagi chekli elementlarning turlari

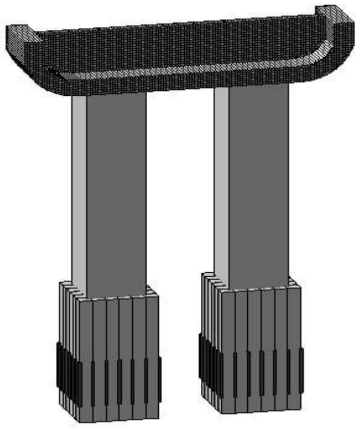
Ko‘prik konstruksiyalarini murakkab tayanchlarni hisoblashda natijalarning yuqori aniqlik bilan olish juda qiyin vazifa bo‘lib, ko‘p hollarda uni hal qilish deyarli mumkin emas. Murakkab tayanch konstruksiyalarini modellashtirish uchun elementlarning turlarini tanlash oddiy ish emas, uni hal qilish ko‘p hollarda nazariy va eksperimental tadqiqotlarni talab qiladi. Lira-Saprda ikkita turdagi elementlar mavjud: fazoviy-sterjin va fazoviy-blok. Beton tayanchning noelastik deformatsiyalarini hisobga olish Lira-Sapr dasturining imkoniyatlari va O‘zbekistonning qabul qilingan standartlari bilan ta’minlandi.[2,8]

Fazoviy-sterjen elementlaridan foydalanish – fazoviy tayanch konstruksiyasini aniqlashning mashhur usullaridan biri uni ma’lum bir ketma-ketlikda bir-biriga bo‘g‘langan fazodagi nuqtalar to‘plami sifatida ko‘rsatishdir. Natijada konstrulsiyani aniqlash va uning sxemasini tahlil qilish jarayoni ancha osonlashadi, agar quyidagi qo‘shimcha shartlar hisobga olinishi kerak [6]:

• Fazoda berilgan koordinatali konstruksiyaning barcha nuqtalari to‘g‘ri chiziqli kesmalar bilan bog‘langan.

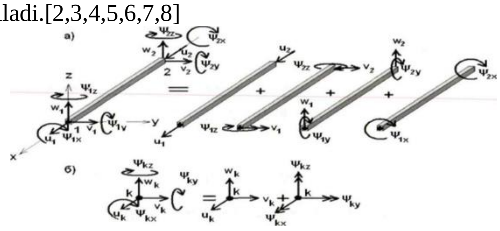
• Kuchlarni o‘tkazmaydigan konstruksiya elementlarining ulanishlari, shuningdek, tayanch mahkamlagichlar sharnirli-qo‘zg‘aluvchan ulanishlar yordamida modellashtiriladi, bunda biriktirish nuqtasida joyidagi sharnir unga yopishgan elementlarni buzadi.

• Konstruksiyaning ma’lum nuqtalarida birlashadigan barcha sterjen elementlar barcha turdagi kuch yuklarini uzatuvchi qattiq bog‘langan deb hisoblanadi (1.1-rasm).



1.1-rasm. Tayanchning fazoviy-sterjen elementlari yordamida chekli elementlar ko‘rinishida ifodalanishi

Fazoviy muammoni yanada to‘g‘ri hal qilish uchun fazoviy sterjen elementlari asosida qattiqlik matritsasi tuziladi.[2,3,4,5,6,7,8]



1.2-rasm. Fazoviy-sterjenning chekli elementi: a) tugun nuqtalarida ko‘chish; b) tugun nuqtalarida siljish vektorlarining ko‘chishi.

Fazoda joylashgan eguvchi sterjenning *i*-chi chekli elementi uchun neytral o‘q *x* o‘qi bo‘ylab harakat qiladi. *y* va *z* o‘qlari kesimning asosiy o‘qlari bo‘ylab yo‘naltirilgan. Tugunli siljish vektorini o‘zgartirish uni ikkita komponentga ajratish imkonini beradi: biri chiziqli siljishlarga mos keladi, ikkinchisi esa aylanish burchaklari bilan bog‘liq. Ushbu komponentlarning vektor tasviri 1.2-rasm, b da ko‘rsatilgan. Umuman olganda, barcha tugun parametrlarining koordinatalarini o‘zgartirish uchun kvazidiagonal matritsadan foydalaniladi.

$$[M]=\begin{bmatrix} m & 0 \\ 0 & m \end{bmatrix} \quad (1.1)$$

$[m]$-yo‘naltiruvchi kosinus matritsasi.

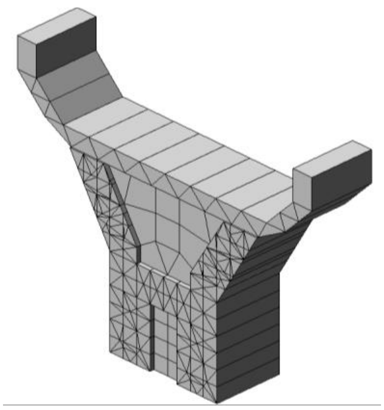
$$[K]_{ij}^{(k)}=[M]^T[H]^T[K]_{ij}^{(k)}[H][M] \quad (1.2)$$

Fazoviy-blokli tuzilishga ega elementlardan foydalanish – sterjen modeli yordamida tasvirlangan to‘g‘ri chiziqli tuzilmalar uchun juda ishonchli natijalarga erishish mumkin,ammo ekvivalent sterjenlarning statik-geometrik xususiyatlarini aniqlash juda murakkab vazifa bo‘lib qolmoqda [4,5,6,7,8,9,10].

Ushbu maqolada qo‘yilgan vazifalarni hal qilish uchun birinchi navbatda oraliq konstruktsiyalardan tayanchlarning qismlariga va tayanchlarning yuqori darajasiga uzatiladigan reaktsiyalarni aniqlash uchun fazoviy-blok elementlariga asoslangan model ishlatiladi. Keyin fazoviy blok elementlarini o‘z ichiga olgan model ishlatiladi.

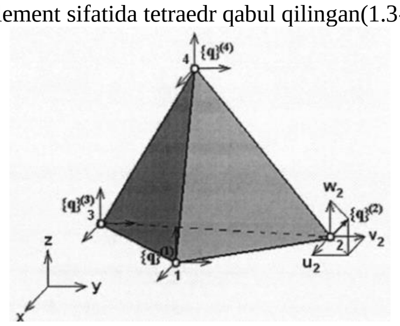
Tayanchlarni hisoblash tartibini uchta asosiy bosqichga ajratish mumkin:

1. Ko‘rib chiqilayotgan tayanchning hisoblash sxemasini taqdim etish, sxemani alohida elementlarga bo‘lish, blok elementlarining tugunlarini raqamlash va umumiy koordinatalar tizimini tanlash.
2. Lokal va global tizimlar o‘rtasidagi bog‘lanishni ta’minlovchi blok elementlarning ko‘chishlari uchun ifodalar tuzish.
3. Har bir blokdagi ko‘chishlar va kuchlanishlarni aniqlash.



1.3-rasm. Fazoviy-blok elementlaridan yasalgan tayanch modeli

Fazoviy chekli elementlarni tanlash quyida keltirilgan. Asosiy element sifatida tetraedr qabul qilingan(1.3-rasm).



1.4-rasm. Tetraedr shaklidagi chekli element

Hajmli chekli elementlar jismning kuchlanish-deformatsiya holatini barcha olti kuchlanish va deformatsiya komponentlari bilan to‘liq tavsiflash mumkin va nuqtalarning siljishlari koordinata o‘qlari bo‘ylab uchta mustaqil komponent bilan aniqlangan hollarda ob’ektlarni yaqinlashtirish uchun ishlatiladi.[2]

$$\{q\}_i=\left\{\{q\}_i^{(1)}\{q\}_i^{(2)}\{q\}_i^{(3)}\{q\}_i^{(4)}\right\} \quad (1.3)$$

Ulardan eng oddiyi tetraedr bo‘lib, uning tepalarida to‘rtta tugun joylashgan.

í -elementning tugun siljishlarining ustun vektori quyidagi shaklda ifodalanadi.

bunda vektorlarning har biri proyeksiyalarning uchta komponenti orqali ifodalanadi.

$$\{q\}_i^k=\left\{\{q\}_1^{(k)}\{q\}_2^{(k)}\{q\}_3^{(k)}\right\}=\{u_k v_k w_k\} \quad (1.4)$$

Tugunli kuchlar vektori xuddi shunday tuzilishga ega.

$$\{R\}_i=\left\{\{R\}_i^{(1)}\{R\}_i^{(2)}\{R\}_i^{(3)}\{R\}_i^{(4)}\right\} \quad (1.5)$$

$$\{R\}_i^k=\left\{\{R\}_1^{(k)}\{R\}_2^{(k)}\{R\}_3^{(k)}\{R\}_4^{(k)}\right\};$$

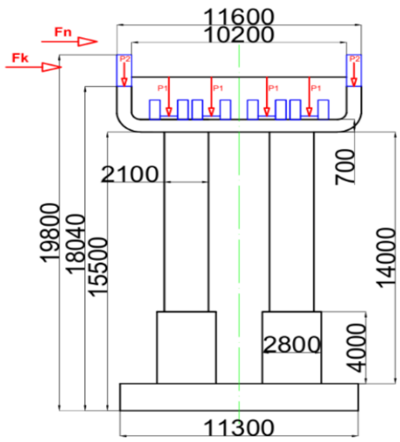
$$\{R\}_i=[R]_i\{q\}_i$$

(1.4) va (1.5) vektorlar orasidagi bog‘lanish blokli tuzilishga ega bo‘lgan qattiqlik matritsasi yordamida amalga oshiriladi $[K]_i$

$$[K]_i=\begin{bmatrix} [K]_{i1}^{(1)} & [K]_{i1}^{(2)} & [K]_{i1}^{(3)} & [K]_{i1}^{(4)} \\ [K]_{i2}^{(1)} & [K]_{i2}^{(2)} & [K]_{i2}^{(3)} & [K]_{i2}^{(4)} \\ [K]_{i3}^{(1)} & [K]_{i3}^{(2)} & [K]_{i3}^{(3)} & [K]_{i3}^{(4)} \\ [K]_{i4}^{(1)} & [K]_{i4}^{(2)} & [K]_{i4}^{(3)} & [K]_{i4}^{(4)} \end{bmatrix} \quad (1.6)$$

Oddiy blok quydagi formula yordamida aniqlanadi:

$$[K]_{ij}^{(k)}=\iiint_{Vi}([B]^{(j)})^T[D][B]^{(k)}dV \quad (1.7)$$



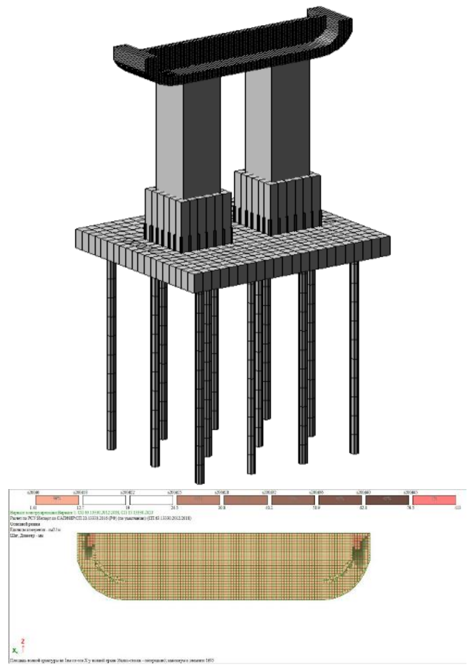
1.5-rasm. Tayanchga ta’sir qiluvchi kuchlar

Misol. Balandligi 14 m bo’lgan oraliq tayanch konstruksiyaning ko‘ndalang kesim sxemasi 9-rasmda ko‘rsatilgan.Tayanch B80 beton sinfidan foydalangan holda monolit temir-betondan yasalgan. Armaturalashda A400 tipidagi po‘lat armatura va ABK800 tipidagi bazalt-kompozit armatura qo‘llanildi. Tayanch ustunlarining balandligi 14 m, pastki 4 metrning kesimi 2800 x 2800 mm, tayanchning yuqori qismi esa 2100 x 2100 mm kesimga ega.

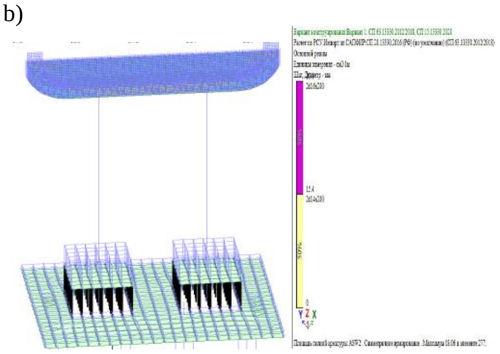
Qurilish maydonchasining seysmikligi 9 ballga teng qabul qilinadi. F_n – markazdan qochirma kuch; F_k – harakat tarkibining tayanchga ko‘ndalang vaqtinchalik ta’siri; P_1 – o‘z og‘irligi; P_1 – doimiy chegaralovchi balkaning og‘irligi.[1,9].

Temirbeton tayanchning yuqori qismidagi kuchlanish zo‘nalari va oldindan zo‘riqtirilgan armaturali tayanch qismlari 1.5-rasmda ko‘rsatilgan.

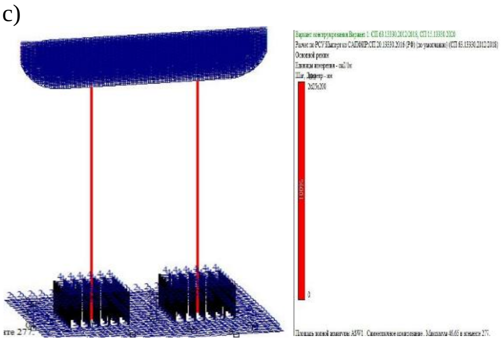
a)



b)



c)



1.5-rasm. Tayanch va eng yuqori kuchlanish zo‘nasining hisoblash modelli: a)- chekli elementlar modeli; b)- eng kuchlanishli zo‘nalar; c)- ko‘ndalang gorizontal armatura; d)- ko‘ndalang vertikal armatura

3. Xulosa

Lira-SAPR kabi ixtisoslashtirilgan dasturiy paketlardan foydalangan holda chekli elementlar usulidan foydalanish ko‘prik tayanchlari va boshqa konstruktiv elementlarning mexanik ishini tahlil qilishni sezilarli darajada oshirishga imkon beradi. Bu kuchlanishlar, deformatsiyalar va boshqa jismoniy miqdorlarning taqsimlanishini batafsilroq hisobga olish imkonini beradi, bu esa konstruksiya hisoblarining aniqligini oshirishga yordam beradi. O‘z navbatida, bu loyihalashtirilgan inshootni optimallashtirish, ularning xavfsizlik standartlariga muvofiqligini, ekspluatatsiya ishonchliligi va chidamliligini ta’minlashga yordam beradi. Bunday vositalar turli xil tashqi omillarning, jumladan, statik va dinamik yuklarning ta’sirini, shuningdek, infratuzilma ob’ektlarini loyihalashda ayniqsa muhim bo’lgan atrof-muhit va harorat ta’sirini har tomonlama ko’rib chiqishga imkon beradi.

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Mualliflar to‘g‘risida ma’lumot/ Information about the authors

Abduqadirov Farxod / Farkhod Abdukadirov	Toshkent davlat transport universiteti "Amaliy mexanika" kafedrasi dotsenti. t.f.f.d, PhD E-mail: farkhod.erkinovich@mail.ru Tel.: +998977722447 https://orcid.org/0000-0003-2271-3768
Xasanov Temurbek / Temurbek Khasanov	Toshkent davlat transport universiteti "Amaliy mexanika" kafedrasi doktaranti E-mail: tima.maksudovich.1991@mail.ru Tel.: +998974552979 https://orcid.org/0009-0007-8137-853x

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