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Зміст

Формоутворення каркасів технічних форм, заданих на площині неявними функціями

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Анотація. При проектуванні форм робочих поверхонь машин і механізмів, технологічного устаткування, а також складних будівельних конструкцій, що піддаються впливу зовнішніх сил, інженери і дослідники вдаються до використання фізико-математичних методів отримання функцій відповідних форм. Дуже часто функції таких форм будуються на основі аналізу кінематики руху цілого комплексу конструктивних елементів робочого обладнання або на основі розв’язання задач системної оптимізації, що базуються на пошуку умовних екстремумів. В результаті, одержана функція приймає неявну форму, а процес побудови її графіку представляє собою виділення окремих ізоліній поля на координатній площині.

В роботі розглянуто ефективність двох способів побудови дискретних образів функцій, заданих на площині в неявній формі. Перший − передбачає комбіноване використання методу скінченних різниць та формул для знаходження похідних неявних функцій диференціальної геометрії. Другий спосіб передбачає реалізацію процесу формоутворення дискретного аналога моделі фізичної сітчастої конструкції з подальшим управлінням формою цієї моделі для переміщення її вузлів в точки, що задовольняють заданій неявної функції. Наведено приклади використання обох підходів з порівнянням точності інцидентності координат отриманих дискретних моделей графіку досліджуваної неявної функції. Проаналізовано переваги та недоліки запропонованих підходів.

Ключові слова: формоутворення, дискретний образ, неявні функції, чисельні методи, скінченні різниці, диференціальна геометрія, параметричні рівняння.

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ПОСТАНОВКА ПРОБЛЕМИ

Методи побудови функцій форм технічних поверхонь та обводів (кривих) беруть свій початок в різних розділах фізики і математики, таких як теоретична механіка, векторний аналіз, теорія поля, диференціальна геометрія (як, наприклад, в разі пошуку рівнянь сімейства огинаючих ліній), топологія, дискретна геометрія і т.д., що є наслідком необхідності максимально точно врахувати фізичні особливості подальшої роботи отриманої форми в умовах експлуатації. Крім того, часто шукані форми є наслідком специфічної кінематики руху складних багатокомпонентних конструкцій, а їх функції виводяться на основі параметричного аналізу з подальшим зв'язуванням або вилученням окремих параметрів, в тому числі натуральних.

В результаті, отримані функції нерідко записуються в неявній формі, що ускладнює процес подальшої побудови їх графіків і дослідження їх властивостей. Знаходження графіків неявних функцій в основному зводиться до побудови їх дискретного каркаса у вигляді ряду точок, координати яких з тією або іншою точністю задовольняють досліджуваному рівнянню. Згадана точність, а також відстані між точками отриманого каркаса, відіграють велику роль, так як вони впливають на результуючу точність обчислення диференціальних характеристик шуканої поверхні або кривої, одержуваних в даному випадку переважно з використанням апроксимаційних співвідношень (наприклад, скінченних різниць або поділених різниць). Однак, точність обчислення даних характеристик дуже важлива в наслідок того, що шукані дискретні образи часто не відображають фізичних особливостей роботи самих конструкцій, описуваних досліджуваними неявними функціями, а значить про властивості образів можна судити виключно за характером розподілу їх точок. При цьому не варто забувати, що конструкції, що вимагають застосування методів формоутворення, працюють в більшості випадків, перебуваючи під впливом великих навантажень, і передбачають високий рівень відповідальності інженерів і дослідників. Дана проблема є досить поширеною в рамках вирішення завдань архітектурного формоутворення.

АНАЛІЗ ПОПЕРЕДНІХ ДОСЛІДЖЕНЬ

Якщо мова йде про задачу отримання плоских кривих (наприклад, плоских перетинів оболонок покриття архітектурних конструкцій), то найпростішим виходом для візуалізації і подальшого аналізу форми досліджуваної неявної функції є застосування одного з чисельних алгоритмів, що дозволяють шляхом послідовного звуження зони пошуку знаходити окремі точки кривої в заданій області [1 − 5]. Такі алгоритми можуть вимагати значної продуктивності комп'ютерної техніки і можуть не привести до шуканого рішення в разі невдалого вибору зони пошуку. Тому, краще використовувати або чисельні методи, що дозволяють визначати форму шуканої кривої при точному завданні крайових і початкових умов, або один з методів формоутворення дискретної геометрії. В роботі [6] було продемонстровано алгоритм побудови дискретного каркасу кривої довільної досліджуваної неявної функції:

$$\varsigma(x,y)=0 \qquad (1)$$

з використанням методу кінцевих різниць, а також фундаментальних співвідношень диференціальної геометрії для знаходження часткових похідних від неявних функцій. Алгоритм передбачає побудову комбінованих різницевих рівнянь з похідними 1-го і 2-го порядку від функції $\varsigma(x,y)$ з подальшим вирішенням системи отриманих рівнянь відносно координат умовно вільних вузлів (координати яких не є крайовими умовами). Дані рівняння мають наступну форму:

1. Для знаходження дискретного образу з заданим кроком по осі абсцис (Ox):

$$\begin{aligned} &y_{i-1}-2\cdot y_i+y_{i+1}=\\ &=h^2\cdot\Big(2\cdot\varsigma'_x(x,y)\cdot\varsigma'_y(x,y)\cdot\varsigma''_{xy}(x,y)-\\ &-\left(\varsigma'_y(x,y)\right)^2\cdot\varsigma''_{xx}(x,y)-\\ &-\left(\varsigma'_x(x,y)\right)^2\cdot\varsigma''_{yy}(x,y)\Big)\Big/\left(\varsigma'_y(x,y)\right)^3, \text{ чи:} \end{aligned} \qquad (2)$$

$$\begin{aligned} &b\cdot y_{i-1}+a\cdot y_i+c\cdot y_{i+1}=\\ &=\Big(2\cdot\varsigma'_x(x,y)\cdot\varsigma'_y(x,y)\cdot\varsigma''_{xy}(x,y)-\\ &-\left(\varsigma'_y(x,y)\right)^2\cdot\varsigma''_{xx}(x,y)-\\ &-\left(\varsigma'_x(x,y)\right)^2\cdot\varsigma''_{yy}(x,y)\Big)\Big/\left(\varsigma'_y(x,y)\right)^3, \end{aligned} \qquad (3)$$

$$b=2\big/\left[\Delta x_{i-1,i}\cdot\left(\Delta x_{i-1,i}+\Delta x_{i,i+1}\right)\right], \qquad (4)$$

$$a=-2\big/\left(\Delta x_{i-1,i}\cdot\Delta x_{i,i+1}\right), \qquad (5)$$

$$c=2\big/\left[\Delta x_{i,i+1}\cdot\left(\Delta x_{i-1,i}+\Delta x_{i,i+1}\right)\right]. \qquad (6)$$

Рівняння (2) призначене для випадку, коли обрано рівномірний крок h_x по осі Ox, тоді як рівняння (3) адаптоване для довільного кроку вузлів.

2. Для знаходження дискретного образу з заданим кроком по осі ординат (Oy):

$$\begin{aligned} &x_{i-1}-2\cdot x_i+x_{i+1}=\\ &=h_y^2\cdot\Big(2\cdot\varsigma'_y(x,y)\cdot\varsigma'_x(x,y)\cdot\varsigma''_{xy}(x,y)-\\ &-\left(\varsigma'_x(x,y)\right)^2\cdot\varsigma''_{yy}(x,y)- \end{aligned} \qquad (7)$$

$$-\left(\varsigma'_y(x,y)\right)^2 \cdot \varsigma''_{xx}(x,y)\Big/\left(\varsigma'_x(x,y)\right)^3 \text{, чи:}$$

$$\begin{gathered} e \cdot x_{i-1} + d \cdot x_i + g \cdot x_{i+1} = \\ = \Big(2 \cdot \varsigma'_y(x,y) \cdot \varsigma'_x(x,y) \cdot \varsigma''_{xy}(x,y) - \\ - \left(\varsigma'_x(x,y)\right)^2 \cdot \varsigma''_{yy}(x,y) - \\ \left(\varsigma'_y(x,y)\right)^2 \cdot \varsigma''_{xx}(x,y)\Big)\Big/\left(\varsigma'_x(x,y)\right)^3, \end{gathered} \tag{8}$$

$$e = 2\Big/\left[\Delta y_{i-1,i} \cdot \left(\Delta y_{i-1,i} + \Delta y_{i,i+1}\right)\right], \tag{9}$$

$$d = -2\Big/\left(\Delta y_{i-1,i} \cdot \Delta y_{i,i+1}\right), \tag{10}$$

$$g = 2\Big/\left[\Delta y_{i,i+1} \cdot \left(\Delta y_{i-1,i} + \Delta y_{i,i+1}\right)\right]. \tag{11}$$

Рівняння (7) призначене для випадку, коли обрано рівномірний крок h_y по осі Oy, тоді як рівняння (8) адаптоване для довільного кроку вузлів.

У рівняннях (2), (3), (7) і (8) праві їх складові мають наступний сенс:

$$\varsigma'_x(x,y) = \partial\varsigma(x,y)/\partial x, \tag{12}$$

$$\varsigma''_{xx}(x,y) = \partial^2\varsigma(x,y)/\partial x^2, \tag{13}$$

$$\varsigma'_y(x,y) = \partial\varsigma(x,y)/\partial y, \tag{14}$$

$$\varsigma''_{yy}(x,y) = \partial^2\varsigma(x,y)/\partial y^2, \tag{15}$$

$$\varsigma''_{xy}(x,y) = \partial^2\varsigma(x,y)/\partial x\partial y. \tag{16}$$

Початкові координати вузлів пропонується обчислювати, вирішуючи в першому наближенні нижче наведені рівняння:

1. Для подальшого вирішення системи рівнянь типу (2) і (3) відповідно:

$$y_{i-1} - 2 \cdot y_i + y_{i+1} = 0, \tag{17}$$

$$b \cdot y_{i-1} + a \cdot y_i + c \cdot y_{i+1} = 0. \tag{18}$$

2. Для подальшого вирішення системи рівнянь типу (7) і (8) відповідно:

$$x_{i-1} - 2 \cdot x_i + x_{i+1} = 0, \tag{19}$$

$$e \cdot x_{i-1} + d \cdot x_i + g \cdot x_{i+1} = 0. \tag{20}$$

Такі попередні розрахунки початкових координат необхідні внаслідок того, що рівняння (2), (3), (7) і (8) можуть мати високу нелінійність, а права половина цих рівнянь з фізичної точки зору являє собою векторне поле, в якому в процесі ітераційного числення рухаються до шуканих положень вільні вузли дискретної моделі. Тому, при невдалому заданні початкових координат вільних вузлів (тобто всіх, крім першого і останнього, які задаються в обов'язковому порядку і служать в якості крайових умов моделювання), відповідні вузли можуть опинитися у віддаленій області, де поле впливу має різкий або несприятливий характер. У цьому випадку, на кожній наступній ітерації вільні вузли можуть опинятися в інших не менш віддалених областях досліджуваної області, або навіть за її межами. Як результат, ітераційний процес може й зовсім не зійтися.

Ще одним методом побудови дискретного каркасу плоскої кривої, представленим в роботі [6], було моделювання дискретних образів, які є аналогами фізичних сітчастих безмоментних структур, з використанням параметричних рівнянь стану зв'язків (стрижнів) моделей для системного управління їх формою. Метод передбачає початкове формоутворення дискретного образу, шляхом побудови і рішення рівнянь рівноваги його вільних вузлів, що мають вигляд:

$$\sum_{j=1}^{n}\left(s_j - s_i\right) \cdot \aleph_{i,j} + \Im_{si} = 0. \tag{21}$$

Тут: s – узагальнене позначення координат (x і y); n – кількість вільних (незафіксованих) вузлів моделі; $\Im_{s\,i}$ – проекції векторів вузлових сил $\overline{\Im}_i$; $\aleph_{i,j}$ – параметри умовної жорсткості зв’язків, що є співвідношеннями абсолютних величин поздовжніх зусиль в цих зв'язках $R_{i,j}$ до їх довжин $\delta_{i,j}$:

$$\aleph_{i,j} = R_{i,j}/\delta_{i,j}, \tag{22}$$

$$\delta_{i,j} = \left((x_j - x_i)^2 + (y_j - y_i)^2\right)^{1/2}. \tag{23}$$

Після первинного формоутворення конструкції шляхом вирішення системи рівнянь типу (21) відносно координат вільних вузлів, необхідно шляхом управління розподілом параметрів жорсткості (а значить і внутрішніх зусиль) в зв'язках конструкції, помістити обрані її вузли в точки на площині, що задовольняють досліджуваній неявній функції $\varsigma(x,y)$. Для цього необхідно скласти і вирішити систему параметричних рівнянь стану всіх стрижнів. Відповідні рівняння можуть бути записані в такій формі:

1) для зв'язків, що з'єднують два вільних вузла моделі (S_a і S_b):

$$\sum_{i=1}^{m-1}\delta^2_{a,i}\cdot\aleph_{a,i}+\chi\cdot\delta^2_{a,b}\cdot\aleph_{a,b}+\sum_{j=1}^{n-1}\delta^2_{b,j}\cdot\aleph_{b,j}- -(\varphi_a+\varphi_b)+B_{a,b}=0\ ; \quad (24)$$

2) для зв'язків, що з'єднують один вільний і один нерухомий вузли моделі (S_a і S_{fix}):

$$\sum_{i=1}^{m-1}\delta^2_{a,i}\cdot\aleph_{a,i}+\chi\cdot\delta^2_{a,fix}\cdot\aleph_{a,fix}-\varphi_a+ +(R_{x\,fix}\cdot x_{fix}+R_{y\,fix}\cdot y_{fix})+B_{a,fix}=0\,, \quad (25)$$

де m та n – кількість вузлів, сполучених з a-м та b-м вузлами; χ – деяка константа ($\chi\geq 0$), величина якої обумовлена топологічними особливостями моделі; φ_a та φ_b – вузлові значення скалярного потенціалу (поля досліджуваної неявної функції); R_{fix} – величини зусиль у зв'язках, що з'єднуються з шарнірними опорами; $B_{a,b}$ та $B_{a,fix}$ – загальні операційні константи інтегрування.

Функція скалярного потенціалу при даній постановці задачі повинна відповідати досліджуваній неявній функції:

$$\varphi_i=\varphi(x_i\,,y_i\,)=\varsigma(x_i\,,y_i\,)\,, \quad (26)$$

а вектори вузлових навантажень $\overline{\Im}$ можуть знаходиться в градієнтній залежності від потенціалу φ:

$$\overline{\Im}=\nabla\varphi=\left(\partial\varphi/\partial x\right)\cdot\bar{\mathbf{e}}_x+\left(\partial\varphi/\partial y\right)\cdot\bar{\mathbf{e}}_y\,. \quad (27)$$

При співпадінні вільних вузлів з графіком функції $\varsigma(x,y)$, координати цих вузлів будуть задовольняти виразу (1), а значить, очікуваними значеннями вузлових потенціалів будуть нулі: $\varphi'_i=0$.

В [7] було показано, що вирішення задачі формоутворення і коригування відповідної сітчастої конструкції в матричній формі має такий вигляд:

$$\left[s^p\right]=\left[\aleph^{p-1}\right]^{-1}\cdot\left(-\left[g^{p-1}\right]-\left[\Im^p\right]\right), \quad (28)$$

$$\left\{\aleph^p\right\}=\left[\left(\delta^p\right)^2\right]^{-1}\cdot\left(\left\{\varphi'^{\,p}\right\}-\right. \left.-\left\{\varphi^p\right\}+\left[\left(\delta^p\right)^2\right]\cdot\left\{\aleph^{p-1}\right\}\right). \quad (29)$$

Тут: $[s]$ – матриця координат (розмірністю $k\times 2$, де k – кількість вільних вузлів системи); $[g]$ – матриця крайових умов (розмірністю $k\times 2$); $[\Im]$ – матриця зовнішніх впливів (розмірністю $k\times 2$); $[\aleph]$ – матриця параметрів умовної жорсткості сітчастої конструкції (розмірністю $k\times k$); $\{\aleph\}$ – вектор-стовпець параметрів умовної жорсткості сітчастої конструкції; $[\delta^2]$ – матриця геометричних параметрів сітчастої конструкції (розмірністю $h\times h$, де h – кількість зв'язків моделі); $\{\varphi\}$ – вектор-стовпець вузлових показників скалярного потенціалу; $\{\varphi'\}$ – вектор-стовпець очікуваних вузлових показників скалярного потенціалу; p – індекс, що відповідає поточному кроку ітераційного числення.

Системні рішення (28) і (29) повинні виконуватися послідовно і циклічно, реалізуючи ітераційне числення. При цьому система (28) може мати високу нелінійність, а система (29) – складається з лінійних (в більшості випадків) рівнянь.

ОСНОВНЕ ДОСЛІДЖЕННЯ

Розглянемо приклад використання обох вище згаданих способів отримання дискретних образів на практиці. Для того, щоб мати чітке уявлення про вигляд і особливості поведінки досліджуваної кривої скористаємося елементарною функцією квадратної параболи:

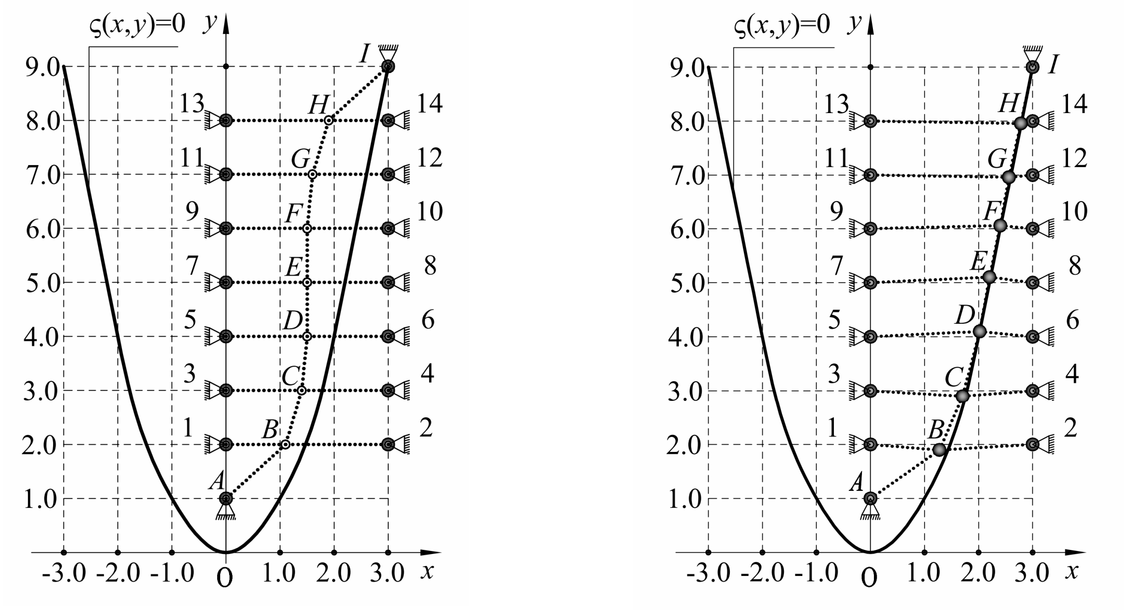
$$y(x)=x^2\cdot \quad (30)$$

Приведемо цю функцію до неявній форми, записавши її в наступному вигляді:

$$\varsigma(x, y) = y - x^2 = 0 \cdot \qquad (31)$$

Почнемо з другого способу, заснованого на розв'язанні параметричних рівнянь. Для цього задаємося топологічною інформацією щодо майбутнього дискретного образ. Нехай образ складається з 7-ми вільних вузлів та 16-ти нерухомих – базових – вузлів, що з'єднуються між собою 22-ма зв'язками в порядку, показаному на Рис.1, *а*.

В даному випадку, лише вільні вузли дискретної кривої будуть після завершення процесу коригування інцидентними шуканій кривій неявної функції. При цьому, очевидно (як було показано в [6]), сама модель не є прообразом лінії, кожен вузол якої сполучається виключно з наступним по порядку. Запропонована модель топологічно еквівалентна складній багатокомпонентній стрижневій конструкції, кожен вільний вузол якої з'єднається з чотирма сусідніми вузлами (як вільними, так і фіксованими), дозволяючи розширити зону пошуку шуканих точок кривої неявної функції за межами розташування початкового образу. Справа в тому, що, будучи прообразом реальної механічної конструкції, навантаженої зовнішніми силами, що мають польовий функціональний характер і змінюють напрямок і величину в кожній точці, модель просто не зможе в разі відповідності елементарному ланцюгу досягти стану статичної рівноваги. У той же час, будучи геометрично незмінною, модель легко врівноважиться під впливом практично будь-яких зовнішніх навантажень.



а *б*

Рис.1. Побудова дискретного образу кривої неявну функції з використанням параметричних рівнянь типу (24) і (25): *а* − дискретний образ досліджуваної функції на першому етапі моделювання (топологічна схема); *б* − дискретний образ досліджуваної функції після завершення процесу коригування.
Умовні позначення (тут і надалі): ▬▬ – неперервний графік неявної функції; •••••••••• – дискретний образ графіка неявної функції; ○ і ● – вільні вузли дискретного образу в початковій та результуючої формах відповідно; ⚲ – базові (фіксовані) вузли дискретного образу

Fig.1. The construction of a discrete image of curved line of an implicit function using parametric equations of the types (24) and (25): *а*− the discrete image of the function on the first stage (the topological scheme); *б* − the discrete image of the function after the correction process. Symbols (here and below): ▬▬ – continuous graph of implicit function; •••••••••• – discrete image of the graph of implicit function; ○ and ● – free nodes of the discrete image in the initial and the resulting forms; ⚲ – basic (fixed) nodes of a discrete image

По-перше, складемо систему рівнянь рівноваги типу (21) для всіх вільних вузлів представленої на Рис.1 моделі. Для цього визначимо форму векторного поля впливів відповідно до формули (27). В результаті одержимо вираз (32).

З урахуванням формули (32) система статичної рівноваги усіх вільних вузлів, складена за аналогом рівнянь типу (21), матиме вигляд (33) – (46).

По-друге, складемо систему параметричних рівнянь типу (24) і (25) для всіх стрижнів (ланок) моделі. Дана система буде мати вигляд (47) – (58).

$$\bar{\Im} = \left(\partial(y - x^2)/\partial x\right)\cdot \bar{\mathbf{e}}_x + \left(\partial(y - x^2)/\partial y\right)\cdot \bar{\mathbf{e}}_y = -2\cdot x \cdot \bar{\mathbf{e}}_x + 1\cdot \bar{\mathbf{e}}_y . \quad (32)$$

$$-(\aleph_{A,B} + \aleph_{B,1} + \aleph_{B,2} + \aleph_{B,C})\cdot x_B + \aleph_{A,B}\cdot x_A + \aleph_{B,1}\cdot x_1 + \aleph_{B,2}\cdot x_2 + \aleph_{B,C}\cdot x_C - 2\cdot x_B = 0, \quad (33)$$

$$-(\aleph_{B,C} + \aleph_{C,3} + \aleph_{C,4} + \aleph_{C,D})\cdot x_C + \aleph_{B,C}\cdot x_B + \aleph_{C,3}\cdot x_3 + \aleph_{C,4}\cdot x_4 + \aleph_{C,D}\cdot x_D - 2\cdot x_C = 0, \quad (34)$$

$$-(\aleph_{C,D} + \aleph_{D,5} + \aleph_{D,6} + \aleph_{D,E})\cdot x_D + \aleph_{C,D}\cdot x_C + \aleph_{D,5}\cdot x_5 + \aleph_{D,6}\cdot x_6 + \aleph_{D,E}\cdot x_E - 2\cdot x_D = 0, \quad (35)$$

$$-(\aleph_{D,E} + \aleph_{E,7} + \aleph_{E,8} + \aleph_{E,F})\cdot x_E + \aleph_{D,E}\cdot x_D + \aleph_{E,7}\cdot x_7 + \aleph_{E,8}\cdot x_8 + \aleph_{E,F}\cdot x_F - 2\cdot x_E = 0, \quad (36)$$

$$-(\aleph_{E,F} + \aleph_{F,9} + \aleph_{F,10} + \aleph_{F,G})\cdot x_F + \aleph_{E,F}\cdot x_E + \aleph_{F,9}\cdot x_9 + \aleph_{F,10}\cdot x_{10} + \aleph_{F,G}\cdot x_G - 2\cdot x_F = 0, \quad (37)$$

$$-(\aleph_{F,G} + \aleph_{G,11} + \aleph_{G,12} + \aleph_{G,H})\cdot x_G + \aleph_{F,G}\cdot x_F + \aleph_{G,11}\cdot x_{11} + \aleph_{G,12}\cdot x_{12} + \aleph_{G,H}\cdot x_H - 2\cdot x_G = 0, \quad (38)$$

$$-(\aleph_{G,H} + \aleph_{H,13} + \aleph_{H,14} + \aleph_{H,I})\cdot x_H + \aleph_{G,H}\cdot x_G + \aleph_{H,13}\cdot x_{13} + \aleph_{H,14}\cdot x_{14} + \aleph_{H,I}\cdot x_I - 2\cdot x_H = 0, \quad (39)$$

$$-(\aleph_{A,B} + \aleph_{B,1} + \aleph_{B,2} + \aleph_{B,C})\cdot y_B + \aleph_{A,B}\cdot y_A + \aleph_{B,1}\cdot y_1 + \aleph_{B,2}\cdot y_2 + \aleph_{B,C}\cdot y_C + 1 = 0, \quad (40)$$

$$-(\aleph_{B,C} + \aleph_{C,3} + \aleph_{C,4} + \aleph_{C,D})\cdot y_C + \aleph_{B,C}\cdot y_B + \aleph_{C,3}\cdot y_3 + \aleph_{C,4}\cdot y_4 + \aleph_{C,D}\cdot y_D + 1 = 0, \quad (41)$$

$$-(\aleph_{C,D} + \aleph_{D,5} + \aleph_{D,6} + \aleph_{D,E})\cdot y_D + \aleph_{C,D}\cdot y_C + \aleph_{D,5}\cdot y_5 + \aleph_{D,6}\cdot y_6 + \aleph_{D,E}\cdot y_E + 1 = 0, \quad (42)$$

$$-(\aleph_{D,E} + \aleph_{E,7} + \aleph_{E,8} + \aleph_{E,F})\cdot y_E + \aleph_{D,E}\cdot y_D + \aleph_{E,7}\cdot y_7 + \aleph_{E,8}\cdot y_8 + \aleph_{E,F}\cdot y_F + 1 = 0, \quad (43)$$

$$-(\aleph_{E,F} + \aleph_{F,9} + \aleph_{F,10} + \aleph_{F,G})\cdot y_F + \aleph_{E,F}\cdot y_E + \aleph_{F,9}\cdot y_9 + \aleph_{F,10}\cdot y_{10} + \aleph_{F,G}\cdot y_G + 1 = 0, \quad (44)$$

$$-(\aleph_{F,G} + \aleph_{G,11} + \aleph_{G,12} + \aleph_{G,H})\cdot y_G + \aleph_{F,G}\cdot y_F + \aleph_{G,11}\cdot y_{11} + \aleph_{G,12}\cdot y_{12} + \aleph_{G,H}\cdot y_H + 1 = 0, \quad (45)$$

$$-(\aleph_{G,H} + \aleph_{H,13} + \aleph_{H,14} + \aleph_{H,I})\cdot y_H + \aleph_{G,H}\cdot y_G + \aleph_{H,13}\cdot y_{13} + \aleph_{H,14}\cdot y_{14} + \aleph_{H,I}\cdot y_I + 1 = 0, \quad (46)$$

$$\chi\cdot\delta^2_{A,B}\cdot\aleph_{A,B} + \delta^2_{B,1}\cdot\aleph_{B,1} + \delta^2_{B,2}\cdot\aleph_{B,2} + \delta^2_{B,C}\cdot\aleph_{B,C} - \varphi_B + \left(R_{xA}\cdot x_A + R_{yA}\cdot y_A\right) + B_{A,B} = 0 , \quad (47)$$

$$\chi\cdot\delta^2_{B,1}\cdot\aleph_{B,1} + \delta^2_{A,B}\cdot\aleph_{A,B} + \delta^2_{B,2}\cdot\aleph_{B,2} + \delta^2_{B,C}\cdot\aleph_{B,C} - \varphi_B + \left(R_{x1}\cdot x_1 + R_{y_1}\cdot y_1\right) + B_{B,1} = 0 , \quad (48)$$

$$\chi\cdot\delta^2_{B,2}\cdot\aleph_{B,2} + \delta^2_{A,B}\cdot\aleph_{A,B} + \delta^2_{B,1}\cdot\aleph_{B,1} + \delta^2_{B,C}\cdot\aleph_{B,C} - \varphi_B + \left(R_{x2}\cdot x_2 + R_{y_2}\cdot y_2\right) + B_{B,2} = 0 , \quad (49)$$

$$\chi\cdot\delta^2_{B,C}\cdot\aleph_{B,C} + \delta^2_{A,B}\cdot\aleph_{A,B} + \delta^2_{B,1}\cdot\aleph_{B,1} + \delta^2_{B,2}\cdot\aleph_{B,2} + \delta^2_{C,3}\cdot\aleph_{C,3} + \delta^2_{C,4}\cdot\aleph_{C,4} + \delta^2_{C,D}\cdot\aleph_{C,D} - \left(\varphi_B + \varphi_C\right) + B_{B,C} = 0 , \quad (50)$$

$$\chi\cdot\delta^2_{C,3}\cdot\aleph_{C,3} + \delta^2_{B,C}\cdot\aleph_{B,C} + \delta^2_{C,4}\cdot\aleph_{C,4} + \delta^2_{C,D}\cdot\aleph_{C,D} - \varphi_C + \left(R_{x3}\cdot x_3 + R_{y_3}\cdot y_3\right) + B_{C,3} = 0 , \quad (51)$$

$$\chi\cdot\delta^2_{C,4}\cdot\aleph_{C,4} + \delta^2_{B,C}\cdot\aleph_{B,C} + \delta^2_{C,3}\cdot\aleph_{C,3} + \delta^2_{C,D}\cdot\aleph_{C,D} - \varphi_C + \left(R_{x4}\cdot x_4 + R_{y_4}\cdot y_4\right) + B_{C,4} = 0 , \quad (52)$$

$$\chi\cdot\delta^2_{C,D}\cdot\aleph_{C,D} + \delta^2_{B,C}\cdot\aleph_{B,C} + \delta^2_{C,3}\cdot\aleph_{C,3} + \delta^2_{C,4}\cdot\aleph_{C,4} + \delta^2_{D,5}\cdot\aleph_{D,5} + \delta^2_{D,6}\cdot\aleph_{D,6} + \delta^2_{D,E}\cdot\aleph_{D,E} - \left(\varphi_C + \varphi_D\right) + B_{C,D} = 0 , \quad (53)$$

$$\chi\cdot\delta^2_{D,5}\cdot\aleph_{D,5} + \delta^2_{C,D}\cdot\aleph_{C,D} + \delta^2_{D,6}\cdot\aleph_{D,6} + \delta^2_{D,E}\cdot\aleph_{D,E} - \varphi_D + \left(R_{x5}\cdot x_5 + R_{y_5}\cdot y_5\right) + B_{D,5} = 0 , \quad (54)$$

$$\chi\cdot\delta^2_{D,6}\cdot\aleph_{D,6} + \delta^2_{C,D}\cdot\aleph_{C,D} + \delta^2_{D,5}\cdot\aleph_{D,5} + \delta^2_{D,E}\cdot\aleph_{D,E} - \varphi_D + \left(R_{x6}\cdot x_6 + R_{y_6}\cdot y_6\right) + B_{D,6} = 0 , \quad (55)$$

$$\chi\cdot\delta^2_{D,E}\cdot\aleph_{D,E} + \delta^2_{C,D}\cdot\aleph_{C,D} + \delta^2_{D,5}\cdot\aleph_{D,5} + \delta^2_{D,6}\cdot\aleph_{D,6} + \delta^2_{E,7}\cdot\aleph_{E,7} + \delta^2_{E,8}\cdot\aleph_{E,8} + \delta^2_{E,F}\cdot\aleph_{E,F} - \left(\varphi_D + \varphi_E\right) + B_{D,E} = 0 , \quad (56)$$

$$\chi\cdot\delta^2_{E,7}\cdot\aleph_{E,7} + \delta^2_{D,E}\cdot\aleph_{D,E} + \delta^2_{E,8}\cdot\aleph_{E,8} + \delta^2_{E,F}\cdot\aleph_{E,F} - \varphi_E + \left(R_{x7}\cdot x_7 + R_{y_7}\cdot y_7\right) + B_{E,7} = 0 , \quad (57)$$

$$\chi\cdot\delta^2_{E,8}\cdot\aleph_{E,8}+\delta^2_{D,E}\cdot\aleph_{D,E}+\delta^2_{E,7}\cdot\aleph_{E,7}+\delta^2_{E,F}\cdot\aleph_{E,F}-\varphi_E+\left(R_{x8}\cdot x_8+R_{y8}\cdot y_8\right)+B_{E,8}=0\ , \tag{58}$$

$$\chi\cdot\delta^2_{E,F}\cdot\aleph_{E,F}+\delta^2_{D,E}\cdot\aleph_{D,E}+\delta^2_{E,7}\cdot\aleph_{E,7}+\delta^2_{E,8}\cdot\aleph_{E,8}+\delta^2_{F,9}\cdot\aleph_{F,9}+\delta^2_{F,10}\cdot\aleph_{F,10}+\delta^2_{F,G}\cdot\aleph_{F,G}-\left(\varphi_E+\varphi_F\right)+B_{E,F}=0\ , \tag{59}$$

$$\chi\cdot\delta^2_{F,9}\cdot\aleph_{F,9}+\delta^2_{E,F}\cdot\aleph_{E,F}+\delta^2_{F,10}\cdot\aleph_{F,10}+\delta^2_{F,G}\cdot\aleph_{F,G}-\varphi_F+\left(R_{x9}\cdot x_9+R_{y9}\cdot y_9\right)+B_{F,9}=0\ , \tag{60}$$

$$\chi\cdot\delta^2_{F,10}\cdot\aleph_{F,10}+\delta^2_{E,F}\cdot\aleph_{E,F}+\delta^2_{F,9}\cdot\aleph_{F,9}+\delta^2_{F,G}\cdot\aleph_{F,G}-\varphi_F+\left(R_{x10}\cdot x_{10}+R_{y10}\cdot y_{10}\right)+B_{F,10}=0\ , \tag{61}$$

$$\chi\cdot\delta^2_{F,G}\cdot\aleph_{F,G}+\delta^2_{E,F}\cdot\aleph_{E,F}+\delta^2_{F,9}\cdot\aleph_{F,9}+\delta^2_{F,10}\cdot\aleph_{F,10}+\delta^2_{G,11}\cdot\aleph_{G,11}+\delta^2_{G,12}\cdot\aleph_{G,12}+\delta^2_{G,H}\cdot\aleph_{G,H}-\left(\varphi_F+\varphi_G\right)+B_{F,G}=0\ , \tag{62}$$

$$\chi\cdot\delta^2_{G,11}\cdot\aleph_{G,11}+\delta^2_{F,G}\cdot\aleph_{F,G}+\delta^2_{G,12}\cdot\aleph_{G,12}+\delta^2_{G,H}\cdot\aleph_{G,H}-\varphi_G+\left(R_{x11}\cdot x_{11}+R_{y11}\cdot y_{11}\right)+B_{G,11}=0\ , \tag{63}$$

$$\chi\cdot\delta^2_{G,12}\cdot\aleph_{G,12}+\delta^2_{F,G}\cdot\aleph_{F,G}+\delta^2_{G,11}\cdot\aleph_{G,11}+\delta^2_{G,H}\cdot\aleph_{G,H}-\varphi_G+\left(R_{x12}\cdot x_{12}+R_{y12}\cdot y_{12}\right)+B_{G,12}=0\ , \tag{64}$$

$$\chi\cdot\delta^2_{G,H}\cdot\aleph_{G,H}+\delta^2_{F,G}\cdot\aleph_{F,G}+\delta^2_{G,11}\cdot\aleph_{G,11}+\delta^2_{G,12}\cdot\aleph_{G,12}+\delta^2_{H,13}\cdot\aleph_{H,13}+\delta^2_{H,14}\cdot\aleph_{H,14}+\delta^2_{H,I}\cdot\aleph_{H,I}-\left(\varphi_G+\varphi_H\right)+B_{G,H}=0\ , \tag{65}$$

$$\chi\cdot\delta^2_{H,13}\cdot\aleph_{H,13}+\delta^2_{G,H}\cdot\aleph_{G,H}+\delta^2_{H,14}\cdot\aleph_{H,14}+\delta^2_{H,I}\cdot\aleph_{H,I}-\varphi_H+\left(R_{x13}\cdot x_{13}+R_{y13}\cdot y_{13}\right)+B_{H,13}=0\ , \tag{66}$$

$$\chi\cdot\delta^2_{H,14}\cdot\aleph_{H,14}+\delta^2_{G,H}\cdot\aleph_{G,H}+\delta^2_{H,13}\cdot\aleph_{H,13}+\delta^2_{H,I}\cdot\aleph_{H,I}-\varphi_H+\left(R_{x14}\cdot x_{14}+R_{y14}\cdot y_{14}\right)+B_{H,14}=0\ , \tag{67}$$

$$\chi\cdot\delta^2_{H,I}\cdot\aleph_{H,I}+\delta^2_{G,H}\cdot\aleph_{G,H}+\delta^2_{H,13}\cdot\aleph_{H,13}+\delta^2_{H,14}\cdot\aleph_{H,14}-\varphi_H+\left(R_{xI}\cdot x_I+R_{yI}\cdot y_I\right)+B_{H,I}=0\ . \tag{68}$$

Використовуючи систему (33) - (68), будуємо компоненти тотожностей (28) і (29). Матриця $[s^p]$ матиме вигляд:

$$\left[s^p\right]=\left[X^p\quad Y^p\right], \tag{69}$$

де $\{X^p\}$ та $\{Y^p\}$ – вектори координат вузлів, які мають такий вигляд:

$$\left\{X^p\right\}^T=\left[x_B^p\quad x_C^p\quad x_D^p\quad x_E^p\quad x_F^p\quad x_G^p\quad x_H^p\right], \tag{70}$$

$$\left\{Y^p\right\}^T=\left[y_B^p\quad y_C^p\quad y_D^p\quad y_E^p\quad y_F^p\quad y_G^p\quad y_H^p\right]. \tag{71}$$

Матриця $[g^{p\text{-}1}]$ виглядатиме так:

$$\left[g^{p-1}\right]=\left[g_x^{p-1}\quad g_y^{p-1}\right], \tag{72}$$

де $\{g^{p\text{-}1}{}_x\}$ та $\{g^{p\text{-}1}{}_y\}$ – вектори крайових умов, які мають вигляд:

$$\left\{g_x^{p-1}\right\}=\begin{bmatrix}\aleph_{A,B}\cdot x_A+\aleph_{B,1}\cdot x_1+\aleph_{B,2}\cdot x_2\\ \aleph_{C,3}\cdot x_3+\aleph_{C,4}\cdot x_4\\ \aleph_{D,5}\cdot x_5+\aleph_{D,6}\cdot x_6\\ \aleph_{E,7}\cdot x_7+\aleph_{E,8}\cdot x_8\\ \aleph_{F,9}\cdot x_9+\aleph_{F,10}\cdot x_{10}\\ \aleph_{G,11}\cdot x_{11}+\aleph_{G,12}\cdot x_{12}\\ \aleph_{H,13}\cdot x_{13}+\aleph_{H,14}\cdot x_{14}+\aleph_{H,I}\cdot x_I\end{bmatrix}, \tag{73}$$

$$\left\{g_y^{p-1}\right\}=\begin{bmatrix}\aleph_{A,B}\cdot y_A+\aleph_{B,1}\cdot y_1+\aleph_{B,2}\cdot y_2\\ \aleph_{C,3}\cdot y_3+\aleph_{C,4}\cdot y_4\\ \aleph_{D,5}\cdot y_5+\aleph_{D,6}\cdot y_6\\ \aleph_{E,7}\cdot y_7+\aleph_{E,8}\cdot y_8\\ \aleph_{F,9}\cdot y_9+\aleph_{F,10}\cdot y_{10}\\ \aleph_{G,11}\cdot y_{11}+\aleph_{G,12}\cdot y_{12}\\ \aleph_{H,13}\cdot y_{13}+\aleph_{H,14}\cdot y_{14}+\aleph_{H,I}\cdot y_I\end{bmatrix}. \tag{74}$$

Матриця $[\Im^p]$ буде виглядати так:

$$\left[\Im^p\right]=\left[\Im_x^p\quad \Im_y^p\right], \tag{75}$$

де $\{\Im^p{}_x\}$ та $\{\Im^p{}_y\}$ – вектори компонентів зовнішніх впливів, що мають вигляд:

$$\left\{\Im_x^p\right\}^T=\left[-2\cdot x_B^p\quad -2\cdot x_C^p\quad -2\cdot x_D^p\quad\rightarrow\right.$$
$$\left.\rightarrow\ -2\cdot x_E^p\quad -2\cdot x_F^p\quad -2\cdot x_G^p\quad -2\cdot x_H^p\right], \tag{76}$$

$$\left\{\Im_y^p\right\}^T=\left[1\quad 1\quad 1\quad 1\quad 1\quad 1\quad 1\right]. \tag{77}$$

Матриця $[\aleph^{p\text{-}1}]$ матеме такий вигляд:

$$\left[\aleph^{p-1}\right]=\begin{bmatrix}A & C\\ B & D\end{bmatrix}. \tag{78}$$

Тут блоки $[A^{p\text{-}1}]$, $[B^{p\text{-}1}]$, $[C^{p\text{-}1}]$ і $[D^{p\text{-}1}]$ мають наступний вид:

$$[A]=\begin{bmatrix} -\begin{pmatrix} \aleph_{A,B}+\aleph_{B,1}+ \\ +\aleph_{B,2}+\aleph_{B,C} \end{pmatrix} & \aleph_{B,C}\cdot x_C & 0 & 0 \\ \aleph_{B,C}\cdot x_B & -\begin{pmatrix} \aleph_{B,C}+\aleph_{C,3}+ \\ +\aleph_{C,4}+\aleph_{C,D} \end{pmatrix} & \aleph_{C,D}\cdot x_D & 0 \\ 0 & \aleph_{C,D}\cdot x_C & -\begin{pmatrix} \aleph_{C,D}+\aleph_{D,5}+ \\ +\aleph_{D,6}+\aleph_{D,E} \end{pmatrix} & \aleph_{D,E}\cdot x_E \\ 0 & 0 & \aleph_{D,E}\cdot x_D & -\begin{pmatrix} \aleph_{D,E}+\aleph_{E,7}+ \\ +\aleph_{E,8}+\aleph_{E,F} \end{pmatrix} \end{bmatrix}, \qquad (79)$$

$$[B]=\begin{bmatrix} 0 & 0 & 0 & \aleph_{E,F}\cdot x_E \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \qquad (80) \qquad\qquad [C]^T=\begin{bmatrix} 0 & 0 & 0 & \aleph_{E,F}\cdot x_F \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, \qquad (81)$$

$$[D]=\begin{bmatrix} -\begin{pmatrix} \aleph_{E,F}+\aleph_{F,9}+ \\ +\aleph_{F,10}+\aleph_{F,G} \end{pmatrix} & \aleph_{F,G}\cdot x_G & 0 \\ \aleph_{F,G}\cdot x_F & -\begin{pmatrix} \aleph_{F,G}+\aleph_{G,11}+ \\ +\aleph_{G,12}+\aleph_{G,H} \end{pmatrix} & \aleph_{G,H}\cdot x_H \\ 0 & \aleph_{G,H}\cdot x_G & -\begin{pmatrix} \aleph_{G,H}+\aleph_{H,13}+ \\ +\aleph_{H,14}+\aleph_{H,I} \end{pmatrix} \end{bmatrix}. \qquad (82)$$

Вектор $\{\aleph^p\}$ виглядатиме так:

$$\{\aleph^p\}^T=[\,\aleph_{A,B}\ \ \aleph_{B,1}\ \ \aleph_{B,2}\ \ \aleph_{B,C}\ \ \aleph_{C,3}\ \ \aleph_{C,4}\ \ \aleph_{C,D}\ \ \aleph_{D,5}\ \ \aleph_{D,6}\ \ \aleph_{D,E}\ \ \aleph_{E,7}\ \rightarrow$$
$$\rightarrow\ \aleph_{E,8}\ \ \aleph_{E,F}\ \ \aleph_{F,9}\ \ \aleph_{F,10}\ \ \aleph_{F,G}\ \ \aleph_{G,11}\ \ \aleph_{G,12}\ \ \aleph_{G,H}\ \ \aleph_{H,13}\ \ \aleph_{H,14}\ \ \aleph_{H,I}\,]. \qquad (83)$$

Аналогічний вигляд матиме і вектор $\{\aleph^{p-1}\}$, за винятком зміни індексу номера ітераційного числення p-1.

Матриця $[(\delta^p)^2]$ буде виглядати наступним чином:

$$\left[\left(\delta^p\right)^2\right]=\begin{bmatrix} E & G \\ F & H \end{bmatrix}. \qquad (84)$$

Тут $[E]$, $[F]$, $[G]$ и $[H]$ – матричні блоки (розмірністю 11×11 кожен):

$$[E]=\begin{bmatrix}
\chi\cdot\delta^2_{A,B} & \delta^2_{B,1} & \delta^2_{B,2} & \delta^2_{B,C} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\delta^2_{A,B} & \chi\cdot\delta^2_{B,1} & \delta^2_{B,2} & \delta^2_{B,C} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\delta^2_{A,B} & \delta^2_{B,1} & \chi\cdot\delta^2_{B,2} & \delta^2_{B,C} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\delta^2_{A,B} & \delta^2_{B,1} & \delta^2_{B,2} & \chi\cdot\delta^2_{B,C} & \delta^2_{C,3} & \delta^2_{C,4} & \delta^2_{C,D} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \delta^2_{B,C} & \chi\cdot\delta^2_{C,3} & \delta^2_{C,4} & \delta^2_{C,D} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \delta^2_{B,C} & \delta^2_{C,3} & \chi\cdot\delta^2_{C,4} & \delta^2_{C,D} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \delta^2_{B,C} & \delta^2_{C,3} & \delta^2_{C,4} & \chi\cdot\delta^2_{C,D} & \delta^2_{D,5} & \delta^2_{D,6} & \delta^2_{D,E} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{C,D} & \chi\cdot\delta^2_{D,5} & \delta^2_{D,6} & \delta^2_{D,E} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{C,D} & \delta^2_{D,5} & \chi\cdot\delta^2_{D,6} & \delta^2_{D,E} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{C,D} & \delta^2_{D,5} & \delta^2_{D,6} & \chi\cdot\delta^2_{D,E} & \delta^2_{E,7} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{D,E} & \chi\cdot\delta^2_{E,7}
\end{bmatrix}, \qquad (85)$$

$$[F]=\begin{bmatrix} 0 & \cdots & 0 & \delta^2_{D,E} & \delta^2_{E,7} \\ 0 & \cdots & 0 & \delta^2_{D,E} & \delta^2_{E,7} \\ 0 & \cdots & 0 & 0 & 0 \\ \vdots & \iddots & \vdots & \vdots & \vdots \\ 0 & \cdots & 0 & 0 & 0 \end{bmatrix}, \qquad (86)$$

$$[G]=\begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \iddots & \vdots \\ 0 & 0 & 0 & \cdots & 0 \\ \delta^2_{E,8} & \delta^2_{E,F} & 0 & \cdots & 0 \\ \delta^2_{E,8} & \delta^2_{E,F} & 0 & \cdots & 0 \end{bmatrix}, \qquad (87)$$

$$[H]=\begin{bmatrix}
\chi\cdot\delta^2_{E,8} & \delta^2_{E,F} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\delta^2_{E,8} & \chi\cdot\delta^2_{E,F} & \delta^2_{F,9} & \delta^2_{F,10} & \delta^2_{F,G} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \delta^2_{E,F} & \chi\cdot\delta^2_{F,9} & \delta^2_{F,10} & \delta^2_{F,G} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \delta^2_{E,F} & \delta^2_{F,9} & \chi\cdot\delta^2_{F,10} & \delta^2_{F,G} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \delta^2_{E,F} & \delta^2_{F,9} & \delta^2_{F,10} & \chi\cdot\delta^2_{F,G} & \delta^2_{G,11} & \delta^2_{G,12} & \delta^2_{G,H} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \delta^2_{F,G} & \chi\cdot\delta^2_{G,11} & \delta^2_{G,12} & \delta^2_{G,H} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \delta^2_{F,G} & \delta^2_{G,11} & \chi\cdot\delta^2_{G,12} & \delta^2_{G,H} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & \delta^2_{F,G} & \delta^2_{G,11} & \delta^2_{G,12} & \chi\cdot\delta^2_{G,H} & \delta^2_{H,13} & \delta^2_{H,14} & \delta^2_{H,I} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{G,H} & \chi\cdot\delta^2_{H,13} & \delta^2_{H,14} & \delta^2_{H,I} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{G,H} & \delta^2_{H,13} & \chi\cdot\delta^2_{H,14} & \delta^2_{H,I} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \delta^2_{G,H} & \delta^2_{H,13} & \delta^2_{H,14} & \chi\cdot\delta^2_{H,I}
\end{bmatrix}. \qquad (88)$$

Вектор $\{\varphi^p\}$ буде виглядати так:

$$\begin{aligned}
\{\varphi^p\}^T = [\ & \varphi^p_{AB}\ \ \varphi^p_{B1}\ \ \varphi^p_{B2}\ \ \varphi^p_{BC}\ \ \varphi^p_{C3}\ \ \varphi^p_{C4}\ \rightarrow \\
\rightarrow\ & \varphi^p_{C,D}\ \ \varphi^p_{D,5}\ \ \varphi^p_{D,6}\ \ \varphi^p_{D,E}\ \ \varphi^p_{E,7}\ \rightarrow \\
\rightarrow\ & \varphi^p_{E,8}\ \ \varphi^p_{E,F}\ \ \varphi^p_{F,9}\ \ \varphi^p_{F,10}\ \ \varphi^p_{F,G}\ \rightarrow \\
\rightarrow\ & \varphi^p_{G,11}\ \ \varphi^p_{G,12}\ \ \varphi^p_{G,H}\ \ \varphi^p_{H,13}\ \ \varphi^p_{H,14}\ \ \varphi^p_{H,I}\ ] = \\
= [\ & \varphi^p_B\ \ \varphi^p_B\ \ \varphi^p_B\ \ \left(\varphi^p_B+\varphi^p_C\right)\ \ \varphi^p_C\ \ \varphi^p_C\ \rightarrow \\
\rightarrow\ & \left(\varphi^p_C+\varphi^p_D\right)\ \ \varphi^p_D\ \ \varphi^p_D\ \ \left(\varphi^p_D+\varphi^p_E\right)\ \ \varphi^p_E\ \rightarrow \\
\rightarrow\ & \varphi^p_E\ \ \left(\varphi^p_E+\varphi^p_F\right)\ \ \varphi^p_F\ \ \varphi^p_F\ \ \left(\varphi^p_F+\varphi^p_G\right)\ \rightarrow \\
\rightarrow\ & \varphi^p_G\ \ \varphi^p_G\ \ \left(\varphi^p_G+\varphi^p_H\right)\ \ \varphi^p_H\ \ \varphi^p_H\ \ \varphi^p_H\ ].
\end{aligned} \qquad (89)$$

Тут значення вузлових потенціалів відповідно до виразів (26) і (31) необхідно обчислювати за формулою:

$$\varphi^p_i = y^p_i - (x^p_i)^2. \qquad (90)$$

Вектор очікуваних значень потенціалів $\{\varphi^/\}$ повинен включати тільки нульові значення:

$$\begin{aligned}
\{\varphi^/\}^T = [\ & \varphi^/_{AB}\ \ \varphi^/_{B1}\ \ \varphi^/_{B2}\ \ \varphi^/_{BC}\ \ \varphi^/_{C3}\ \ \varphi^/_{C4}\ \rightarrow \\
\rightarrow\ & \varphi^/_{C,D}\ \ \varphi^/_{D,5}\ \ \varphi^/_{D,6}\ \ \varphi^/_{D,E}\ \ \varphi^/_{E,7}\ \rightarrow \\
\rightarrow\ & \varphi^/_{E,8}\ \ \varphi^/_{E,F}\ \ \varphi^/_{F,9}\ \ \varphi^/_{F,10}\ \ \varphi^/_{F,G}\ \rightarrow \\
\rightarrow\ & \varphi^/_{G,11}\ \ \varphi^/_{G,12}\ \ \varphi^/_{G,H}\ \ \varphi^/_{H,13}\ \ \varphi^/_{H,14}\ \ \varphi^/_{H,I}\ ] = \\
= [\ & 0\ \ 0\ \ 0\ \ (0+0)\ \ 0\ \ 0\ \rightarrow \\
\rightarrow\ & (0+0)\ \ 0\ \ 0\ \ (0+0)\ \ 0\ \rightarrow \\
\rightarrow\ & 0\ \ (0+0)\ \ 0\ \ 0\ \ (0+0)\ \rightarrow \\
\rightarrow\ & 0\ \ 0\ \ (0+0)\ \ 0\ \ 0\ \ 0\ ].
\end{aligned} \qquad (91)$$

Побудувавши вирази (69) − (91), по черзі вирішуємо системи (28) і (29), використовуючи циклічне ітераційне числення. У Табл.1 наведені крайові та початкові умови, а також виконані в якості прикладів розрахунки координат і параметрів жорсткості дискретного образу, показаного на Рис.1, *а*.

Для даної постановки задачі початкові параметри жорсткості для всіх зв'язків прийняті рівними $\aleph^0$ = 5. Початкова форма моделі на першому етапі ітераційного числення була отримана без урахування вузлових навантажень (з використанням координат фіксованих вузлів моделі, представлених на Рис.1, *а*).

Слід зазначити, що при заданні крайових умов – фіксованих вузлів моделі – лише один вузол був інцидентним графіку досліджуваної функції (вузол *I*). Однак зовсім не обов'язково, щоб хоч один базовий вузол моделі точно збігався з шуканим графіком.

Табл. 1. Крайові умови і результати моделювання
Table 1. Boundary conditions and simulation results

Вид даних		Номер задачі							
		№ 1			№ 2			№ 3	
Кількість ітерацій		1	15	30	1	30	100	1	30
Коефіцієнт χ		0	0	0	0	0	0	-	-
Координати вільних вузлів моделі (x_i, y_i)	x_B	1.3065 (1.0982)*	1.2537	1.1701	1.025	1.5929	1.6033	0.353	0.855
	x_C	1.7033 (1.3929)*	1.7132	1.6773	1.3	1.7156	1.7678	0.707	1.309
	x_D	1.8256 (1.4732)*	1.9538	2.0067	1.375	1.8257	1.8746	1.06	1.651
	x_E	1.8687 (1.5000)*	2.1178	2.2167	1.4	2.0008	2.0419	1.414	1.938
	x_F	1.9016 (1.5268)*	2.2779	2.4075	1.425	2.22	2.2462	1.767	2.191
	x_G	1.9771 (1.6071)*	2.452	2.59	1.5	2.4152	2.4285	2.121	2.419
	x_H	2.2159 (1.9018)*	2.6681	2.7809	1.775	2.6125	2.62	2.474	2.631
	y_B	1.9268 (2.0000)*	1.9336	1.9283	1	2.5354	2.5659	1	1
	y_C	2.9072 (3.0000)*	2.965	2.9395	2	3.0036	3.1175	2	2
	y_D	3.9021 (4.0000)*	4.089	4.1329	3	3.4744	3.5165	3	3
	y_E	4.9010 (5.0000)*	5.0879	5.119	4	4.1834	4.1718	4	4
	y_F	5.9021 (6.0000)*	6.0509	6.0652	5	5.0631	5.0456	5	5
	y_G	6.9072 (7.0000)*	6.9701	6.9758	6	5.9049	5.8975	6	6
	y_H	7.9268 (8.0000)*	7.9264	7.9418	7	6.8624	6.8642	7	7
Значення потенціалів вільних вузлів моделі (φ_i)	φ_B	0.2199	0.3619	0.5592	-0.0510	-0.002	-0.005	0.875	0.27
	φ_C	0.0058	0.0301	0.1262	0.3100	0.0603	-0.008	1.5	0.288
	φ_D	0.5694	0.2718	0.1062	1.1094	0.1411	0.0024	1.875	0.274
	φ_E	1.4092	0.6028	0.2051	2.0400	0.18	0.0024	2.001	0.244
	φ_F	2.2860	0.862	0.2691	2.9694	0.1347	8E-05	1.876	0.201
	φ_G	2.9984	0.958	0.2678	3.7500	0.0716	-2E-04	1.501	0.146
	φ_H	3.0168	0.8075	0.2086	3.8494	0.0374	-4E-05	0.877	0.08
Параметри жорсткості зв'язків моделі ($\aleph_{i,j}$)	$\aleph_{A,B}$	5	5.6977	6.8888	0.3	0.2851	0.2285	-	-
	$\aleph_{B,1}$	5	6.0637	7.9506	0.3	0.2618	0.1592	-	-
	$\aleph_{B,2}$	5	5.5931	6.4665	0.3	0.3582	0.2238	-	-
	$\aleph_{B,C}$	5	5.3758	6.29	0.3	3.5763	2.1496	-	-
	$\aleph_{C,3}$	5	4.7145	4.5658	0.3	1.5915	1.5438	-	-
	$\aleph_{C,4}$	5	4.4983	4.2408	0.3	1.8224	1.7307	-	-
	$\aleph_{C,D}$	5	5.5365	5.7206	0.3	10.835	12.143	-	-
	$\aleph_{D,5}$	5	5.5816	5.8237	0.3	2.6614	2.8775	-	-
	$\aleph_{D,6}$	5	6.657	7.5612	0.3	4.1047	4.7992	-	-
	$\aleph_{D,E}$	5	8.3207	9.7416	0.3	11.723	13.445	-	-
	$\aleph_{E,7}$	5	6.2106	6.6247	0.3	3.3998	3.6309	-	-
	$\aleph_{E,8}$	5	9.6376	12.389	0.3	7.8471	9.3423	-	-
	$\aleph_{E,F}$	5	11.117	13.6	0.3	11.792	12.632	-	-
	$\aleph_{F,9}$	5	6.7019	7.2024	0.3	3.372	3.4572	-	-
	$\aleph_{F,10}$	5	13.953	20.224	0.3	12.806	14.109	-	-
	$\aleph_{F,G}$	5	13.878	17.197	0.3	13.537	13.899	-	-
	$\aleph_{G,11}$	5	6.9394	7.4171	0.3	2.9764	2.9969	-	-
	$\aleph_{G,12}$	5	21.179	34.33	0.3	20.653	21.435	-	-
	$\aleph_{G,H}$	5	13.504	16.2	0.3	9.5555	9.6564	-	-
	$\aleph_{H,13}$	5	6.3345	6.6281	0.3	1.7256	1.7363	-	-
	$\aleph_{H,14}$	5	33.405	60.819	0.3	29.869	31.265	-	-
	$\aleph_{H,I}$	5	10.238	12.024	0.3	4.2194	4.2747	-	-

*В дужках наведено координати вільних вузлів моделі до початку дії на них поля $\overline{\mathfrak{I}}$.

Розглянемо тепер перший із запропонованих способів побудови дискретних образів неявних функцій на основі їх апроксимаційних кінцево-різницевих співвідношень і приватних похідних.

Для застосування даного методу необхідно в першу чергу отримати приватні похідні, що входять в праву половину рівняння (7). У нашому випадку доцільно застосовувати саме це рівняння, так як для подальшого порівняння цього способу з раніше розглянутим, бажано визначити з його допомогою координати відповідної кількості вільних вузлів моделі (як і на Рис.1), розміщених для простоти обчислень з рівним кроком h_y = 1 по осі *Oy*. Отже, шукані похідні (12) – (16) будуть мати наступний вигляд:

$$\varsigma'_x(x_i, y_i) = \partial\varsigma(y_i - x_i^2)/\partial x = -2 \cdot x_i\,, \quad (92)$$

$$\varsigma''_{xx}(x_i, y_i) = \partial^2\varsigma(y_i - x_i^2)/\partial x^2 = -2\,, \quad (93)$$

$$\varsigma'_y(x_i, y_i) = \partial\varsigma(y_i - x_i^2)/\partial y = 1\,, \quad (94)$$

$$\varsigma''_{yy}(x_i, y_i) = \partial^2\varsigma(y_i - x_i^2)/\partial y^2 = 0\,, \quad (95)$$

$$\varsigma''_{xy}(x_i, y_i) = \partial^2\varsigma(y_i - x_i^2)/\partial x\partial y = 0 \cdot \quad (96)$$

Використовуючи вирази (92) – (96), будуємо систему рівнянь типу (7) для вільних вузлів моделі, представленої на Рис.2, *а*. Слід зазначити, що перший і останній вузли дискретної моделі повинні належати графіку досліджуваної функції ς(*x*,*y*). Ці два вузла будуть служити крайовими умовами моделювання. Система буде мати вигляд:

$$x_A - 2 \cdot x_B + x_C = -1/(4 \cdot x_B^3)\,, \quad (97)$$

$$x_B - 2 \cdot x_C + x_D = -1/(4 \cdot x_C^3)\,, \quad (98)$$

$$x_C - 2 \cdot x_D + x_E = -1/(4 \cdot x_D^3)\,, \quad (99)$$

$$x_D - 2 \cdot x_E + x_F = -1/(4 \cdot x_E^3)\,, \quad (100)$$

$$x_F - 2 \cdot x_F + x_G = -1/(4 \cdot x_F^3)\,, \quad (101)$$

$$x_F - 2 \cdot x_G + x_H = -1/(4 \cdot x_G^3)\,, \quad (102)$$

$$x_G - 2 \cdot x_H + x_I = -1/(4 \cdot x_H^3)\,. \quad (103)$$

Вирішуючи цю систему відносно координат вільних вузлів, ми отримаємо дискретний образ графіка досліджуваної функції, використовуючи ітераційне числення. Однак, в якості похибки даного числення можна розглядати лише абсолютну або відносну похибку між поточними і попередніми координатами вузлів. При цьому, впливати на рівень точності задоволення функції ς(*x*,*y*) не представляється можливим. Таким чином, дана методика не дозволяє контролювати точність співпадіння точок дискретного образу, що моделюється, зі своїм безперервним графіком. Результати рішення системи (97) – (103) представлені в Табл.1 (задача №3). На Рис.1, *б* представлено результуючу форма дискретного образу неявної функції (31).

Очевидно, що такий спосіб побудови дискретної кривої неявної функції в досліджуваній області є більш залежним від початкових умов моделювання, що робить його менш ефективним.

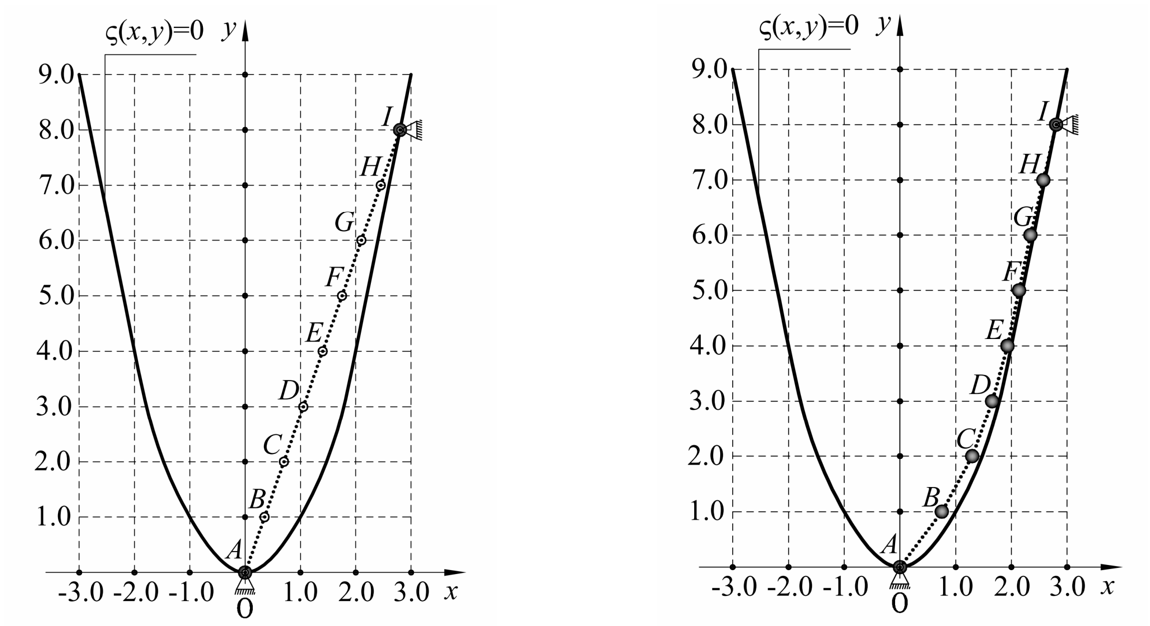
Для додаткової демонстрації переваг попереднього методу моделювання дискретних образів вирішимо аналогічну до попередньої задачу з використанням параметричних рівнянь стану, і використовуючи дискретний образ, топологічно подібний до моделі на Рис.1, *а*, однак зміщений нижче, як показано на Рис.3, *а*.

В даному прикладі ми будемо використовувати дещо інший підхід, який полягає в тому, що рівняння рівноваги вільних вузлів моделі повинні складатися без урахування вектора зовнішнього впливу $\bar{\Im}$, тобто:

$$\bar{\Im}_i = 0 \cdot \bar{\mathbf{e}}_x + 0 \cdot \bar{\mathbf{e}}_y\,. \quad (104)$$

Можливість такого підходу була пояснена в [7]. Його доцільність полягає в тому, щоб в разі, коли градієнтне векторне поле змушує більшість вузлів переміщатися в одному і тому ж напрямку, зосереджуючи їх в одній і при тому не дуже інформативній області, дати можливість цим вузлам досягти найближчих або максимально інформативних ділянок досліджуваної області. При цьому кінцеве положення вузлів залежить тільки від розподілу параметрів жорсткості (і як наслідок внутрішніх зусиль) в зв'язках моделі, і перебуває під впливом лише вузлових значень цільових функцій (вузлових потенціалів). Для даної постановки задачі початкові параметри жорсткості для всіх зв'язків прийняті рівними $\aleph^0$ = 0.3.

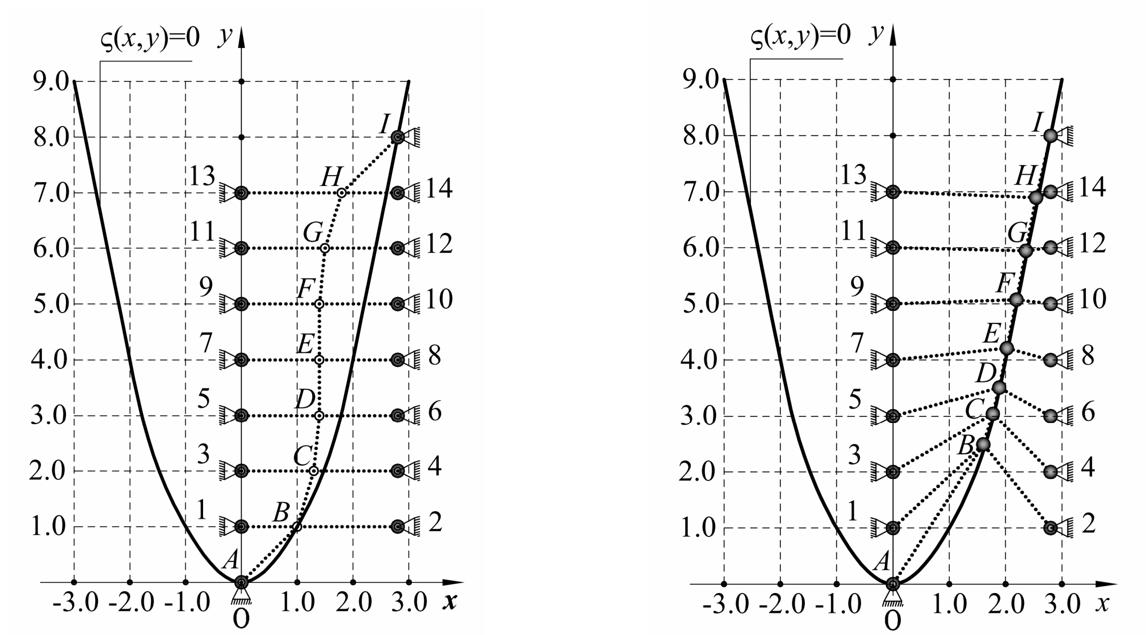
Результати моделювання дискретного образу з використанням відповідного підходу представлені в Табл.1 (задача №2)



а *б*

Рис.2. Побудова дискретного образу кривої неявної функцію з використанням скінченно-різницевих співвідношень і часткових похідних в рівняннях типу (7): *а* − дискретний образ досліджуваної функції на першому етапі (топологічна схема); *б* − дискретний образ досліджуваної функції після сходження ітераційного процесу

Fig.2. The construction of a discrete image of curved line of an implicit function using finite-difference relations and partial derivatives in equations of the type (7): *а*− the discrete image of the function on the first stage (the topological scheme); *б* − the discrete image of the function after the iteration process converges



а *б*

Рис.3. Побудова додаткового дискретного образу кривої неявної функції з використанням параметричних рівнянь типу (24) і (25): *а* − дискретний образ досліджуваної функції на першому етапі (топологічна схема); *б* − дискретний образ досліджуваної функції після сходження процесу ітераційного числення

Fig.3. The construction of an additional discrete image of the curved line of an implicit function using parametric equations of types (24) and (25): *а* − the discrete image of the function on the first stage (the topological scheme); *б* − the discrete image of the function after the iteration process converges

та проілюстровані на Рис.3, *б*. Як видно на цьому рисунку, вільні вузли моделі з високою точністю інцидентні графіку функції $\varsigma(x,y)$, однак розташовуються на ньому не з регулярним кроком, на відміну від вузлів дискретного образу, отриманого з використанням різницевих співвідношень.

Слід зазначити, що метод, заснований на застосуванні параметричних рівнянь дозволяє визначити координати з будь-якою заданою точністю, яка відповідає точності задоволення цільовій функції, тобто досліджуваній неявній функції.

ВИСНОВКИ І ПЕРСПЕКТИВИ ПОДАЛЬШИХ ДОСЛІДЖЕНЬ

Очевидно, перший із запропонованих способів отримання дискретних образів неявних функцій є більш ефективним і гнучким по відношенню до крайових і початкових умов моделювання. При цьому існує можливість як враховувати, так і ігнорувати векторне градієнтне поле впливу на вільні вузли моделі. Врахування даних впливів найбільш актуальне у випадку, якщо графік досліджуваної функції являє собою візуалізацію ізоліній або характерних обводів реальних фізичних полів (таких як температурне, вологістне або електричне) або об'єктів (технічних форм деталей машин і механізмів) відповідно. При цьому, якщо досліджувана функція несе інформацію про характер розвитку абстрактних процесів або систем (таки як економічні, фінансові чи соціальні), то доцільніше ігнорувати векторні компоненти градієнтного поля зовнішніх впливів, оскільки вони можуть привести до неінформативного розташування вільних вузлів шуканого дискретного образу.

У той же час, другий спосіб побудови дискретних каркасів кривих неявних функцій з використанням скінченно-різницевих співвідношень не вимагає складання і вирішення додаткової системи рівнянь стану зв'язків, а тому є більш легким і швидким в застосуванні. Його слабкою стороною є обмеження рівня досяжної точності моделювання.

На завершення слід зазначити, що кожен з представлених способів може бути цілком застосовним для вирішення різних класів задач. Перший спосіб є універсальним і особливо цікавим, так як одержувані на основі його застосування дискретні образи представляють собою моделі реальних стрижневих (та/або вантових) безмоментних конструкцій, форма яких може з високою точністю відповідати безперервному аналогу графіків досліджуваних функцій. Даний спосіб дозволяє якісно розширити інструментальну базу архітекторів і конструкторів щодо вирішення завдань формоутворення. Другий з розглянутих способів також може бути застосовний при проектуванні архітектурних форм і обводів технічних поверхонь, проте в більшості випадків лише на етапі побудови ескізів, оскільки точність його не достатня для вирішення завдань конструктивної надійності і стійкості.

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Shaping of the frameworks of technical forms, which defined by implicit functions on a plane

Volodymyr Skochko

Abstract. During designing the shapes of working surfaces of machines and mechanisms, technological equipment, as well as complex building structures, which exposed to external forces, engineers and researchers resort to the use of physical and mathematical methods for obtaining the functions of appropriate forms. Very often, the functions of such forms must be constructed on the basis of analysis of the kinematics of the motion of constructive elements complex of the working equipment or on the basis of solving the systemic optimization tasks basing on the search for conditional extremums. As a result, the received functions take an implicit form, and the process of constructing their graphs consist in a search of individual isolines of the potential fields on the coordinate plane.

In this paper, the effectiveness of two methods of constructing discrete images of functions, defined on the plane in implicit form is considered. The first method involves the combined using of the finite difference method and formulas for finding derivatives of implicit functions of differential geometry. The second method provides the realization of the process of shaping a discrete analogue of the model of a physical grid structure with the subsequent control of the shape of this model to move its nodes to points that satisfy to given implicit function. An example of using both approaches is considered to compare the accuracy of the incidence of the obtained discrete models coordinates to the graph of the given implicit function. The advantages and disadvantages of the proposed approaches are analyzed.

Keywords: morphogenesis, discrete image, implicit functions, numerical methods, finite differences, differential geometry, parametric equations.

Geoportal as a means to popularize geological heritage of Ukraine

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Abstract. The article discusses issues of using geological natural monuments (GNM) for scientific and educational purposes. It is a part of a general problem of preservation and use of geological heritage of the Earth, which has become internationally important lately. Local and international practice shows the need for thematic geotours that heavily rely on geological natural monuments.

Geological tourism has a potential to improve socio-economic situation of local communities in Ukraine, to preserve and popularize Earth sciences. As of this day, there are no means to draw public attention to Ukrainian geoheritage and geotourism, which makes this research highly relevant.

Geoportals and web GIS components will enable ordinary citizens to interact with a map of Ukrainian GNM, obtain interesting information, thereby getting involved in geological tourism themselves. To achieve this goal, the following goals were accomplished: gathering information on geoheritage in Ukrainian regions, designing and filling a database, creating interactive maps, developing a concept and a prototype of a corresponding geoportal.

The article starts by explaining the concepts of geological tourism, natural monuments and their significance. Discussed are important related concepts as geoheritage, geoheritage and geopark. Further described is the classification of geological landmarks. The main part introduces a concept of geoportals and methodology to develop a geoportal about geological tourism in Ukraine. It is expected that a developed geoportal with web GIS will encourage sharing within general audience and systematize information about objects of geological heritage in Ukraine.

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Keywords: geotourism, geological tourism, geological natural monuments, geoportal, web GIS, spatial database.

INTRODUCTION

Research problem. Geological tourism is an important part of tourism, because it provides essential insights into the past of a region and prospects for its future development. Despite the economical crisis in Ukraine, tourism industry has been remaining stable. Conditions that allow it include advantageous geographical location, significant recreational potential, favorable climatic conditions, well-developed transportation network, abundant natural and cultural heritage. Ukraine is a unique country in Europe due to its various natural resources, unique landforms, relict flora and fauna, diverse and unique culture. However, there are issues that prevent development of a novel type of tourism, namely, geological tourism.

Aspects of the problem. Among unresolved problems of geological tourism highlighted is the problem of insufficient information coverage of geological heritage, lack of transportation infrastructure and facilities, inappropriate conditions of the natural landmarks etc. In addition, there are a number of obsolete laws and regulations about protected areas that hinder the development of natural parks, hence, any form of tourism in the areas. It becomes a major obstacle to popularize certain routes.

Relevance of the research lies in novelty of geological tourism to engage people in recreational and scientific activity while preserving geosites. Development of geotourism in Ukraine, a country that has multiple prominent geological landmarks, creates an opportunity to promote this niche to an international level, improve socio-economical situation, preserve nature and popularize geosciences.

Recent research and publications. Ukrainian Society for Nature Conservation and the Ministry of Geology of the USSR publicized first academic works on the importance of environmental protection and conservation of geological heritage in the 1960 s. In 1984, there was a geological map of attractions Ukraine published (O.I.Zaryckyj, N.E.Korotenko, K.O. Sukhodolskyi, O.S.Shyrytsya); in 1985 a publisher “Naukova dumka” printed a reference book and a guide “Geologicheskiye pamyatniki Ukrainy” (Geological landmarks of Urkaine) (auth. N.E.Korotenko, O.S.Shyrytsya, A.Y.Kanyevskyy et al.). This followed published guides to several regions of Ukraine (V.G.Ena “Landshaftnyye pamyatniki” (Landscape monuments), 1966; V.I.Lebedynskyy "Geologicheskiye ekskursii po Krymu” (Geological tours of Crimea), 1976 etc. Thus, the 1960 − 1980 s was the beginning of a long-term focus on identification, certification and the assignment of status of protected areas to Ukrainian geological landmarks.

Subsequently, a fundamental work “Heolohichni pamyatky Ukrayiny” (Geological landmarks of Ukraine) [2] was published, the European Association for the protection of geological heritage and the European register of geological objects of Ukraine were established; International Union of Geological Sciences created a project Geosites under the auspices of UNESCO etc.

Academics N.P.Gerasimenko, A.A.Ishchenko, V.V.Manyuk, V.P.Gritsenko study issues of identification and protection of geological sites. M.V.Kosmachova’s works are dedicated to ranking geological and geographical natural landmarks according to of their scientific, educational and practical importance [9]. Since 2006 there were two international conferences in Ukraine on environmental protection in the geological field and popularization of geo-landmarks [12].

Application of geographic information systems (GIS) for the geological tourism was developed first for Crimean region [13]. In 2011, National Service of Geology and Mineral Resources of Ukraine announced a project “Capacity development of geographic information industry in Ukraine” under a bilateral Finnish-Ukrainian program. It included development of a web portal with a section devoted to “Geological Tourism” [14]. Unfortunately, the web portal does not function. All of this resultes in a shortage of information resources to draw public attention to geological landmarks, popularize geoheritage and importance of geoconservation.

A term “geotourism” was first introduced by a British scientist Thomas Hose: “The provision of interpretive and service facilities to enable tourists to acquire knowledge and understanding of the geology and geomorphology of a site (including its contribution to the development of the Earth sciences) beyond the level of mere aesthetic appreciation” [3]. Based on conducted studies, a Polish researcher Piotr Mihon [1] indicated that a prefix “geo” relates to “geology, geomorphology and natural features of the landscape such as landforms, fossils, rocks and minerals, with a focus on identifying and understanding processes that formed these elements of the environment".

Polish authors Tadeusz Slomka and Alicja Kisieska-Svidzerska [1] emphasize educational and emotional aspects associated with visiting geological and geomorphological sites. According to them, geotourism is a type of tourism based on studies of geological (geomorphological) objects and processes, as well as on aesthetic impressions about the natural site.

METHODOLOGY

The aim of the work is popularization (and, eventually, commercialization) of geological heritage on the Internet using a web technologies and server GIS, which are cornerstones of a geoportal (geographical web portal). Geotourism can be defined through a didactic function, and its main goal is to interpret scientific knowledge in geology and geomorphology for public.

The objectives are to design and fill a spatial database of Ukrainian geological landmarks, develop of a fully-functional prototype of a geoportal about geotourism with web maps, multimedia and informative content.

The research object are geological landmarks of Ukraine, attracting them to the hiking trails will promote their preservation and promotion.

RESULTS

To analyze the prospects of tourism industry in Ukraine, one must emphasize that tourism sphere intertwines both economical and social factors. Precisely society should be central to novel national tourism policies, development of which can positively influenceeconomic and social situation of Ukraine, stimulate a number of important sectors,improve an image of Ukraine in the global arena. There was a SWOT analysis conducted (Table 1) to confirm the for geotourism development.

The following are the most important characteristics of geological tourism [8]:

- protects and preservs the environment;
- stimulates infrastructure development and socio-economic growth of local communities;
- involves educational activities within the geosciences.

Lack of available and integrated tourism database rather reduces possibilities of promoting this new and attractive type of activity. Therfore, systematic work aimed at registration, accounting and visualization of information on geosites is highly important.

Since 2004 UNESCO strongly supports geotourism for educational, environmental and socio-economical factors. The Division of Ecological and Earth Sciences at UNESCO presented a new concept called "International Geosciences and Geoparks Programme", and in 2002 there was a special UNESCO program launched called "Global Network of National Geoparks". Currently, it includes 120 geoparks in 33 countries [9].

This concept is consistent with the trend of integration of science and culture, while recognizing the importance of preserving the physical landscape. In addition to educational and training opportunities, tourism facilities have a great potential to increase awareness and understanding of geological heritage and environmental protection. During geotourism activities, the audience, children or adults, locals or tourists, can learn about the geological history of the area directly and comprehend various geological processes. This is a clear communication of science to the general public.

A geological landmark is a unique natural or anthropogenic object that characterizes local and/or regional geological processes and their results; has a scientific, historic, aesthetic, and educational value [15]. To map these sites on web, we used the following classification of geological natural landmarks [10]: *mineralogical* – sights with mineral resources; *petrographic* – rock outcrops that are characteristic of certain petrographic formations; *stratigraphic* – outcrops of stratified formations that characterize relative geological age of these rocks; *hydrogeological* – unique

Table 1. SWOT analysis of geotourism development in Ukraine

Strengths	Weaknesses
• convenient economic and geographical position; • significant natural and recreational potential of protected areas (about 4% of the national territory), which can be a possible site of geoparks • contributes to other alternative types of tourism (educational, sports, green, agro- tourism etc.) • abundant natural and recreational resources • increasing rates of infrastructure development for recreational use • wealthy historical and cultural heritage, unique ethnic and cultural identity of Ukrainians; plentiful national traditions and crafts, festivals • multiple historical and cultural monuments (about 130,000 monuments)	• negative image of the country due to political issues and conflict in the Eastern Ukraine • slow economic development • insufficient information provision • underdeveloped social, industrial, service infrastructure • poor training of locals in the service and touristm area • underestimation of the value of natural landmarks by locals • unsatisfactory condition and quality of transport services • poor maintenance of historical and cultural monuments • weak support from the government and private sector • underfunded scientific research in earth sciences
Threats	**Opportunities**
• poor coordination between organizations involved in geotourism and green tourism • lack of common strategic objectives for geotourism development • unstable political and economic situation is not conducive to foreign investors • damage and destruction of geological objects during tourism activities • overuse and depletion of natural resources • negative impacts of natural disasters on the objects of geotourism • insufficient control over the use of natural resources (deforestation, unauthorized hunting, fishing etc.) • insufficient educational provision for geotourism activities	• socio-economic growth, since geotourism development promotes capital inflow, creates employment opportunities and improves the quality of life • influx of tourists contributes to protection and restoration of cultural and historical monuments • geoparks (especially with a member status of the European Geoparks Network) can ensure preservation of geological heritage • new tourism infrastructure and trails • improvement of rural dwellings, rural social infrastructure, services etc. • increased international cooperation and exchange of experience in geotourism, green tourism

groundwater springs; *paleontological* – sights with fossils of ancient organism; *geochronological* –reflecting the chronological sequence of rock formations; *tectonic* – sites with evidence of crustal movements, geological structures; *complex* – several classes of geological landmarks. This classification was expanded to provide users with a more detailed information to 15 classes. which belong to the classification system developed in the work [4]. Additional classes include *volcanic, geomorphological, speleological, cosmogenic, historical mining, glacial, coastal and aquatic, museum collection*. Although this classification provides types according to subject and genetic principles, this expansion has a great advantage (namely, an opportunity to choose from a greater number of classes) in the context of interaction with future geoportal users.

For the last years, the use of GIS for tourism management and planning has been increasing [15]. Existing geographic information systems, literature, reports from government institutions, and public data provide a large volume of material for identification of potential geotourism areas. Analysis of their tourism potential in the context of other environmental and infrastructure datasets can be done with

GIS tools. It is also possible to analyze suitability of these areas with several geoprocessing tools, such as buffer analysis of potential threat areas or analysis of access level for different visitors (analyzing types and slopes of surfaces), distance to existing tourism clusters, etc. [16].

Despite apparent disadvantages, scanned paper maps are still widely used. However, over time these static maps will be replaces with interactive computer versions [15]. For example, a user of a tourism geoportal has a possibility plan a route, click on symbols on the map to obtain detail content make requests, view photos, and navigate to related sites, and receive information about accommodation and tours.

Technological advancement provided new tools, user interface and options to interact with web maps. For instance, these platforms include Google Maps, ArcGIS Online, MapBox, GISCloud, MangoMap, NextGIS, CartoDB and others. They provide to a publisher web applications, mapping services, which can be embedded with HTML code into other web pages.

Web technologies are an extremely powerful tool and relatively inexpensive compared to traditional printing. Geotourism as a new and attractive industry can use these benefits to popularize geological heritage and market touristic activities on geosites. The conceptual idea is to visualize a desired image of a specific destination for future visitors, while providing comprehensive information, interesting and interactive science communication content. Web GIS is the best option to achieve those goals by transmission of spatial and attributive information. Web technologies can significantly improve "intelligence" of generated thematic maps (Fig.1) [15].

Fig.1. Increasing the "intellectual" level of web maps

Phases of the web portal development for geotourism industry are introduced on Fig.2.

The following features will be implemented on the geoportal about geotourism in Ukraine in the order of importance:

- publication and search for GIS resources;
- publication of information on geological landmarks and multimedia content;
- simple queries (identification of objects, filtering of attributes etc.);
- support for multiple languages;
- individualization geoportals, namely, support for user profiles.

It was decided to use the existing web platforms – ArcGIS Online and Web Applications. Ready-made technological solutions can significantly shorten a web development time and allow to focus on concepts, purpose and design of future web products. In addition, this platform is free for a limited use and universal. The problem of this solution is that web applications do not integrate a service and database connection with a free license. As a solution, open-source tools can be used such as Boundless Suite that packages several programs and libraries for coherent data management and building web maps. Open-source software is low-cost, free to use and modify compared to proprietary software. However, it is not straightforward to use, which means longer product development and need for technological support; open-source software also often has issues with compatibility.

A database management system (DBMS) was used to manage spatial information on geological landmarks. The relational database was designed to effectively store, create relations between stored items and query them. Queried results are output as a table and provide necessary information on geosites. These are further shown in a GIS software, on a web map or geoportal. Such queries allow fast processing of spatial data, such as changing the geometry and projection, filtering and modifing items etc.

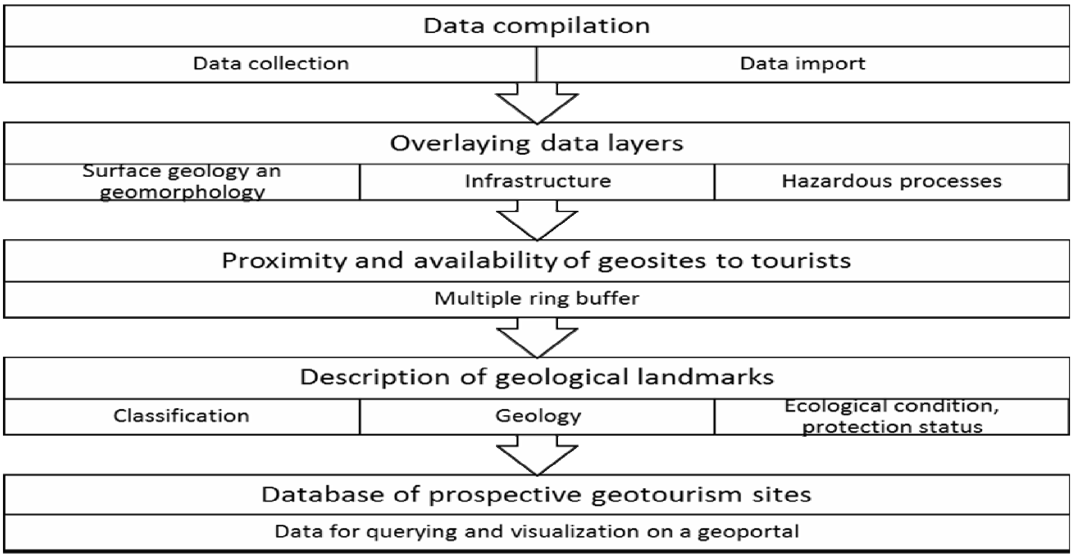

Fig.2. Phases of the geotourism web portal development

PostgreSQL is a popular open-source object-relational DBMS. With the PostGIS spatial extension, it allows organizing, visualizing and analyzing spatial data. As a result, this DBMS made it possible to efficiently store and process coordinates and attributive information of selected geological landmarks. This can also be achieved in a GIS software (ArcGIS, QGIS etc.). However, an object-relational DBMS was chosen for several advantages:

1) it creates more complex spatial relations and queries;

2) allows integrating data to any other database or exporting to multiple file formats;

3) easily introduces relationships between fields and hierarchical database models;

4) natively uses SQL language.

The first step was designing such a PostgreSQL database (Fig.3). Such relationships and tables were created so as to provide a user with a brief but informative description of a geolandmark, such as name, location, coordinates, text description, classification, tectonic structure, official registration status of a protected area, web links to multimedia content (photographs).

The classification table consists of 15 items according to the previously given classification of geological natural landmarks. A user is able to obtain chrono-stratigraphic relationships due to the hierarchical relations between tables (relations "father" − "child"). For example, after making a query for Precambrian geological objects, the user will be given objects that span all eras and periods of Precambrian. This is accomplished by using the server-side programming language (e.g. PHP, Python).

There were nearly 400 geological natural landmarks added to the database; the majority of them are prospective geotourism sites. Spatial and attribute information was collected from the books “Geologichni pamiatky Ukrayiny” (Geological landmarks of Ukraine) [2], open Wikipedia data and governmental reports on natural reserve fund. We should recognize that there are potential limitations associated with existing data on the geological monuments and tourism in Ukraine. For less-documented areas, more information can be acquired through field studies and on-site documentation.

Subsequently, point features are visualized using ArcGIS Online and ArcGIS Web Application. The free license allows uploading geospatial data files, viewing and editing them as a table, customizing web visualization. ArcGIS Web Application is simple analogue of geoportals used by scientists, journalists and organizations around the world to publish maps and data visualizations, to present multimedia and text content. Web Application is generally used for storytelling or integration with enterprise solutions and server support for governmental and research projects.

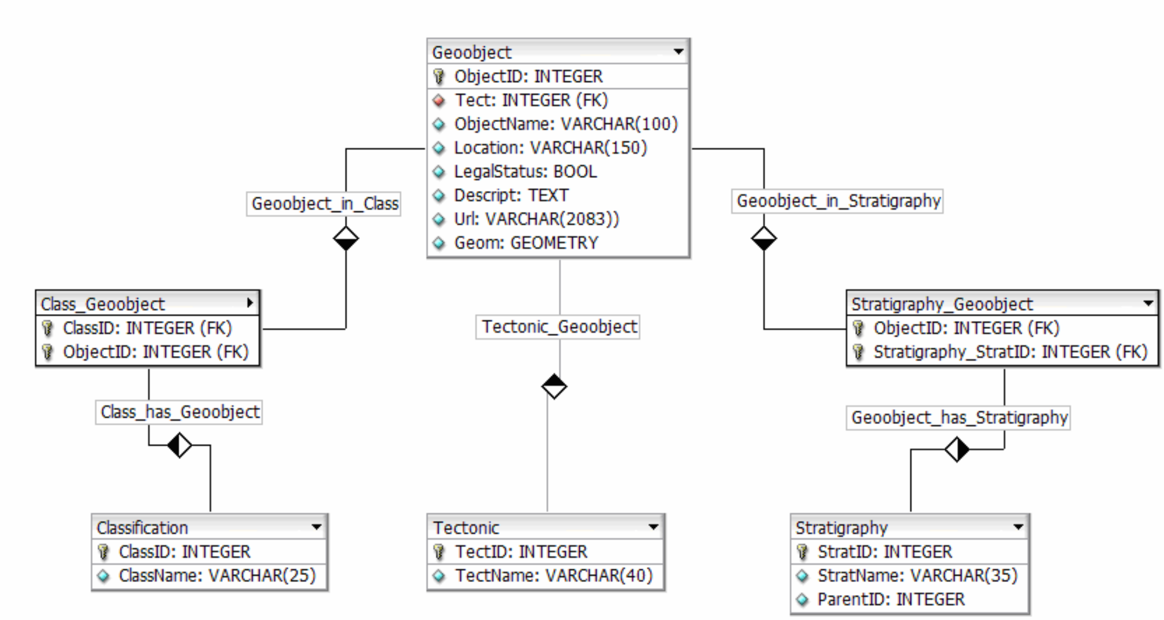

Fig.3. Design of the geotourism database in PostgreSQL DBMS

In the absence of configured web server, the local PostgreSQL database was exported in .csv file extension with joined rows from related tables. Geographic coordinates were presented in a popular web mapping projection WGS84 3857. With enterprise server technologies, such as ArcGIS Server, the web maps or GIS on the web-portal could be directly connected to the database, query it with a server-side programming language, and update the map for the user with results.

The prototype of geoportal on ArcGIS Online includes the following thematics maps, after the introduction to the concept and importance of geological tourism (Fig.4) [2, 17 – 20]:

- geoparks of Europe within the framework of the UNESCO Global Geoparks (Fig.5);
- map of geoheritage. It provides users with important all available information from the database about geological landmarks with a photo (Fig.6);
- map of classification of geological landmarks. There users are able to browse classified landmarks according to a symbology (Fig.7). In the future, it is planned to integrate this map and the previous larger dataset;
- map that represent number of geological landmarks (officially protected areas and not) listed in the database per an administrative-territorial unit (Fig.8). It allows identifying potential areas for geotourism development due to larger clusters of geoheritage.

A code popup window on the ArcGIS Online web map can be edited, which allows changing display order of fields, customizing text and adding pictures. When a user clicks on a location point on the map, a new window popup shows visual and textual information from exported .csv file. For example, Fig.9 represents popup window at a local geological landmark “Kanevsky Cuesta”.

Furthermore, the database, web maps and web GIS can be publicized offline, for example, on CD/DVD, to popularize geotourism and geosciences. Maps can be imbedded into web sites of Ukrainian organizations and governmental agencies, or burnt to compact disks with additional multimedia content in order for educational activities in schools. This educational application of the geoportal may considerably enhance the interest of young people to geological heritage, encourage further studies and protection of geological sites in their region.

CONCLUSION

Geotourism is an activity of exploring nature and geological sites, studying geo-

Fig.4. Introduction to geological tourism

Fig.5. European geoparks

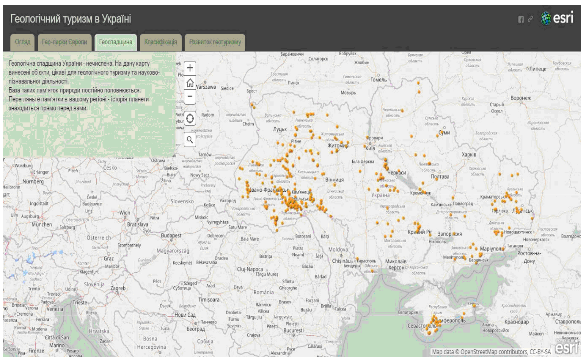

Fig.6. Geoheritage of Ukraine

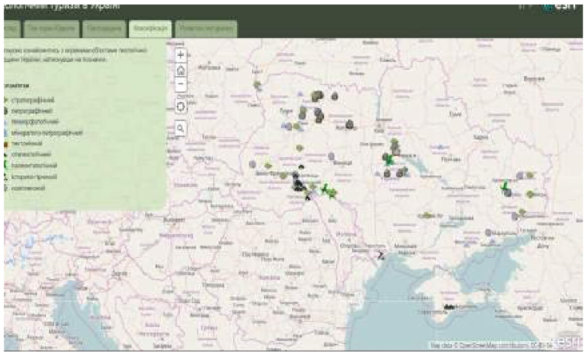

Fig.7. Classified geological landmarks

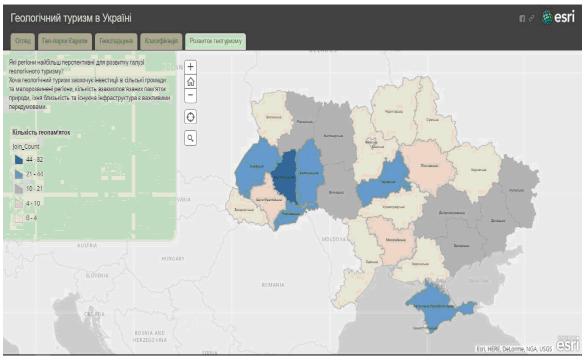

Fig.8. Number of geological landmarks per an administrative-territorial unit

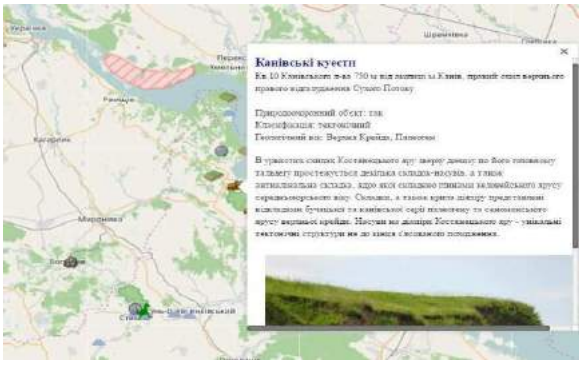

Fig.9. Information popup window of a local geological landmark "Kanivski kuesty"

sciences, and participating in environmental protection. On the other hand, geological tourism has been a promising field to invest in for local communities, government, NGOs, tourism companies and researchers. Over the last decade, UNESCO has been actively developing the Global Geoparks Network, objects of geological tourism.

Databases and web technologies, such as web GIS, web maps integrated into portals, have an increasing influence on tourism and popularization of scientific knowledge to the general public. Unfortunately, even simple interactive web maps that exist on tourism websites in Ukraine often are unattractive and not user-friendly, rely on outdated technology.

This paper shows that it is possible to create a web resource to popularize and collect information on geological natural landmarks with little or no financial cost. It provides potential visitors with information in a visually appealing way. Geotourism as a novel field of Ukrainian tourism, science communication and environmental protection should actively rely on GIS and web technologies to make geosites attractive not only to scientists and nature lovers, but average tourists. On the other hand, databases and GIS can serve as means of collecting, storing, monitoring and managing geological landmarks. So, the concept of a geoportal “Geological tourism of Ukraine” was developed to synthesize and visualization information on geological heritage.

The prototype relies on PostgreSQL software and ArcGIS Online platform. The database allows querying for different classes, geological age, tectonic structures of the geosites, working with spatial data through PostGIS extension, and creating cartographic representation of the data. Actualization of the database with new data on geolandmarks is anticipated. Then, web mapping was used to visualize spatial information and provide user interaction. Future work will include updating the database and creating a fully-functioning geoportal with server technologies, querying possibility and a larger informative component.

The geoportal can facilitate publication of other related products (e.g. printed guides, oral geotours, interactive applications). It integrates scientific and educational components of geotourism, and more precisely, it generates understanding and appreciation of geological components of the environment.

The idea of creating a separate portal is attractive because it will enable the average user to get an interesting interactive information in one place, thus sklonyayuchy its direct participation in the geological tourism.

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Геопорталы как средство популяризации геологического наследия Украины

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Аннотация. Показана проблема использования геологических памятников природы (ГПП) региона в научных и образовательных целях, которая является частью общей проблемы сохранения и использования геологического наследия Земли, приобрела международное значение. Отечественный и международный опыт свидетельствует о необходимости создания тематических ГЕОТУР, опорными объектами которых служат геологические памятники природы (ГПП).

Представлена концепция геологического туризма, памятников природы и их значимости. Раскрыты такие важные смежные понятия, как геонаследие, геоконсервация и геопарк. Кратко описана идея классификации геологических памятников. Изложены концепция и методология создания геопортала, посвященного геологическому туризму в Украине, с последующими итогами результатов. Разработанные веб-ГИС должны способствовать распространению знаний среди общей массы и систематизации информации об объектах геологического наследия.

Геологический туризм в Украине имеет потенциал улучшить социально-экономическое положение местных общин, сохранить геологические объекты и популяризировать науки о Земле. На сегодня не существует реального инструмента для привлечения внимания общественности к геонаследию и геотуризму, что подтверждает большую актуальность данной научной работы.

Создание геопортала позволит гражданам интерактивно взаимодействовать с картой геологических памятников в Украине, получать интересную информацию по объектам, тем самым приобщаясь к геологическому туризму. Для достижения поставленной цели решаются следующие задачи: сбор информации о геологических памятниках, создание дизайна базы данных и ее наполнение, создание интерактивных карт, разработка концепции геопортала и его прототипа.

Основное внимание сосредоточено на рассмотрении концепции геотуризма, международного опыта его применения и важности использования веб-ГИС инструментов для его популяризации. Проанализировав наработки украинских ученых в этой сфере, результаты международных конференций и проектов, следующим этапом стала разработка собственной концепции геопортала с использованием веб-технологий и геоинформационных систем.

Ключевые слова: геотуризм, геологический туризм, геологические памятники природы, геопортал, веб-ГИС, ГПП, пространственная база данных.

Модернізація екскаватора двосекційною поворотною стрілою

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Анотація. Розроблено екскаватор для відкопування протяжних підземних об’єктів з модернізованим робочим обладнанням у вигляді двосекційної поворотної стріли. Першу секцію змонтовано на платформі екскаватора з можливістю повороту у вертикальній площині, а другу − шарнірно прикріплено до першої секції з можливістю повороту в горизонтальній площині відносно вісі пересування машини. Механізм повороту стріли виконано у вигляді шестигранної системи шарнірно з’єднаних важелів, що представляє собою розташовані по обидві сторони секцій шарнірно з’єднані між собою активні й пасивні двоплечі важелі.

Функціональні можливості екскаватора розширюються шляхом зміщення вісі копання на певну відстань за межі ходової частини, що дозволяє відкопувати траншею паралельно вісі його пересуванню в стислих умовах міської забудови. Модернізоване обладнання дає можливість підвищити безпеку експлуатації машини при пересуванні на бермі протяжних підземних об’єктів та у нестійких ґрунтових умовах.

Ключові слова: екскаватор, двосекційна поворотна стріла, зміщена вісь копання, стисливі умови.

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ВСТУП

Одноковшеві екскаватори займають ведуче місце серед будівельних машин для механізації земляних робіт. Їхні техніко-експлуатаційні показники в значній мірі визначаються типом приводу, досконалістю конструкцій, якістю виготовлення і організаційно-технічним рівнем експлуатації.

У країнах СНД одноковшеві будівельні екскаватори випускають з різноманітними приводами – гідравлічними та електричними. Широке розповсюдження гідроприводу корінним чином змінило конструктивні та експлуатаційні показники і значно підвищило їх технічний рівень, тому в останній час основну увагу приділяється розвитку саме таких машин.

Наразі ведеться робота по корінній зміні технічного рівня одноковшевих екскаваторів. Скорочується випуск машин з механічним приводом, нарощується випуск машин з гідравлічним приводом з урахуванням різноманітних напрямів їх удосконалення.

Найбільше розповсюдження у будівництві отримали одноковшеві екскаватори внаслідок кращої пристосованості до перевезення з місця та універсальності. Стає актуальним використання екскаваторів зі зміщеною віссю стріли через те, що часто потрібно виконувати роботи у стиснених умовах – поряд з будинками, біля фундаментів та ін., а також в умовах де використання звичайного екскаватора неможливо (наприклад, коли потрібно відкопувати канаву паралельно вісі пересування екскаватора, копання ґрунту під трубопроводом для його довільного опускання у траншею тощо). За допомогою змінного обладнання такі екскаватори стають незамінними при організації будівельних робіт.

Наразі створено ряд екскаваторів із зміщеною стрілою, технологія створення яких достатньо розвинена. Особливо гострим є питання врівноваження екскаватора під час копання. Оскільки вісь копання не співпадає з віссю екскаватора можливе його перекидання. Тому є потреба вдосконалювання та створення нових високотехнічних екскаваторів.

Одним з таких екскаваторів, який було взято за прототип, виготовлено заводом ім. Комінтерну (ВО „ТЯЖЭКС”) ЭО-5122 Б. Він включає в себе базову машину, до якої за допомогою маніпулятора приєднано робоче обладнання типу обернена лопата, що включає в себе стрілу, рукоять і ківш, шарнірно з’єднані між собою з можливістю направленого переміщення стріли у перпендикулярній площині відносно вісі копання.

Отже, створення екскаваторів зі зміщеною віссю копання слід вважати перспективним.

Мета розробки полягає у розширенні функціональних можливостей під час копання протяжних об’єктів паралельно вісі пересування екскаватора та виконання робіт у стислих умовах.

КОНСТРУКЦІЯ ТА ПРИНЦИП ДІЇ РОБОЧОГО ОБЛАДНАННЯ

Зазвичай машини зі зміщеною віссю копання, які містять шарнірно з’єднані робочі органи, розміщенні безпосередньо на їхній поворотній платформі [1 − 3] мають такі недоліки. Вони не можуть відкопувати тра-

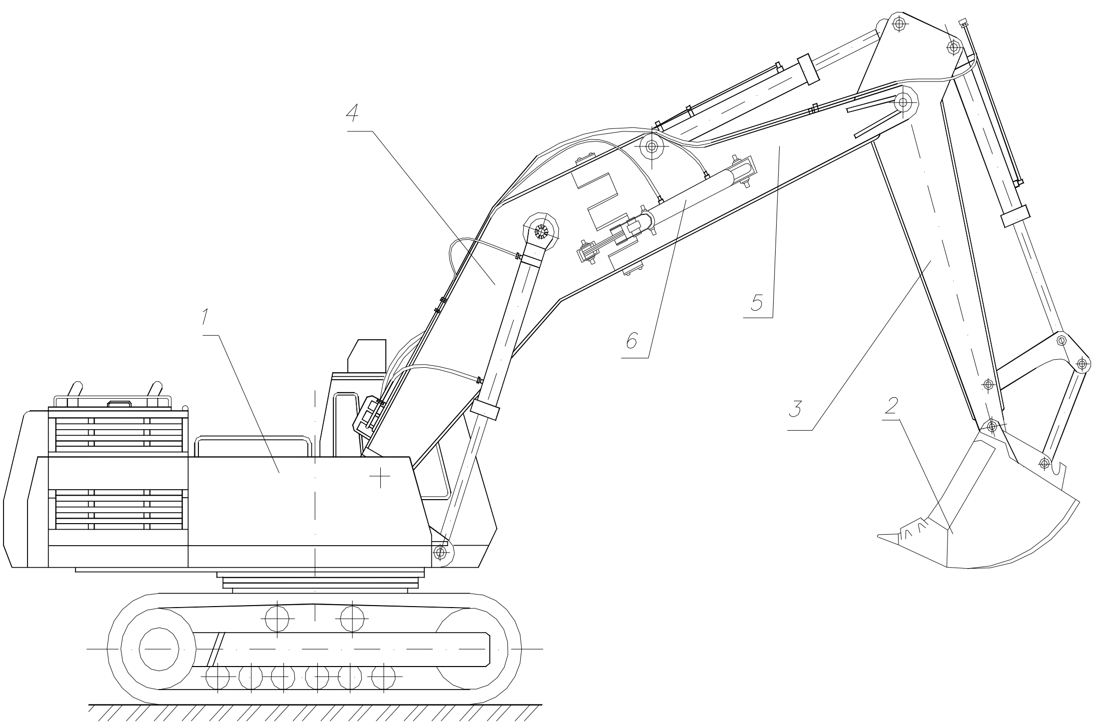

Рис.1. Екскаватор зі зміщеною віссю копання, вид збоку
Fig. 1. Power-shovel with the displaced axis of digging, end-view

ншею за межею ходової частини паралельно вісі пересування; підвищені вимоги до засобів керування положенням робочого органу відносно вісі копання.

Найближчим технічним рішенням є робоче обладнання одноківшевого екскаватора зі зміщеною віссю копання, яке містить рукоять, виконану із двох частин, зв'язаних шарніром з вертикальною віссю [4, 5]. Неповоротну частину рукояті виконано з опорним сектором, виконаним у вигляді двоплечого важеля, одне плече якого з'єднане з гідроциліндром керування механізмом повороту робочого обладнання в горизонтальній площині.

Але при копанні траншеї паралельно вісі пересування екскаватора така конструкція рукояті дозволяє розробляти ґрунт глибиною не більш, ніж довжина поворотної на вертикальному шарнірі рукояті [6]. За допомогою неї також не можна відкопувати траншею за межами ходової частини відносно вісі пересування екскаватора [7, 8].

Тому запропоновано нову конструкцію робочого обладнання, яке дозволяє значно розширити функціональні можливості екскаватора під час копання протяжних об'єктів паралельно вісі пересування машини та виконувати роботи у стислих умовах [9 − 13].

Екскаватор зі зміщеної віссю копання (Рис.1) представляє собою базову машину 1 з поворотною платформою і робочим органом у вигляді ковша 2, рукояті 3, стріли, виконаної із двох шарнірно з'єднаних між собою секцій. Першу секцію 4 змонтовано на платформі екскаватора з можливістю повороту у вертикальній площині, а другу секцію 5 шарнірно прикріплено до першої секції і виконано з можливістю повороту в горизонтальній площині відносно вісі пересування екскаватора. Механізм повороту стріли виконано у вигляді шестигранної системи шарнірно з'єднаних важелів, яка представляє собою розташовані по обидві сторони секцій стріли шарнірно з'єднані між собою активні двоплечі 8, 9 і пасивні 10, 11 важелі (Рис.2).

Один кінець пасивних важелів 10, 11 прикріплено до відповідного краю першої секції 4 стріли, а інший – до коротких кінців активних двоплечих важелів 8, 9. Сере-

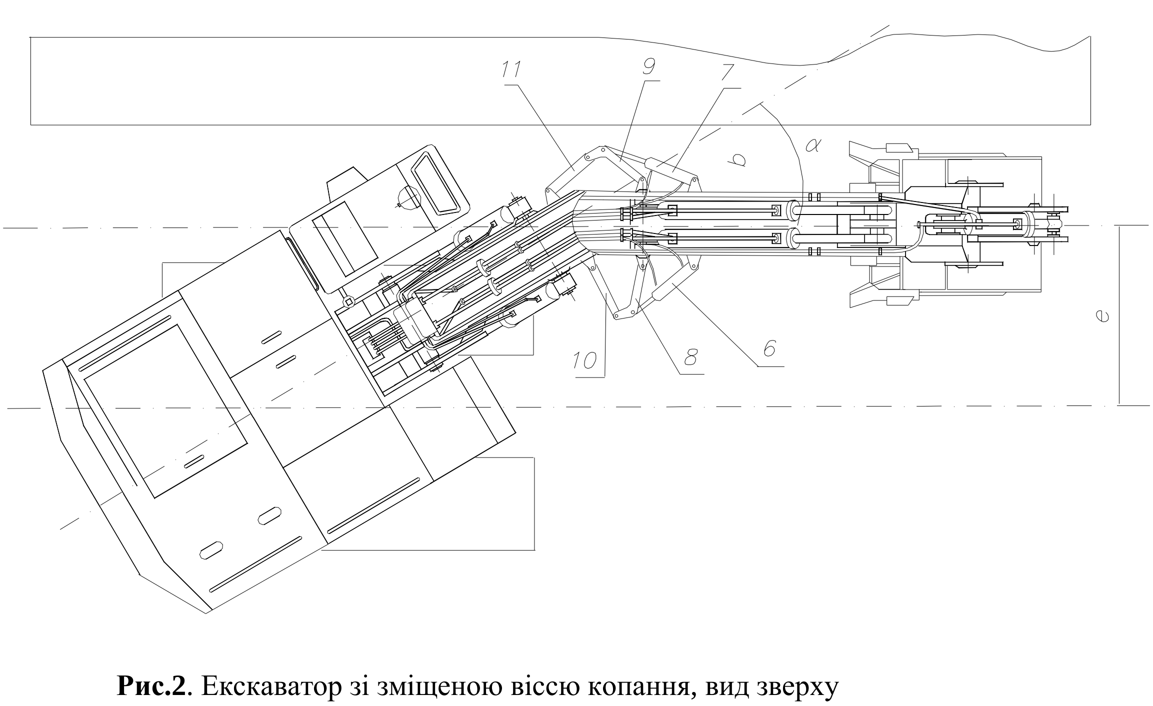

Рис.2. Екскаватор зі зміщеною віссю копання, вид зверху
Fig. 2. Power-shovel with the displaced axis of digging, kind from above

дню частину останніх з’єднано зі штоками гідроциліндрів 6, 7, корпуси яких рухомо закріплено на відповідних сторонах другої, поворотної, секції 5 стріли, яка приводяться в рух за допомогою прикріплених до неї довгих кінців двоплечих активних важелів 8, 9.

Геометричні розміри і форму шестигранної системи важелів та величину ходу штоків гідроциліндрів 4 з кожної сторони стріли кінематично пов’язано з шириною *b* її секцій 4, 5 та кутом повороту α рухомої частини стріли у площині, перпендикулярній вісі копання екскаватора. Відстань *е* між віссю переміщення екскаватора та віссю протяжного об’єкта обумовлено довжиною першої секції стріли і кутом α.

Екскаватор зі зміщеною віссю копання працює таким чином [14 − 17]. При відкопуванні протяжних об’єктів паралельно вісі пересування екскаватора та роботі в стислих умовах, екскаватор 1 встановлюють паралельно вісі протяжного об’єкта та повертають робоче обладнання на поворотній платформі на необхідний кут α, який зумовлюється відстанню *е* між екскаватором 1 і поздовжньою віссю об’єкта.

Гідроциліндри 6, 7 керування поворотом стріли, які розташовані по обидві її сторони, за допомогою двоплечих активних важелів 8, 9, приводять в рух другу, поворотну, секцію 5 стріли. Наприклад, при її повороті праворуч, як показано на Рис.2, шток гідроциліндра 6, розташованого з правої сторони стріли, висувається, діючи на середню частину правого двоплечого активного важеля 8, а шток гідроциліндра 7, розташованого з лівої сторони стріли, синхронно правому гідроциліндру 6 втягується, діючи на середню частину лівого двоплечого активного важеля 9.

Це призводить до складання правої сторони шестигранної системи шарнірно з’єднаних між собою активного двоплечого 8 і пасивного 10 важелів, розташованих праворуч стріли, та до розкладання лівої сторони шестигранної системи шарнірно з’єднаних між собою активного двоплечого 9 і пасивного 11 важелів, розташованих ліворуч стріли.

Під дією сил стискання та розтягування відповідних довгих кінців активних двоплечих важелів 8, 9, прикріплених до поворотної секції 5 стріли, вона повертається в горизонтальній площині праворуч навколо шарніру з вертикальною віссю на кут α, спрямовуючи ківш 2 з рукояттю 3 паралельно вісі пересування екскаватора 1.

Відкопують протяжні об’єкти за допомогою ковша 2, закріпленого на рукояті 3, у звичайному режимі. Для розвантаження ґрунту після підйому ковша 2 екскаватор 1 розвертають на поворотній платформі, вивільняють ківш 2 і повертають робоче обладнання у вихідне положення із зазначеним ексцентриситетом *е* відносно осі пересування екскаватора. Далі робочий цикл повторюють.

ВИСНОВКИ

1. Функціональні можливості екскаватора зі зміщеною віссю копання розширюються завдяки встановленню робочого обладнання з можливістю обертання другої (поворотної) секції стріли у місці її шарнірного з’єднання в горизонтальній площині за межами ходової частини екскаватора на відстані *е* відносно вісі його пересування.
2. Значно збільшується глибина відкопування траншеї за рахунок збільшення відстані між ковшем 2 і шарнірним з’єднанням секцій стріли, яка дорівнює сумі її поворотної частини 5 і довжини рукояті 3.
3. Нова конструкція робочого обладнання екскаватора дає можливість виконувати роботу у стислих умовах міської забудови та підвищити безпеку експлуатації машини при пересуванні на бермі протяжних підземних об’єктів у нестійких ґрунтових умовах.

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Modernization of power-shovel by a two sectional turning arrow

Mykhailo Sukach

Abstract. An excavator for digging out long underground objects with modernized working equipment in two-section swivel boom form was developed.

The first section is mounted on a excavator’s platform with the vertical plane rotation ability. The second section is pivotally attached to the first section to be rotatable in a horizontal plane relatively to the axis of machine’s movement.

The mechanism of boom’s rotation is made in the hexagonal system form with articulation between active and passive two-arm levers, located on both sides of the sections.

The functionality of the excavator is expanded by shifting the digging axis in a certain distance beyond the chassis, which allows digging a trench parallel to the axis of its movement in conditions of tight urban planning.

Modernized equipment makes it possible to increase the safety of operation of the machine while moving on the berm of extended underground objects and in unstable ground conditions.

Keywords: excavator, two-section swivel boom, digging axis shifting, tight urban planning.

Approximation of math model of the combined cutting soil`s critical depth with influence of working speed

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Abstract. The purpose is approximation of mathematical model of processes of cutting and loosening of the soil for the receipt of analytical dependence of determination of critical depth of loosening taking into account the working speed at the combined tiered destruction of soil. An approximation based on regression analysis used in the processing of data derived from experiments with a number of parallel observations in the experiment. Built graph of the dependency between relative critical depth, working speed of the working body and angle cutting soil. Identify the value of critical depth loosening for five types of soil and full range of working speeds, depending on the physical and mechanical properties of the soil.

Keywords: angle cutting, depth loosening, operating speed, critical depth, free cutting, blocked cutting, combined cutting

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INTRODUCTION

To eliminate the overcritical zone soil loosening and reduce the energy workflow [1 – 3, 22], need to know the critical depth of cutting depending on cut conditions (upper lower tier) and initial data for soil and speed of the working body [4 – 7]. Process of tiered combined cutting soil and mathematical model of determination the critical depth of loosening were examined and described in previous articles [8, 9, 20].

To study the combined critical depth considering working speed was considered the destruction of soil unpin based on scheme (Fig.1), at the same time as the initial conditions were accepted the following assumptions:

1) soil − homogeneous isotropic medium characterized clutch, external and internal friction, density and moisture content;

2) the element of chip is viewing as a solid body in the form of a triangular prism with two symmetrical conical sectors on each sides;

3) the normal law of pressure distribution on the frontal plane of the working body in the chipping area is taken linear for the depth;

4) the critical depth is constant apart of work of working body in landing mode or in steady mode.

Because of these researches was obtained mathematical model of the critical depth of cut in the combined tiered destruction of soil considering the working speed:

$$h_{кр.к} = \frac{-B-\sqrt{B^2-4AC}}{2A}, \qquad (1)$$

where v, $\alpha_р$, ψ − speed, cutting angle shear soil and cleaving soil angle; (look Fig.1); $v_{кр}$ − critical cutting speed at which changes the nature of the destruction of soil [9]; q_1 − maximum soil pressure on the knife's surface in the upper tier by free-cutting process; $q_{кр}$ − critical value of pressure; $b_к$ − width of the knife; $\gamma_{гр}$, c − specific gravity and friction coefficient of soil; g − acceleration of gravity; φ − angle of soil external friction; φ_0 − angle of soil internal friction; $k_{пер}$ − the ratio of the depth zone of guaranteed chipping soil ($k_{пер}$ = 0,9…0,95); q_0 − the minimum value of pressure, acting on the surface; $h_в$, $h_{бл2}$ − depth of soil operation in a free and blocked cutting respectively; γ, $\gamma_к$ − collapse zones` angles on combined cutting the soil in upper and lower tiers respectively [21]; ρ, δ, λ − angles formed by lateral chipping plane with the vertical plane.

$$\begin{cases} A = \left(\mathrm{ctg}\psi + \mathrm{ctg}\alpha_р\right) c \left(\dfrac{\rho}{\sin\psi} + \dfrac{\cos\delta}{\cos\lambda}\right) - \dfrac{\sin\left(\alpha_р + \varphi + \varphi_0 + \psi\right)}{\cos\varphi\cos\varphi_0\sin\alpha_р} b_к \left(1 + \dfrac{v}{v_{кр}}\right) \times \\ \quad \times \dfrac{\gamma_{гр}}{g} \dfrac{\sin^2\alpha_р \cos\psi os\psi\varphi}{\sin\left(\alpha_р + \psi\right)\sin(\alpha_р + \varphi)} v^2 \dfrac{\mathrm{ctg}\gamma}{2b_к}; \\ B = -\dfrac{\sin(\alpha_р + \varphi + \varphi_0 + \psi)}{\cos\varphi\cos\varphi_0\sin\alpha_р} b_к \left(1 + \dfrac{v}{v_{кр}}\right) \left(\begin{array}{l} q_1 + \dfrac{q_{кр} - q_1}{2} k_{пер} + \\ + \dfrac{\gamma_{гр}}{g} \dfrac{\sin^2\alpha_р \cos\psi os\psi\varphi}{\sin\left(\alpha_р + \psi\right)\sin(\alpha_р + \varphi)} v^2 \times \\ \times \left(\dfrac{2 \cdot \mathrm{ctg}\gamma_к \cdot h_в}{b_к} - \dfrac{h_в \cdot \mathrm{ctg}\gamma}{b_к} + 1\right) \end{array} \right) + \\ \quad + \left(2h_в \mathrm{ctg}\gamma_к + b_к\right) \dfrac{c}{\sin\psi} - 2c\left(\mathrm{ctg}\psi + \mathrm{ctg}\alpha_р\right)\left(\dfrac{\rho}{\sin\psi} + \dfrac{\cos\delta}{\cos\lambda}\right) h_в; \\ C = \dfrac{\sin(\alpha_р + \varphi + \varphi_0 + \psi)}{\cos\varphi\cos\varphi_0\sin\alpha_р} b_к \left(1 + \dfrac{v}{v_{кр}}\right) h_в \left(\begin{array}{l} \dfrac{q_{кр} - q_1}{2} k_{пер} + \\ \dfrac{\gamma_{гр}}{g} \dfrac{\sin^2\alpha_р \cos\psi \cos\varphi}{\sin\left(\alpha_р + \psi\right)\sin(\alpha_р + \varphi)} v^2 \dfrac{2\mathrm{ctg}\gamma_к h_в}{b_к} \end{array} \right) - \\ \quad - \left(2h_в^2 \mathrm{ctg}\gamma_к + \dfrac{h_в^2 \mathrm{ctg}\gamma}{2}\right) \dfrac{c}{\sin\psi} + c\left(\mathrm{ctg}\psi + \mathrm{ctg}\alpha_р\right)\left(\dfrac{\rho}{\sin\psi} + \dfrac{\cos\delta}{\cos\lambda}\right) h_в^2. \end{cases}$$

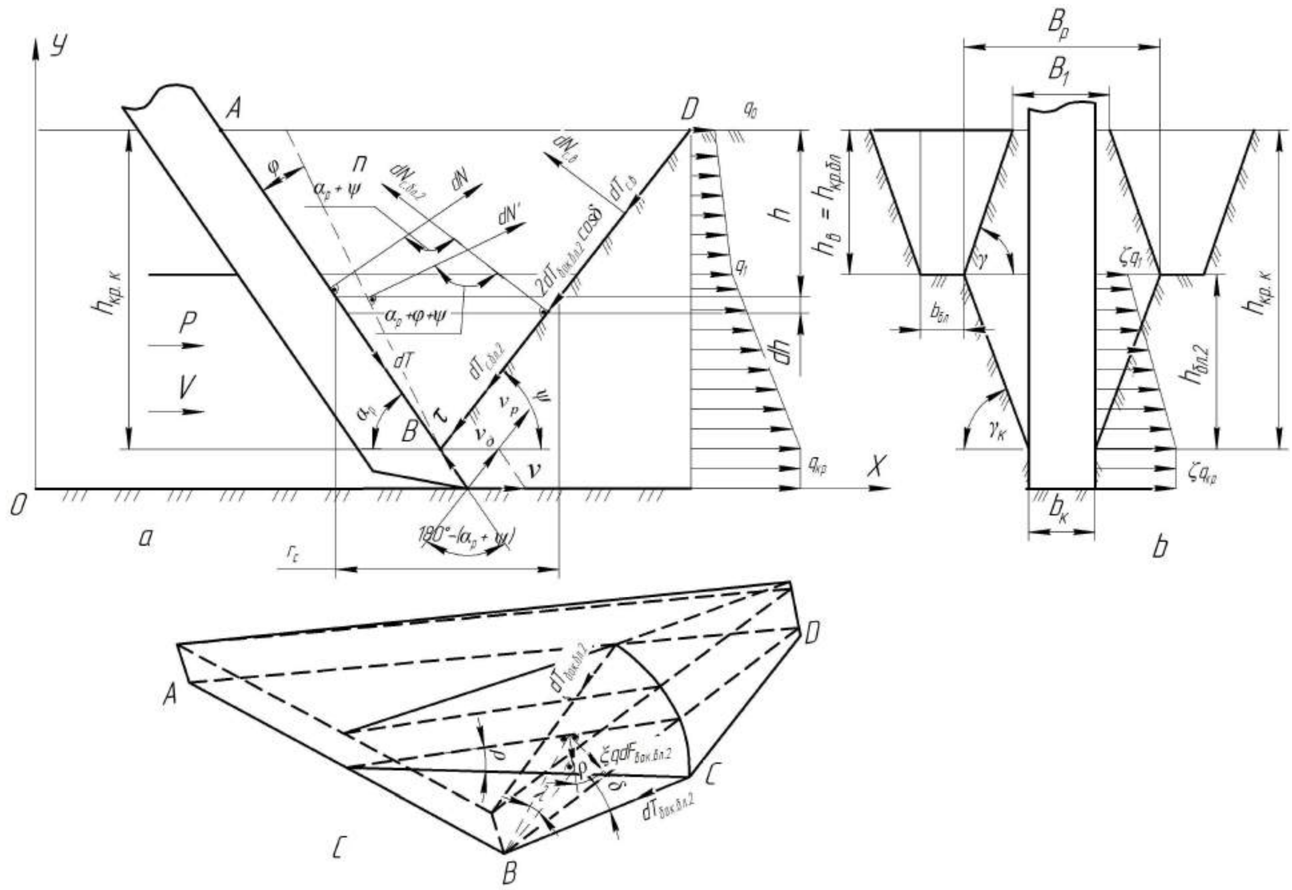

Fig.1. The scheme of interaction of a knife with soil environment about combined cutting soil: *a* − in the longitudinal plane; *b* − in the transverse plane; *c* − the form of chip`s element in the knife hollowing process

Calculated value of the relative depth of cleavage in view of working speed listed in the Table 1.

As the mathematical model is quite cumbersome and not easy to compute and further research is necessary to make an approximation of the model. For realization of approximating will use the regression multivariate analysis [11 − 13].

To determine the b − coefficient used regression analysis based on the method of least squares [18, 19].

Will write the equation of theoretical mathematical model of the critical depth of cut considering the speed in general view:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \\ + b_{1,2} x_1 x_2 + b_{1,3} x_1 x_3 + b_{2,3} x_2 x_3 + , \quad (2) \\ + b_{1,2,3} x_1 x_2 x_3$$

where b_0 − free member;

$b_1, b_2, b_3, b_{1,2}, b_{1,3}, b_{2,3} b_{1,2,3}$ − factors that take into account linear impact on the interaction feedback factors of the first, second and third orders [10].

Draw the transfer of levels` factors natural values in the code dimensionless quantities in order to further build of standard matrix (Table 2):

$$x_k = \frac{X_k - X_{k_0}}{\Delta X_k}, \quad (3)$$

where x_k − coded values of *k*-factor; X_k − natural current value of *k*-factor; X_{k_0} − initial (zero) level $X_{k_0} = \frac{X_{\max} + X_{\min}}{2}$ − factor; ΔX_k − the interval of variation of *k*-factor. the interval of variation of *k*-factor [14 − 16].

After the coding level factors take values: "1" − the upper level; "−1" − lower level; "0" – zero level. As zero level, take the center of spacing, which conducted the study (Table 3).

Table 1. Value of relative critical depth

v, $\frac{m}{s}$ / α_p, °	0	1	2	3	4	5,18
Semi-solid loam						
20	8,90	10,32	11,44	12,69	14,13	16,24
30	7,16	9,02	10,44	11,40	14,07	17,13
40	5,78	7,86	9,43	11,29	13,70	17,69
50	4,58	6,63	8,25	10,20	12,75	17,27
60	3,58	5,47	7,00	8,86	11,33	15,69
Longing clay						
v, $\frac{m}{s}$ / α_p, °	0	1	2	3	4	5,55
20	8,28	10,80	11,56	12,44	13,47	15,45
30	6,83	9,16	10,20	11,44	12,98	16,33
40	5,59	7,79	9,05	10,58	12,53	17,10
50	4,43	6,39	7,73	9,39	11,58	16,95
60	3,33	5,13	6,60	8,44	10,94	17,64
Solid sandy loam						
v, $\frac{m}{s}$ / α_p, °	0	1	2	3	4	4,45
20	12,28	14,13	16,00	18,30	21,25	22,99
30	9,73	12,10	14,42	17,50	21,99	24,72
40	7,73	10,47	13,06	16,58	22,15	25,88
50	6,03	8,72	11,37	15,02	20,93	25,07
60	4,53	6,94	9,29	12,64	18,21	22,19

Regression coefficients calculated by the formula:

$$b_0 = \frac{1}{n}\sum_{x=i}^{n} y_i , \qquad (4)$$

$$b_i = \frac{1}{n}\sum_{i=1}^{n} x_i y_i , \qquad (5)$$

$$b_{iu} = \frac{1}{n}\sum_{i=1}^{n} x_i x_u y_i , \qquad (6)$$

$$b_{iuk} = \frac{1}{n}\sum_{i=1}^{n} x_i x_u x_k y_i , \qquad (7)$$

where x_i, x_u, x_k − natural values i, u, k − factor experiments y_i − parameter optimization feedback.

Perform the calculations of approximated value of critical cutting depth:

$$h_{kp} = b_0 + \frac{b_i}{\Delta X_i}\left(X_i - X_{i0}\right) + \frac{b_{iu}}{\Delta X_i \Delta X_u}\left(X_i - X_{i0}\right)\left(X_u - X_{u0}\right) + \frac{b_{iuk}}{\Delta X_i \Delta X_u \Delta X_k}\left(X_i - X_{i0}\right) \times \left(X_u - X_{u0}\right)\left(X_k - X_{k0}\right); \qquad (8)$$

When substituting numerical values of the components of the equation (8) for different soil types, we obtain the following expression:

Table 2. Value factors and levels of variation for different types of soil

Factor	Marking		Interspace (loam)	Interspace (sandy loam)	Interspace (clay)	Level of variation											
						Natural									Code		
						Semisolid loam			Solid sandy loam			Hardplastic clay					
	Natural	Code				top	mid.	bot.	top	mid.	bot.	top	mid.	bot.	top	mid.	bot.
Blade width, b, m	X_1	x_1	0,1	0,1	0,1	0,25	0,15	0,05	0,25	0,15	0,05	0,25	0,15	0,05	1	0	−1
Knife`s cutting angle, α, rad	X_2	x_2	0,349	0,349	0,349	1,047	0,698	0,349	1,047	0,698	0,349	1,047	0,698	0,349	1	0	−1
Cutting speed, V,m/s	X_3	x_3	2,09	1,725	2,275	5,18	3,09	1	4,45	2,725	1	5,55	3,275	1	1	0	−1

Table 3. Matrix of 3-factor`s planning

№	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$	y_i Semisolid loam	y_i Solid sandy loam	y_i Hardplastic clay
1	+	−1	−1	−1	1	1	1	−1	0,516	0,707	0,54
2	+	1	−1	−1	−1	−1	1	1	2,581	3,533	2,702
3	+	−1	1	−1	−1	1	−1	1	0,274	0,347	0,257
4	+	1	1	−1	1	−1	−1	−1	1,369	1,737	1,285
5	+	−1	−1	1	1	1	−1	1	0,812	1,15	0,773
6	+	1	−1	1	−1	−1	−1	−1	4,061	5,748	3,864
7	+	−1	1	1	−1	1	1	−1	0,785	1,11	0,882
8	+	1	1	1	1	−1	1	1	3,925	5,548	4,411
Average value of feedback y_i									1,79	2,485	1,839

(for semisolid loam):

$$h_{\text{kp}} = 1{,}79 + 11{,}91(b-0{,}15) - 0{,}5788 \div \times(\alpha_{\text{p}} - 0{,}689) + 0{,}2894(\nu - 3{,}09) - 3{,}8682(b-0{,}15)(\alpha_{\text{p}} - 0{,}689) + 1{,}933(b-0{,}15)(\nu-3{,}09) + 0{,}2207 \times (\alpha_{\text{p}} - 0{,}689)(\nu - 3{,}09) + 1{,}4806(b-0{,}15)(\alpha_{\text{p}} - 0{,}689)(\nu - 3{,}09); \quad (9)$$

(for solid sandy loam):

$$h_{\text{kp}} = 2{,}485 + 16{,}57(b-0{,}15) - 0{,}8596 \times (\alpha_{\text{p}} - 0{,}689) + 0{,}524(\nu - 2{,}725) - 5{,}7304(b-0{,}15)(\alpha_{\text{p}} - 0{,}689) + 3{,}4956(b-0{,}15)(\nu - 2{,}725) + 0{,}3986 \times (\alpha_{\text{p}} - 0{,}689)(\nu - 2{,}725) + 2{,}6577 \times (b-0{,}15)(\alpha_{\text{p}} - 0{,}689)(\nu - 2{,}725) \quad (10)$$

(for hardplastic clay):

$$h_{\text{kp}} = 1{,}839 + 12{,}26(b-0{,}15) - 0{,}3752 \times (\alpha_{\text{p}} - 0{,}689) + 0{,}2826(\nu - 3{,}275) - 2{,}4928(b-0{,}15)(\alpha_{\text{p}} - 0{,}689) + 1{,}8857(b-0{,}15)(\nu - 3{,}275) + 0{,}3715 \times (\alpha_{\text{p}} - 0{,}689)(\nu - 3{,}275) + 2{,}4811 \times (b-0{,}15)(\alpha_{\text{p}} - 0{,}689)(\nu - 3{,}275) \quad (11)$$

Puts the obtained coefficients of equations, theoretical and approximated value of critical cutting depth in Table 4 and 5.

Table 4. The coefficients of the regression equation b_i and approximated value of combined cutting critical depths

	Loam	Sandy loam	Clay
b_0	1,790	2,485	1,839
b_1	1,194	1,657	1,226
b_2	-0,202	-0,300	-0,131
b_3	0,605	0,904	0,643
b_{12}	-0,135	-0,200	-0,087
b_{13}	0,404	0,603	0,429
b_{23}	0,161	0,240	0,295
b_{123}	0,108	0,160	0,197

Carry the appreciation of the regression coefficients and adequacy test of regression equations using dispersion analysis.

Determine the degree of deviation values *u* − research of a random variable from its average value:

$$S_u^2 = \sum_{i=1}^{n} (y_i - \bar{y})^2 , \quad (12)$$

where $\bar{y}$ − average value of the research.

Dispersion of the research:

$$S_y^2 = \frac{S_u^2}{N} , \quad (13)$$

where N – numbers of researches.

The statistical significance of the regression coefficients is checked using t − Student's criterion [14 − 17]:

$$t_{bi} = \frac{|b_i|}{S_{bi}} , \quad (14)$$

Table 5. Plan 2^3 and the results of calculations

№	Blade width, m	Cutting angle. rad	Cutting speed, m\s			Teor. values of critical depth, m	Approx. values of critical depth, m	Mistake, %	Teor. values of critical depth, m	Approx. values of critical depth, m	Mistake, %	Teor. values of critical depth, m	Approx. values of critical depth, m	Mistake, %
			Loam	Sandy loam	Clay	Loam			Sandy loam			Clay		
1	0,05	0,349	1,0	1,0	1,0	0,516	0,5156	0,03	0,707	0,707	0,3	0,54	0,54	0,04
2	0,25	0,349	1,0	1,0	1,0	2,581	2,5806	0,03	3,533	3,533	0,8	2,702	2,702	0,04
3	0,05	1,047	1,0	1,0	1,0	0,274	0,2736	0,03	0,347	0,347	0,55	0,257	0,257	0,011
4	0,25	1,047	1,0	1,0	1,0	1,369	1,3686	0,03	1,737	1,737	0,44	1,285	1,285	0,04
5	0,05	0,349	5,18	4,45	5,55	0,812	0,8116	0,03	1,15	1,15	0,88	0,773	0,773	0,011
6	0,25	0,349	5,18	4,45	5,55	4,061	4,0606	0,03	5,748	5,748	0,88	3,864	3,864	0,044
7	0,05	1,047	5,18	4,45	5,55	0,785	0,7846	0,03	1,11	1,11	0,66	0,882	0,882	0,011
8	0,25	1,047	5,18	4,45	5,55	3,925	3,9246	0,03	5,548	5,548	0	4,411	4,411	0

$$S_{bi}^2 = \frac{S_y^2}{N}, \tag{15}$$

Defined by the formula (11) value t_{bi} is compared with tabulated values t_m [13, Tab.3.2.]. When $t_{bi} > t_m$, the coefficient of the regression equation is significant. Otherwise, this ratio should be excluded from the equation.

Table 6. Research dispersion, the statistical significance of the regression coefficients, quadratic error of regression coefficients

	Semisolid loam				Solid sandy loam				Hardplastic clay			
№	S_u^2	S_y^2	S_{bi}	t_{bi}	S_u^2	S_y^2	S_{bi}	t_{bi}	S_u^2	S_y^2	S_{bi}	t_{bi}
1	1,623	2,051	0,506	3,535	3,161	4,137	0,719	3,456	1,688	2,251	0,530	3,467
2	0,626			2,357	1,098			2,304	0,744			2,312
3	2,298			0,399	4,571			0,417	2,504			0,246
4	0,177			1,196	0,560			1,257	0,307			1,213
5	0,956			0,266	1,782			0,277	1,137			0,164
6	5,157			0,797	10,647			0,838	4,100			0,808
7	1,010			0,319	1,891			0,333	0,916			0,555
8	4,558			0,213	9,382			0,222	6,614			0,370

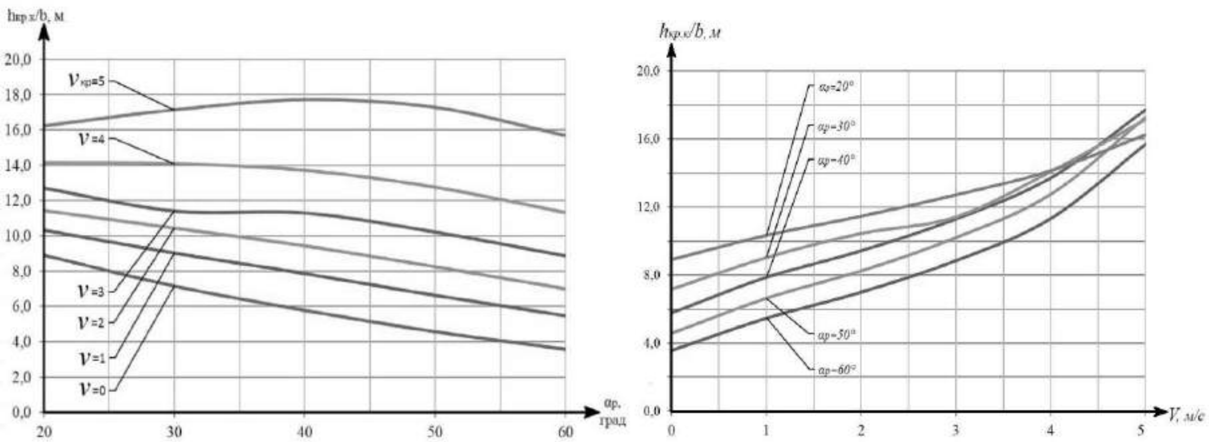

Fig.2. Dependence of the approximated relative critical depth combined cutting soil $h_{кр.к.}$ from the speed by changing the angle of cutting for semisolid loam

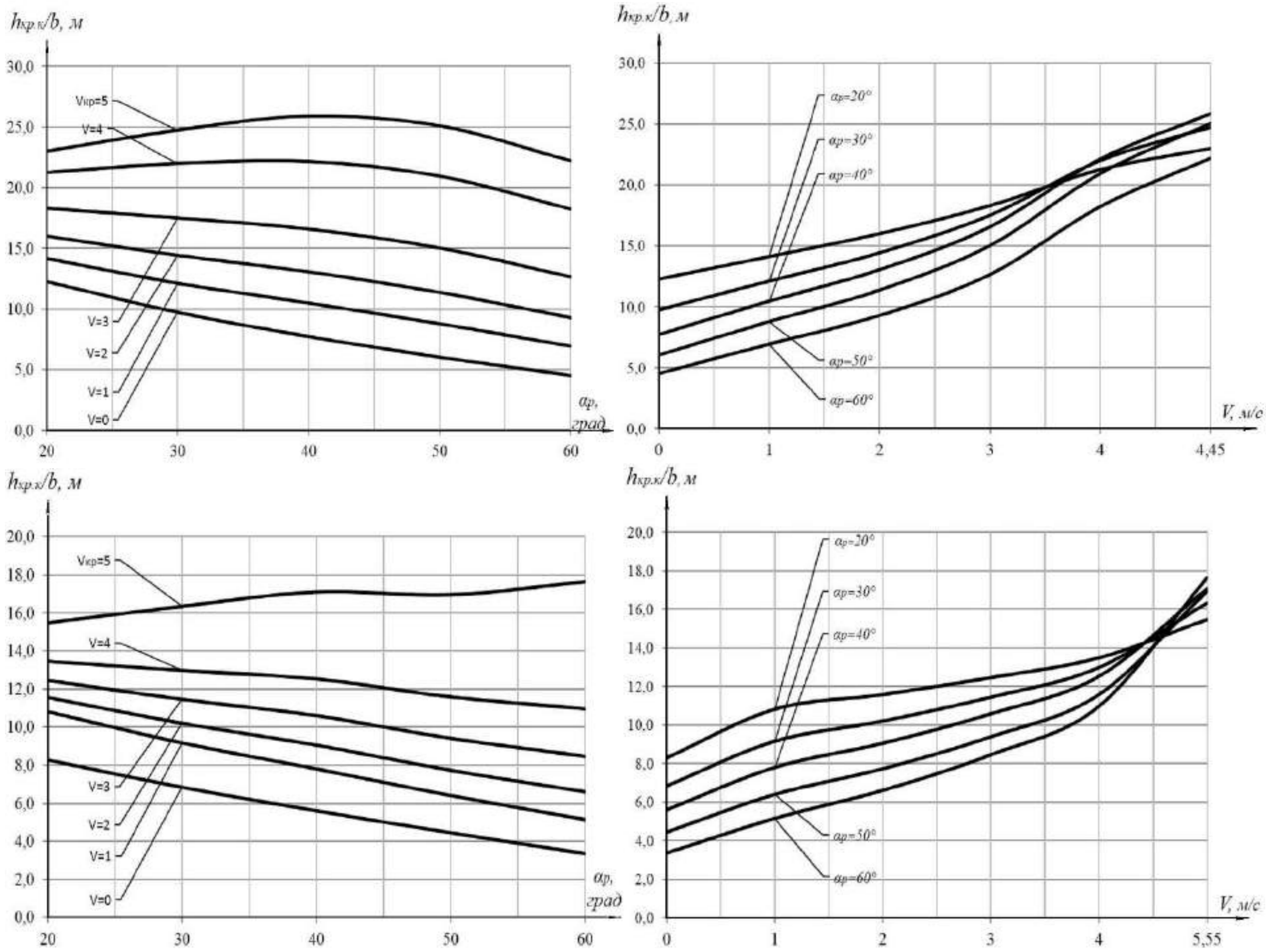

Fig.3. Dependence of the approximated relative critical depth combined cutting soil $h_{кр.к.}$ from the speed by changing the angle of cutting and dependence of approximated relative critical depth combined cutting soil $h_{кр.к.}$ from the angle when changing cutting speed, solid sandy loam and hardplastic clay

The value of the research dispersion, statistical significance of regression coefficients and quadratic error of the regression coefficients are entered in Table 6. Dependence of the approximated relative critical depth combined cutting soil $h_{кр.к.}$ from the speed for different types of soil are shown on Fig. 2 and Fig. 3.

CONCLUSIONS

1. The possibility of regression analysis applying of analytical model to approximate the critical depths of combined cutting soil has been shown.
2. Critical depth of combined cutting soil is approximated by the equation with a combination of factors like (8…15), approximation error is less than 1%.
3. Under the calculation dependence, increasing operating speed of 0 m/s to 4 m/s approximated value of relative critical depth of combined cutting $h_{кр.к.}$ increases from 3,58 to 14,13 meters for semi-loam; from 4,53 to 22,15 for solid sandy loam; from 3,33 to 13,47 for hardplastic clay depending on the cutting angle.

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Аппроксимация математической модели критической глубины комбинированного резания грунтов на основе регрессионного анализа

Святослав Кравец, Роман Зоря

Аннотация. Представлены результаты аппроксимации математической модели процессов резания и рыхления почвы для получения аналитической зависимости определения критической глубины разрыхления с учетом скорости рабочего органа при комбинированном поярусном разрушении почвы. Проведено аппроксимацию на основе регрессионного анализа, используемую при обработке данных, полученных в результате экспериментов с определенным количеством параллельных наблюдений в опыте. Построены графики зависимости между аппроксимированной относительной критической глубиной, рабочей скоростью рабочего органа и углом резки почвы. Определены значения критической глубины разрыхления для пяти типов грунта и полного диапазона рабочих скоростей, в зависимости от физико-механических свойств почвы.

Ключевые слова: угол резания, глубина разрыхления, рабочая скорость, критическая глубина, комбинированная резка, уравнение регрессии, дисперсия исследования.

Study on working peculiarities of glue laminated beams under conditions of slanting bending

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Abstract. Current rules do not take into account the peculiarities of glue laminated beams under the conditions of slanting bending. In fact, the rules do not consider the real change in the stress-strain behavior of such elements upon the load change from its initial application till fracture under the conditions of slanting bending due to the fact that material (wood) behavior in the construction is currently assumed as nominally elastic. What is more, this issue is not sufficiently studied either theoretically or experimentally.

This article is devoted to the study of the working peculiarities of glue laminated beams made of glued pine boards under the conditions of slanting bending.

The main issues are as follows, the description of research methodology and experimental prototypes, analysis and processing of the research results, working peculiarities of the material as part of the glue laminated wooden beams under the conditions of slanting bending.

The article presents the results of experimental studies on the bearing capacity and deformity of glue laminated beams under the conditions of slanting bending. The results will give the opportunity to design wooden constructions taking into account the profound knowledge on material capacity as well as the working peculiarities of its components, which will lead to a more practical cross section of structural components.

Investigation of the process of laminar deformation upon the section height and indication of the peculiarities of the stress-strain behavior of these layers due to the stress of physical force under the conditions of slanting bending will allow to perform more reliable calculations of stress-strain behavior and design of glue laminated beams at different stages.

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Keywords: wood, bearing capacity, slanting bending, strain, stress, stiffness.

INTRODUCTION

Wood is not only one of the oldest construction materials, but also an important material to be used both in the present and future. Considerable increase in its use in the construction industry is an irresistible argument to this. Modern building wood has several benefits, such as light weight, easy manufacture, firmness and relatively cheap cost, constant natural renewability, which help to create new architectural forms. The appearance of laminated wooden structures has significantly stimulated and diversified the scope of use of wood in construction. They are currently used for raising one-storied industrial and sports facilities as well as multi-storied residential and public buildings.

The behavior of solid beams as well as glue laminated beams which are under the conditions of slanting bending is currently poorly known. Operative rules and existing studies [1] do not address the real behavior of the beams under the conditions of slanting bending or make it impossible to establish the neutral line position and the stress-strain distribution of the cross section at various stages of loading the construction in general.

PURPOSE AND METHODS

The purpose of this research is the study of the working peculiarities of glue laminated beams under the conditions of unsymmetrical bending [2, 3].

Wood moisture content at the moment of manufacture of the samples was within 12 %, according to [7]. Glue laminated beams were manufactured from a set of seventh boards 3250 mm long with the section of 100×150 mm. The study of the beams was carried out on the previously made experimental installation [8]. Metal supports provided the required slope angle for organizing the prototypes. The supports were made of steel 4 mm thick and were set in the places for the beams to rest on them as well as in the points of application of two concentrated loads. Loading of the beam was executed with the help of a hydraulic jack which was housed on a metal traverse. The base of the traverse amounted 900 mm which made 1/3 of the experimental beam span. The load level was controlled with the help of a dynamometer which was marked in advance. The load was applied by degrees of 8…10% of the assumed devastating load taking into account the guidelines and requirements [9]. The scheme of the experimental installation and the location of the devices on the prototype are shown in Fig.1.

Pilot testing of a glue laminated block is the principle method for solving the specified problems.

Glue laminated wooden beams were made from first pine wood with due account for the requirements [4 − 6]. Class D3 resorcinol resin adhesive was used for gluing beams.

To reduce the impact of the rotational moment on the working peculiarities of the beam [10, 11] ties were organized in the points of load application.

Locking of the beam deformation was performed with the help of 6 PAO deflectometers and strain gauges. The latter were glued to the beam amid the span around the cross-section perimeter with BF-2 glue. The surface of the beam was polished and degreased prior to glu-

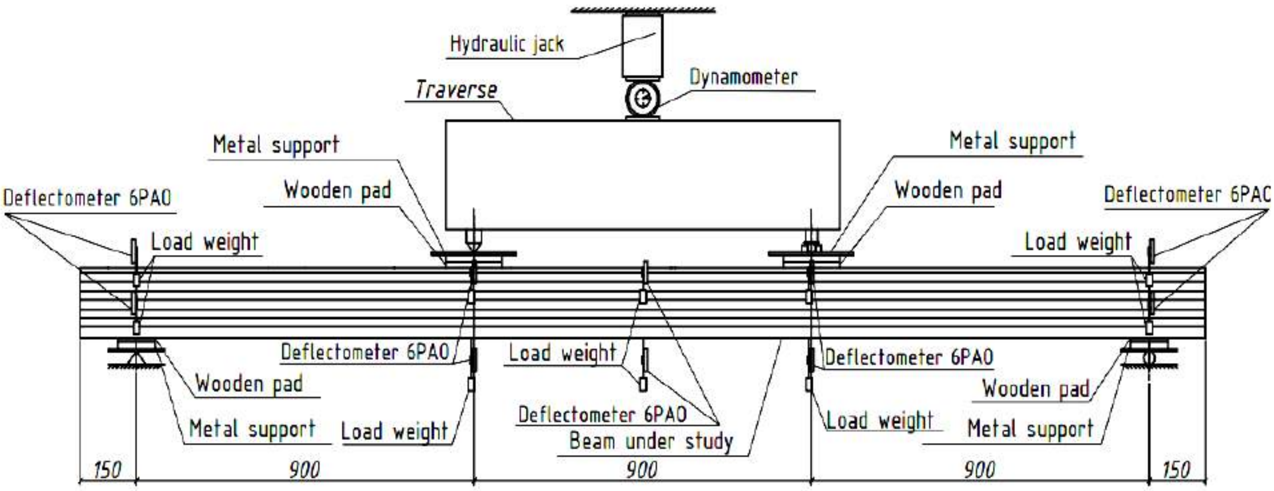

Fig.1. The scheme of the experimental installation and the location of the devices

ing. Serviceability check of the strain gauges was performed in advance. The first check was performed prior to gluing by at ester; the second was performed after gluing and soldering by the computer software. The SIIT-3 strain-gauge station was responsible for sensor reading. Deflectometers were set on the supports in the points of load application and in the middle of the span to calculate deflections along the Y-Y and Z-Z directions. All the devices that were used in the experiment were preliminary approved by the State certification licensing authority.

The values of deflection of the beams were recorded prior to the load application which ranged to 80% of the assumed devastating load since further load application could lead to immediate fracture of the prototypes and, consequently, to the eventual fracture of the measurement instrumentation.

RESULTS

Laminated wooden beams GLB-1 and GLB-2 were tested at the slope angle of 10°, GLB-3 and GLB-4 beams were tested at the slope angle of 25°.

Five minute delay was permitted at each stage of the load application to take the readings from all devices.

During the experiment, control was executed over the level of load application permitting critical deflection values [12, 13]. According to [12], the maximum allowed deflection of the beams is 1/150 *l*, where l is the span of a beam. In our experiment, the maximum allowed deflection of the beams is as follows:

$$w_{fin} = \frac{l}{150} = \frac{2700}{150} = 18\ mm \qquad (1)$$

In the first place, the deflections along the Y-Y and Z-Z directions were calculated [13].

Afterwards load-strain diagrams were drawn, which were calculated by the formula:

$$w = \sqrt{w_y^2 + w_z^2} \qquad (2)$$

where: w_Y is the deflection along the Y-Y direction, mm; w_Z is the deflection along the Z-Z direction, mm.

As reflected by the graph (Fig.2), at different slope angles the critical deflection was achieved at different values of the moment. The critical deflection for GLB-1 and GLB-2 beams occurred at 7,2 kNm and 8,28 kNm moment, while for GLB-3 and GLB-4 beams at 10,35 kNm and 10,8 kNm respectively. This can be explained by a greater slope angle of the beam, since the secant line of the force direction creates the cross-section which is vertically more expanded at a slope angle of 25° in comparison with the cross section at a slope angle of 10°.

All prototype beams GLB-1 − GLB-4 frac-

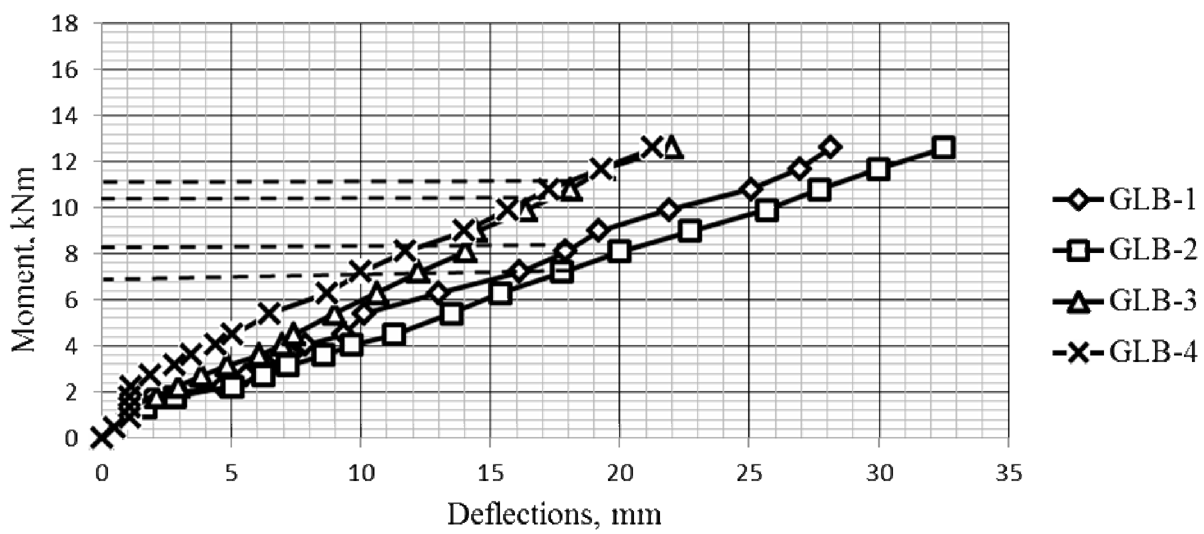

Fig.2. The full-scale deflections of glue laminated beams

tured in the area of pure bending and so did the beams at direct bending [14 − 17]. The first cracking of the beams occurred when tested at the slope angle of 10° at 30 kN moment, whereas at the slope angle of 25° it occurred at 32 kN. Afterwards, the rapid increase in strain occurred under the further increase of the load application, which lead to fracture of the unit [18 − 22], which started from the marginal board in the area of pure bending and was followed by crack propagation towards the supports. The fracture behavior of the GLB-1 and GLB-3 beams is shown in Fig.3 and in Fig.4.

The breaking moment for glue laminated beams GLB-1 and GLB-2 at the slope angle of 10° amounts 17,1 kNm and 17,33 kN, while this figure amounts 17,55 kN and 17,82 kN accordingly for the GLB-3 and GLB-4 beams at a slope angle of 25°.

The position of the neutral line at different levels of stress in a normal section in the area of pure bending of the askew-bended elements made from glue laminated wood was also determined by means of linear interpolation of the sensor readings. This method of determining the neutral line is the most conventional.

Fig.3. Fracture of the GLB-1

Fig.4. Fracture of the GLB-3

The neutral line of all the prototype glue laminated wooden beams changed its position towards increasing the area of the compressed zone under the increased load, simultaneously its slight twisting could be observed. The position of the neutral line for GLB-1 and GLB-3 beams under the different load levels are shown in Fig.5 and in Fig.6.

On processing the results obtained from the strain gauges, the deformation diagram was carried out for the deformation of the layers of wood in both the compressed and stretched areas of the prototype beams under the loads accommodation from the start of the load application and towards the loads on the verge of fracture while working under the conditions of slanting bending at the slope angles of 10° and 25°.

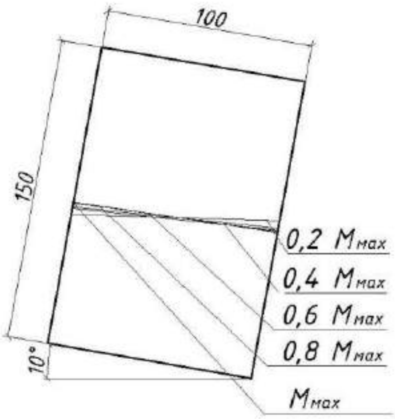

Fig.5. Change in the position of the neutral line of the GLB-1

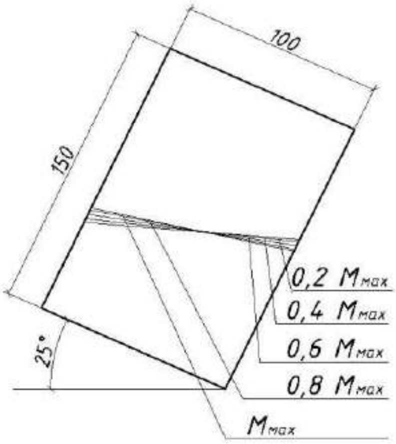

Fig.6. Change in the position of the neutral line of the GLB-3

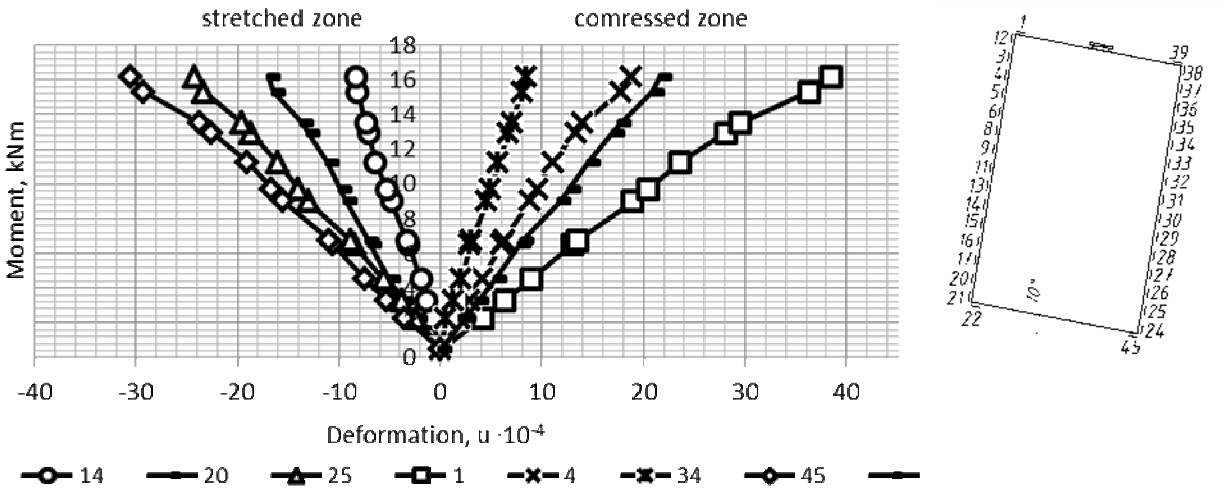

Fig.7. The diagram of GLB-1 deformation under the unsymmetrical bending at a slope angle of 10°

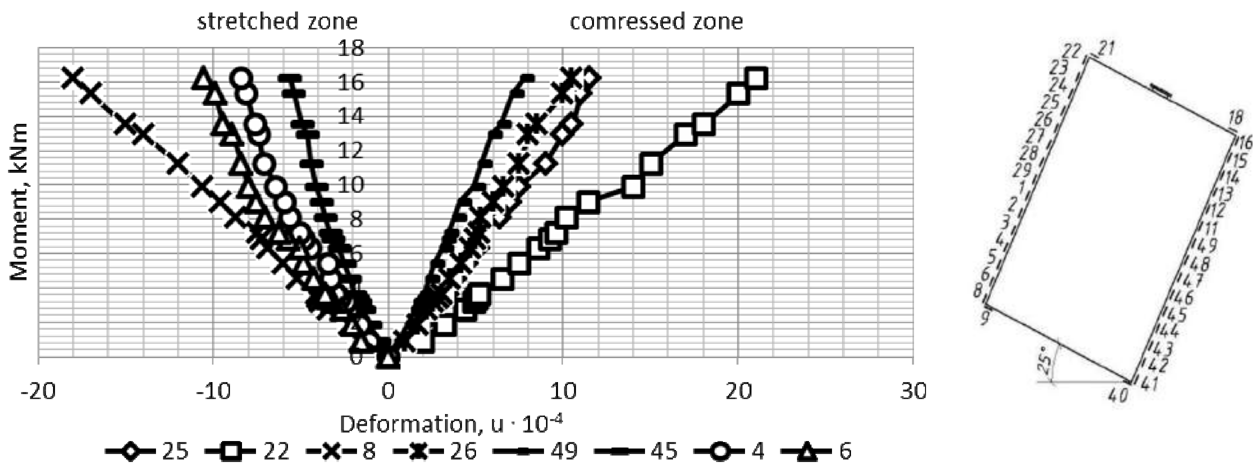

Fig.8. The diagram of GLB-3 deformation under the unsymmetrical bending at a slope angle of 25°

These graphs are shown in Fig.7 and in Fig.8. The number of strain gauges and their location on glue laminated beams are indicated to the right of the diagrams.

Deflectometers were positioned in the areas of load application in order to determine the value of the modulus of elasticity of glue laminated beams [16, 23]. The modulus of elasticity was calculated according to the formula:

$$E_x = \frac{F \cdot l^3}{548 \cdot I \cdot (w_c - w_{н})}, \qquad (3)$$

where F − is the load affecting the beam, kN;
l − is the calculated span of the beam, m;
I − is the cross-sectional moment of inertia of the prototype beam, m^3;
w_C − is the beam deflection in the middle of the span, mm;
w_N − is the beam deflection at the point of load application, mm.

The values of the elastic modulus at different levels of load application are shown in Table 1.

The elastic modulus of the glue laminated wood for GLB-1 beam amounted 13814 MPa, for GLB-2 beam − 13945 MPa.

Table.1. The elastic modulus of the beams at different load application levels

Beam	Load Application Level	Elastic Modulus, E, MPa
GLB-1	0,2 $M_{мах}$	18476
	0,4 $M_{мах}$	14105
	0,6 $M_{мах}$	12091
	0,8 $M_{мах}$	10585
GLB-2	0,2 $M_{мах}$	18363
	0,4 $M_{мах}$	14367
	0,6 $M_{мах}$	12364
	0,8 $M_{мах}$	10689

CONCLUSIONS

On the basis of experimental works the following conclusions can be drawn:

- the moment of fracture for glue laminated beams GLB-1 and GLB-2 at the slope angle of 10° amounted 17,1 kNm and 17,33 kN, for GLB-3 and GLB-4 beams at the slope angle of 25° − 17,55 kN and 17,82 kN, respectively
- GLB-1 beam reached critical deflection values at the moment of 8.28 kNm, GLB-2 beam − at 7,2 kNm, GLB-3 beam − at 10,35 kNm, GLB-4 beam − at 10,8 kNm;
- the value of the elastic modulus of the GLB-1 amounts 13814 MPa, for GLB-2 − 13945 MPa;
- fracture behavior of the glue laminated wooden beams under the unsymmetrical bending at the slope angles of 10° and 25° was determined;
- the position of the neutral line of the beams under the slanting bending was determined and the method of its defining was suggested;
- the change in position of the neutral line of the askew-bended beams at the slope angles of 10° and 25° from the initial load application till fracture was specified.

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Исследование работы балок из клееной древесины в условиях косого изгиба

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Аннотация. Действующие нормы не учитывают особенностей работы балок из клееной древесины при косом изгибе. Также нормы не учитывают реальное изменение напряженно-деформированного состояния таких элементов при изменении нагрузки от начала приложения до разрушения в условиях косого изгиба, поскольку в настоящее время работа материала (древесины) в конструкциях принимается условно упругой, и кроме того, этот вопрос как теоретически, так и экспериментально еще недостаточно изучен.

Статья посвящена изучению особенностей работы деревянных балок из клееных сосновых досок при косом изгибе. Основными вопросами являются следующие: описание методики исследований опытных образцов, анализ и обработка полученных результатов исследований, изучение особенностей работы материала в составе дощатоклееных деревянных балок в условиях косого изгиба. В статье приведены результаты экспериментальных исследований несущей способности и деформативности балок из клееной древесины в условиях косого изгиба. Результаты позволят проектировать конструкции из древесины, используя более полный учет возможностей материала и особенностей работы элементов, что приведет к более экономному подбору поперечного сечения элементов конструкций.

Исследование процесса послойного деформирования по высоте сечения и установление особенностей напряженно-деформированного состояния этих слоев под действием нагрузки при работе на косой изгиб позволит с большей достоверностью проводить расчет на разных стадиях напряженно-деформированного состояния при проектировании клееных деревянных балок.

Ключевые слова: древесина, несущая способность, косой изгиб, деформации, напряжения, жесткость.

Determination of limits for acoustical pollution from main roads at the stage of urban area zoning

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Abstract. The intensive automobilization of cities involves some problems relating to traffic arrangement, and as a result, requires to extend the transportation corridors of main trunk road networks, increase traffic capacity, and develop models of transportation flows in the conditions of existing urban development. In such conditions, environmental pressures on urban areas increase. The impact of technogenic factors on the areas also increases, and as a result, the concentration of environmental pressures enhances. The desire to increase the traffic capacity and city building density can induce ecological instability of some urban areas. At the present time, there are normative documents that regulate the conditions for development and planning of urban areas.

The functionality of urban areas and environmental pressures on the areas and their limits must be clearly determined at the stages of developing the general plans and detailed plans of the urban area development.

In the conditions of decentralization and formation of territorial communities, which are entitled to independently deal with their financial problems and form social living environment, it is required to use comprehensive professional methods for designing strategic programs for the development of cities and settlements.

At the present time, city planning specialists are capable of taking into account various factors relevant to the development and planning of urban areas with consideration for future environmental pressures and their limits. Due to this, it will be possible to save financial costs when carrying out actions required for decreasing the technogenic impact on the ecology and living environment, and planning the perspectives of regional development.

For this reason, the analysis of environmental pressures from the city main roads network is relevant for any city.

This paper contains the calculated data on the results of analysis of the city main roads characterized by different planning concepts.

These data are required for determining the corresponding planning actions.

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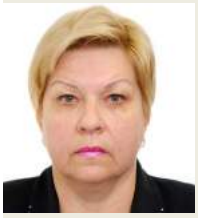

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Keywords: noise propagation paths, limiting acoustic discomfort characteristics, isodecibels.

INTRODUCTION

Acoustic pollution of urban areas is one of the negative results of the intensive automobilization of the country cities. The determination of levels of noise generated by various noise sources, as well as the estimation of noise propagation within the urban area is characterized by specific features and depends on the noise source characteristics and on the city planning stage at which the noise propagation is estimated. With consideration for this, at the detailed planning stage, an effective method was developed for drawing up noise charts for stationary and mobile noise sources. This method allows constant noise level lines (isodecibels) clearly to be drawn, and accordingly, the noise level in every specific urban area to be determined. For this purpose, it is required to have cartographic documents for the city planning area, at a scale of 1:500 through 1:2000, data on the road cross sections and road characteristics, and data on the parameters of transportation flows. But at the stages of technical and economic assessment, development of diagrams and projects according to the general city planning scheme, and preparation of cartographic documents at a scale of 1:10000 through 1:25000, or even 1:50000, there are no need and possibility to draw up the detailed charts characterizing the noise pollution in the areas studied. At these project stages, the estimation of acoustic pollution consists only in determining the predicted noise levels from various noise sources and drawing up noise diagrams. In this case, it is possible to compare different main roads depending on noise levels and distinguish the noisiest streets, but it is impossible to estimate the degree of noise propagation within the urban area.

STATEMENT OF THE PROBLEM

The purpose of this study is to determine the limits of acoustic impact of the city main roads when specifying the functionality of the urban areas at the stage of zoning the urban area and designing the detailed urban area plan. The development of a model for environmental pressures, with consideration for their impact, and the prediction of extension of the environmental pressures on the certain planning area is one of the purposes of activity in city planning.

ANALYSIS OF THE LATEST RESEARCH AND PUBLICATIONS

The results of analysis of scientific papers and effective normative documents relating to city planning demonstrate the actuality of this study issue, as the intensive automobilization of cities more and more promote the study of factors which have an effect on transportation flows simulation and on environmental pressures on the urban area. The city transport and the ecological state of the city environment are subjects of studies by such well-known specialists as Solukha B.V. [3], Fuks H.B. [3], Furmanenko O.S. [4], Shilova T.O. [5], Ustynova I.I. [6], Solukha I.B. [7], Diomin M.M., Reitsyn Ye.O., and others. The stable integrated approach in performing scientific studies will promote the introduction of new practical methods in the planning and arrangement of urban areas at the corresponding planning stage.

LIMITS FOR ACOUSTICAL POLLUTION FROM MAIN ROADS AT THE STAGE OF URBAN AREA ZONING

For the predictive estimation of noise pollution of urban areas from line noise pollution sources, a method was developed for analyzing propagation of noise from the city main roads inward the urban areas located near the streets [23, 24]. Specifically, at the stage of the urban area zoning, when different functional zones in the urban area are to be identified, there is a possibility to take into account the normative allowable noise levels and the characteristic features of the corresponding urban areas [25].

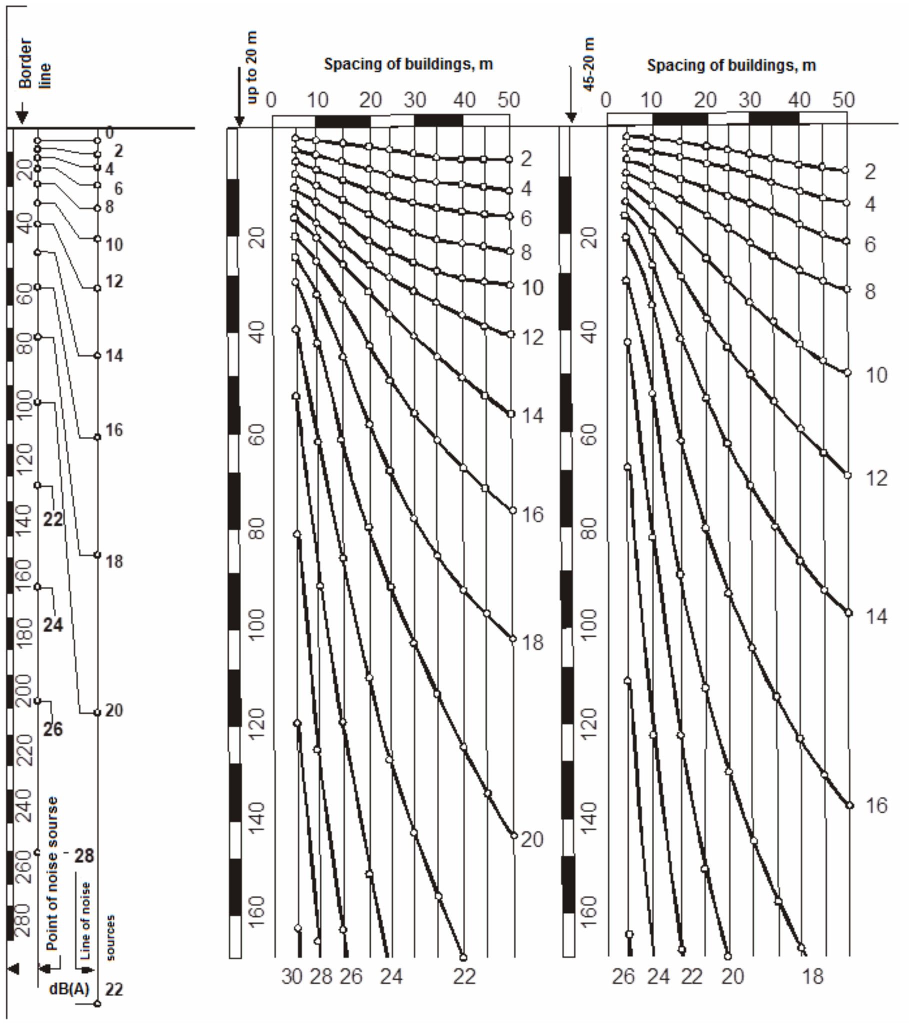
In this case, the following unbuilt and built-up urban areas with various allowable noise levels are defined:

- built-up areas with buildings for therapeutic, recreation, and fitness purposes: 50 dB(A);
- unbuilt areas and built-up areas with low-rise, high-rise, and mixed buildings: 55 dB(A);

- areas with long-completed buildings, which are subjected to reconstruction, and areas of industrial enterprises and estates: 60 dB(A).

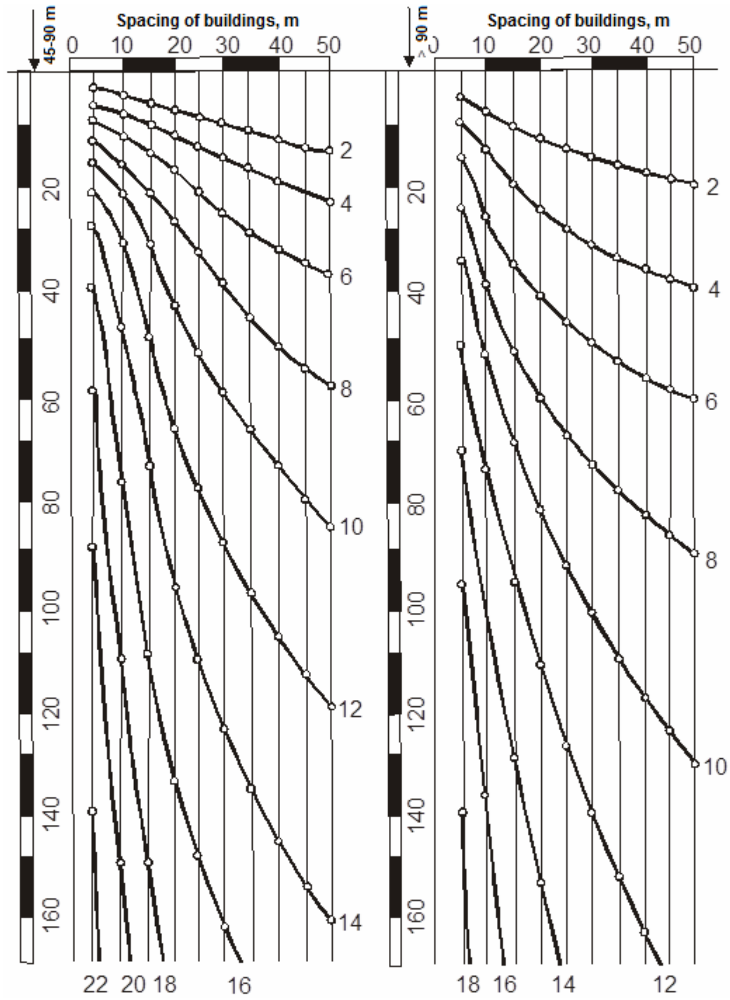
When performing acoustical analysis in such a case, it is recommended to determine noise pollution paths, that is, the areas located near line noise pollution sources, such as automobile roads and railways, with noise levels arranged between the isodecibels corresponding to the normative noise levels. It is accomplished by plotting limiting acoustic discomfort characteristics, which separate noise-polluted areas from areas with acoustic comfort conditions, that is, from the areas where noise levels are less then the noise levels specified in the sanitary standards [23, 24].

It is appropriate to determine the width of noise propagation paths according to the method described in [26], using a noise recorder developed in the Dnipropetrovsk Civil Engineering Institute [27].



a *b* *c*

Fig.1 (the beginning). Noise recorder data. The nomographic chart for determining the decrease of noise levels in unbuilt areas and in spacing's of buildings located at the specified distance from the border line [27]



d *e*

Fig.1 (the end). Noise recorder data. The monographic chart for determining the decrease of noise levels in unbuilt areas and in spacings of buildings located at the specified distance from the border line [27]

For the possibility to use a noise recorder, we determined, on the basis of the experience achieved in designing and analyzing various building projects, the following average spacing of buildings for various building types:

- for industrial buildings, such as production plant buildings, industrial facilities, warehouses, and garages: 10 m;
- for low-rise and mixed buildings: 15 m;
- for high-rise buildings: 20 m.

When performing overall calculations, it is assumed that roadside planted land in areas with individual and single-floor buildings decreases noise levels by 5 dB(A).

Limiting acoustic discomfort characteristics should be plotted as follows:

- within unbuilt areas, noise propagation should be determined according to the characteristic describing the propagation of noise from a line noise pollution source [26], or according to the first part of the noise recorder data [27] (Fig.1 *a*), obtained for the unbuilt area in which decrease of noise levels is caused only by distance from a noise pollution source;
- in areas with smallholding building, parks, or gardens, where the decrease of noise levels is caused by planted land, the width of noise propagation paths should be de-

termined in the same manner as for unbuilt areas but with consideration for the noise attenuation by 5 dB (A) due to the presence of the planted land;

- in areas with buildings of different types, the width of noise propagation paths should be determined according to the spacing's of buildings (Fig.1 *b*, *c*, *d*, *e*) with consideration for the characteristic features of the buildings and the characteristics of traffic arteries.

By using a noise recorder, for the specified spacing's of buildings and widths of traffic arteries within the controlled building-up areas, it is required to determine the distance at which the calculated level of noise caused by the presence of the traffic artery decreases to the sanitary standard level.

When determining the width of the noise pollution path from a railway, it is assumed that the basic normative requirements are fulfilled for providing sanitary protection area 100 m in width and 50-percent planting of the area. In this case, it should be considered that the decrease of noise levels by plants in the sanitary protection area is 6 dB (A) on an average. If the traffic artery is located within the railway right of way, the noise levels caused by both the noise pollution sources should be added with consideration for the noise energy generated by each source.

As an example, the use of the proposed method is illustrated by the data in Table 1, obtained in calculating the traffic noise levels from the main roads in Solomianskyi District in Kyiv.

Table 1 (the beginning). Propagation of noise from main roads in the Solomianskyi District in Kyiv

	Main roads	Existing state		
		Noise level, dB(A)	Distance, m	Note concerning the noise propagation conditions
1	2	3	4	5
	Ringway			
1	From the railway to Odesa Square	76,5	90/120*	*Unbuilt area
	Astronaut Komarov Avenue			
2	From the railway to V.Havel Avenue	76,6	93	High-rise buildings
3	From V.Havel Avenue to Industrialna Street	77,9	100	High-rise buildings
	Industrialna Street			
4	From Peremohy Avenue to Borshchahivska Street	80,8	170/100*	*Industrial buildings
5	From Borshchahivska Street to Ushynskyi Street	78,0	115	High-rise buildings
	Chokolivskyi Avenue			
6	From Ushynskyi Street to Sevastopolska Square	77,3	100	High-rise buildings
	V.Lobanovskyi Avenue			
7	From Sevastopolska Street to A.Holovko Street	77,5	97	High-rise buildings
8	From A.Holovko Street to Kirovohradska Street	80,0	120	Mixed buildings
	Peremohy Avenue			
9	From the railway to Dehtiarivska Street	79,5	135/70*/85**	*Park **Industrial buildings

Table 1 (the end)

1	2	3	4	5
10	From Dehtiarivska Street to O.Dovzhenko Street	78,0	115/55*	*Industrial buildings
11	From O.Dovzhenko Street to V.Vasylevska Street	78,3	125/70*	*Industrial buildings
12	**Borshchahivska Street**	78,0	110	High-rise buildings
	Povitroflotskyi Avenue			
13	From the ringway to Volynska Street	74,9	90	Unbuilt area
14	From Volynska Street to Sevastopolska Square	75,1	73/30*/95**	*Park **Industrial building
15	From Sevastopolska Square to Solomian-ska Square	76,7	93/50*	*Park
16	From Solomianska Square to I.Ohienko Street	78,7	115	High-rise buildings
17	From I.Ohienko Street to Borshchahivska Street	75,2	95	Unbuilt area
18	**Metropolitan V.Lypkivskyi Street**	76,1	87	High-rise buildings
	Solomianska Street			
19	From Protasiv Yar Street to A.Holovko Street	72,5	40	High-rise buildings
20	From A.Holovko Street to Solomianska Square	72,4	40/27*	*Park
21	**Kirovohradska Street**	75,1	30/37*	*Cemetery
	V.Havel Avenue			
22	From Vasylenko Street to Komarov Ave-nue	73,8	50/25*	*Industrial buildings
23	From Komarov Avenue to Vidradnyi Av-enue	73,0	45/22*	*Industrial buildings
24	**Medova Street**	71,6	50	Unbuilt area
	Narodnoho Opolchennia Street			
25	From Sevastopolska Street to Ernst Street	72,1	38	High-rise buildings
26	From Ernst Street to Medova Street	70,2	28/15*	*Industrial buildings
27	**A.Holovko Street**	73,5	48	High-rise buildings
28	**Protasiv Yar Street**	76,4	115	Unbuilt area
	Vidradnyi Avenue			
29	From Symyrenko Street to V.Havel Ave-nue	75,8	70/38*	*Industrial buildings
30	From V.Havel Avenue to Harmatna Street	74,3	35	Mixed buildings
31	**M.Hrinchenko Street**	70,6	20	Mixed buildings
	Vasylenko Street			
32	From Peremohy Avenue to V.Havel Ave-nue	77,8	50/30*	*Industrial buildings

The noise propagation paths caused by automobile and railway transportation vehicles and determined according to the above-mentioned method can be shown on the city district development map at the map scale. The data on the noise propagation paths can be used as basic data for differentiating the urban areas, developing more substantiated noise protection facilities, and taking decisions in relation to the planning and development of the urban areas.

CONCLUSIONS

The calculated data presented in this paper can be used as basic data in determining limit environmental pressures on the urban areas located near main roads, specifying the functionality of the urban areas, and taking the corresponding decisions for providing the quality of the city environment, selecting methods for the technical protection of the urban areas, studying the urban areas in conditions of compact planning, determining the type of building-up along the city main roads, and simulating the ecological state of the city environment.

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Определение границ акустических загрязнений от магистрали на стадии зонинга территории

Алексей Приймаченко, Татьяна Шилова

Аннотация. Повышение автомобилизации в городах влечет за собой ряд проблем по организации движения транспорта, что в свою очередь требует расширения транспортных коридоров улично-дорожной сети увеличения пропускной способности, разработки моделей транспортных потоков в условиях сложившейся застройки города. Также в этих условиях увеличивается и экологическая нагрузка на территорию ее техногенный потенциал влияния начинает расти, что приводит к увеличению концентрации экологических нагрузок. Желание увеличения пропускной способности и плотности застройки может привести к экологической дестабилизации определенных городских территорий. На сегодняшний день существует ряд нормативных документов, которые регламентируют условия застройки и планировки городских территорий.

Формирование функционального назначения территории и определены экологических влияний и их границ должно быть четко определено на стадиях разработки генеральных планов и планов детальной застройки территории.

В условиях децентрализации и формирования территориальных общин, самостоятельного определения их финансового развития в определенных отраслях и формирования социальной среды обитания требует многогранного профессионального подхода к разработке стратегии развития территорий и поселений.

На сегодняшний день специалисты в области градостроительства способны учесть всю многофакторность влияния на формирование развития и планирования территории с учетом последующих экологических нагрузок, их границ влияния, что в дальнейшем даст возможность экономии финансов при разработке мероприятий по снижению техногенного влияния на экологию и среду обитания человека и перспектив регионального развития. Поэтому задача исследования экологических нагрузок от магистральной уличной сети является актуальной для города.

Приведены расчетные данные обследованных магистральных улиц с различными планировочными решениями, собраны данные, необходимые для принятия соответствующих планировочных решений.

Ключевые слова: коридоры распространения звука, кривые акустического дискомфорта, изодецибелы.

Ways of considering traditions when forming the system of maintenance in Ukraine

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Abstract. The size of the territory, the density of the city dwellers, the number of cars for personal use, planning conditions and network configuration of highways and roads are the main components that influence the placement features of maintenance of motor vehicles in cities of Ukraine.

The article develops the structure of the distribution of cities under types, factors, kinds of functions performed in relation to the economic level and importance of the city as a part of the country; analyzes the impact criteria on the formation of the traditional system of management and living of the people of Ukraine; reveals the traditional approaches to the formation of maintenance in Ukraine.

Keywords: Cities of Ukraine, traditions, crafts and trades, transport and planning structures of the city, motorization level, system of maintenance of motor vehicles for personal use, methods of marketing management.

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INTRODUCTION

Ukrainian nation has a rich culture, a huge treasure of which has been formed by valuables and achievements of many generations. Since the ancient times, Ukrainians have accumulated wisdom and guidance on lifestyle. They resulted in the Ukrainian customs, rituals, folklore and life and make the basis for sense of the global consciousness of our people. This influences the relationship between people, the value of spiritual culture of the individual and the nation in general [1].

Today, the pressing issues include the formation and development of Ukrainian ethnic culture, the discovery of features of the traditional system of management, sustainment by crafts and trades, settlement, housing, transport vehicles and their maintenance.

Each city is a natural and technogenic complex, a component of the landscape area converted by the effort of many generations. It is based on a range of complexes − ramparts, moats, walls, houses, industrial and cultural constructions, reservoirs with dams, bridges, etc. A city is not just the structures with different values put in a natural landscape, but also the peculiar form of coexistence of people, civilization cores, and centers of cultural attraction [2, 3]. The main task of the urban development is to establish the best conditions for living and welfare of the population improve the transport system, streets and roads and localize the points for maintenance of motor vehicles for personal use.

Usually, most cities in Ukraine are small and medium-sized that are located on the territory irregularly. These include centers of administrative districts with different industrial and agro-industrial social facilities. Cities are divided into types depending on the number of population, the size of the area, planning structure, geography, climate and transport infrastructure and the type of functions performed. Their ratio determines the level of the economic role of city in the region or the country in general [4].

From the period of establishing cities up to currently, we can trace close ties between a number of complex components.

Customs are those unwritten laws that govern daily and the largest all-national affairs, such as the language; they were formed and perfected throughout life and development of every nation. Each former historic period in the life of society brings scientific achievement for the next generation. The method of trial and error leads to results, new ideas and opportunities, refines certain elements. Care about the next generations requires forecasting and thinking what can occur in the environment and with what consequences.

PURPOSE AND METHODS

The aim of the article is to identify the main criteria of influence on the global consciousness and the existing system of maintenance of motor vehicles for personal use in Ukraine; having analyzed the historical periods of its development, traditions, development stages up to the present times, to describe the existing system of maintenance of motor vehicles for personal use; highlight the issues and trends in the development of this system in future.

Tradition (lat. − transfer) − elements of social and cultural heritage that are conveyed to future generations and preserved for a long time by the society as a whole or in separate groups. It appears as appointed, stereotyped behavior, customs, rituals, social ideas, moral and ethnic elements, etc. [5].

The search and researches conducted helped find out the following criteria on forming the influence of the traditional system of management and sustainment of the population in ci-ties of Ukraine:

1) functions of the city:

- number of residents;
- Genesis (what nation has founded the city and when);
- place in the settlement system (an agglomeration center, a satellite city, a local center, a recreational, scientific or industrial center, a transit point)
- occupations of residents (mostly unrelated to agriculture);
- type of construction of the territory;
- development of villages; traditions;
- density of the population; versatility of trades;
- existence of a market as a constant commodity exchange at the settlement (commodity character of production activities) [2, 6].

The main tasks of planning and urban development are, as follows: to justify future needs and determine the preferred areas for the use of the territories; take into account the state, public and private interests during planning, construction and other use of the territories; justify the division of lands for the intended purpose and the use of the territories for urban needs [7].

Function of the city determines its role in society. The main activities of city dwellers cause the following features: city-forming (exogenous) and city-servicing (endogenous).

2) Economic and geographical (transport and geographical) location of the city is one of the main factors of the formation of the city on the territory; it affects the development of production and the creation of inter-territory relations of different scale:

- industrial and geographical location depending on the source of energy, raw materials (wood, metal), processing industry;
- agro-geographical – location depending on the production bases and agricultural raw materials;
- transport and geographical – location depending on sea and main-line tracks, transport hubs;

- sales and geographical – location depending on markets for sale of capital goods (coal, ferrous metals), markets for consumer goods;

- demo-geographic – location depending on human resources, scientific and technical personnel. Production and territorial relations are important, in terms of freight traffic flows − a location foreign economic relations; concerning passenger traffic – mostly domestic transportations [2, 8].

3) number of residents.

In Ukraine, according to statistics as of January 2013, there are about 450 cities. According to DBN/State Construction Coe 360-92* depending on the number of population, cities of Ukraine are divided into the following groups:

- the most significant (larger) – the population is over 1 million people (Kyiv, Kharkiv, Odessa);

- significant (large) – the population is 1 million − 500 thousand (Dnipro, Donetsk, Zaporizhzhia, Lviv, Kryvyi Rig). Cities in this group are the centers of industry, transport and service sector;

- big – 14 cities with the population of 500-250 thousand people and 22 cities with the population of 250 − 100 thousand people;

- average – 47 cities with the population of 100-50 thousand people;

- small – 341 cities with the population less than 50 thousand people [9 − 11].

The functional structure of the city actively influences the number of its inhabitants. Multifunctional cities are more densely populated with faster growth rates in the population. This affects the age and professional composition of the dwellers, their living standards.

National peculiarities of beauty perceptions are closely related to the specific local conditions that are clearly seen on the architecture. Traditional housing in different regions is mostly adapted to climatic and environmental conditions and activities of the inhabitants. Traditions of constructing a dwelling were conveyed from generation to generation, buildings were aesthetic zed; people got accustomed to their home, it was the most beautiful to them. Even later, when the assortment of building materials increased, when clay and wood were replaced by brick, the construction of buildings continued preserving the previous forms, as they were considered natural, they comply with local tastes and determined the style of a particular area. Artistic features initially merged with national, traditional, folk and ethnic ones and became the signs of ethnicity.

Along with the changing lifestyles, our ancestors were acquiring more and more knowledge. It laid the basis for the global consciousness as the system of view points concerning the world and the place of man in it, the relations of human with the surrounding nature and science, changing scientific approaches [12, 15]. For several thousand years, man has developed since the invention of the wheel to the exploration of the universe. The role of transport in the life of the planet, state and city is really important because only movement leads to progress.

The analysis of the history of transportation maintenance and repair of vehicles in Ukraine enables to identify and study periods of formation and establishment of the industry.

The beginning of change in the outlook on the importance of a car is considered to be 15 May 1910, when the International Automobile Exhibition was opened in Kyiv, aimed at "Drawing attention of everyone who has doubts and prove that a car has been already in our lives and there no distances for it" [13, 14].

In the first stage, the need for cars was met due to their imports from abroad. Later, because of the necessity to decide first of all more important national economic and defense problems in the pre-war and post-war years, lorries were preferred. The critical stage of the development transport is considered to be 1929, when it was decided in Russia to construct two large plants in Moscow and Gorkyi.

In 1927 – 1930 years, special garages were organized in Kharkiv, Kyiv, Dnipropetrovsk and Zaporizhzhia. It was time for preventive maintenance of vehicles. Since 1932, the mass production of domestic cars has started. In the post-war years, the automotive industry has increased considerably. There automobile factories and enterprises appeared.

Fig.1. Example Car maintenance station in 1932

Fig.2. The facade of the station servicing tires car 25 work stations in 1987

Until 1959 in Ukraine, there were no avtomobile plant. Therefore, its fleet was formed as a result of the acquisition of cars for import and manufacturing plants built in Russia and other republics of the former Soviet Union (Fig.1).

In 1975, the Main Information Center was formed, the chief directorate of "Ukrglav-avtotehobsluzhyvanie"/the Ukrainian Main Automobile Maintenance was reorganized into an independent Respublic Industrial Association "Ukrglavavtotehobslugovuvannia"/the Ukrainian Main Automobile Maintenance.

In 1984, a new industry began functioning on the territory of the CIS – automotive maintenance (Fig.2). Its creation was caused by a high growth of the vehicle fleet. At the same time, we can observe the acceleration of technological progress, technical reequipment and reconstruction of existing production through improving the design of vehicles, consolidation of logistics of automobile enterprises and due to better road conditions.

In 2000 the State Department on Road Transport was established (within the Ministry of Transport and Communication of Ukraine), which is the administrative body of state management in road transport and operates within the transport infrastructure. "Ukravtotrans" performs respectively the following tasks and functions: provides in accordance with the law the state regulation in automobile transport and exercises control over the adherence by Ukrainian and foreign transportation organizations to Ukrainian transport law, rules of passenger and freight transportation, etc., regulations governing the functioning of motor vehicles. It promotes within its area of competence the reduction of harmful effects of road transport on the environment and the implementation of energy saving activities [13, 16].

In 2016, there was a significant increase of cars in Ukraine due to our own production companies: Zaporizhzhia Automobile Plant CJSC – produces motor vehicles: Opel, Daewoo, Chevrolet, Tavria, Slavuta and their lorries: TATA, Dong Fend; Lutsk Automobile Plant, OJSC − VAZ, Izh, KIA, Hyndai; Eurocar CJSC − Skoda, VW, Audi; UkrAVTO corporation (ZAO "ZAZ") [13, 17].

There is considerable competition and oversupply of the market for the sale of vehicles (Fig.3).

RESULTS

The main condition for the successful functioning of any enterprise is the correct marketing management. It enables to predict the future state of the enterprise and the environment, in which it exists; to identify the possible changes and weaknesses in the supply management system in all spheres, based on the predicted activities of the enterprise on the maintenance of motor vehicles for personal use.

Fig.3. Example serviced individual use of cars at the station in 2017

Due to the estimates of predicting sales, lifecycle and profit potential of a particular segment or product market, we can perform a full analysis of the attractiveness of the market (Fig.4). This approach is important for making decisions on the volume of investments in construction of such facilities in future and their production capacity [18].

To this end, we use different methods of prognosis. Based on inductive and deductive approaches, methods of prognosis can be simple and complex [19, 20]. There are:

1) factual – based on facts, information materials on former and current development of the object of prognosis;

2) expert (intuitive) – based on an expert opinion about the object prediction and generalization of their conclusions on its development in the future;

3) combined – include methods with mixed information basis, when factual data is used as initial together with expert opinions.

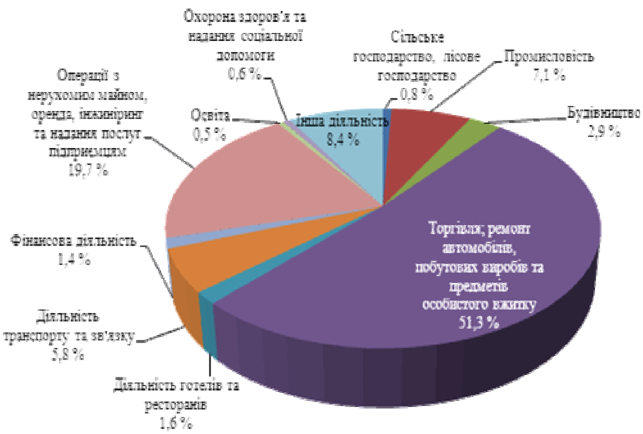

Fig.4. The distribution of economic Business of private enterprises in Ukraine in 2017

To account possible changes and improvements in results and efficiency of activities of the enterprise, one can use statistical methods. The static analysis includes the process of assessing the quality of products and raw materials, the composition of components and tools; estimates of changes in production and technological processes due to statistical management (control cards, management cards). The result is determined by the composition of the original data, their volume, the registration order, storage and verification of the validity; the analysis of data; developed and documented recommendations on the results of data [21].

The method of expert evaluations is rather well-known as well, when experts conduct intuitive and logical analysis of the problem with the quantitative assessment of problems and formal treatment of results. The result gained (the summarized expert opinion) is treated as the solution to the problem. During the process of management, experts form objects (alternative situation, goals, solutions, etc) and carry out measuring of their characteristics (probability of an event, rate of importance of the purpose) [22].

Based of the material provided, we can conclude that in 2017 − 2018 years the number of motor vehicles for personal use in the cities of Ukraine will increase. The annual trend of growth in certain brands of cars is associated with the needs to use these types of facilities. This automatically affects the necessity for their maintenance. There is a directly proportional relation between the size of the city, its population, the level of car ownership and the availability of facilities for servicing [23].

Thus, due to significant changes in the inner transport environment of the city, there is a problem in prognosis of service centers for motor vehicles.

As for some time Ukraine was a part of Russia and had no independent automotive

Fig.5. Example design visualization service stations for passenger cars. A look at the future

Fig.6. Example draft unified stations for cars individual use. A look at the future

manufacturing and the car park was formed due to the acquisition of vehicles via imports, even now we use both domestic and foreign brands.

Traditional approaches to designing and construction of maintenance facilities in Ukraine should be aimed at improving the economy (Fig.5). In order to gain fast profit and return investment put in the project, it is advisable to use standardized structural elements and tested materials, improve software and hardware and technologies (Fig.6).

CONCLUSIONS

1. The main tasks of planning and urban development are: to justify future needs and determine the preferred areas for the use of the territories; take into account the state, public and private interests during planning, construction and other use of the territories; justify the division of lands for the intended purpose and the use of the territories for urban needs.

2. We have analyzed historical periods of the automotive industry. Enterprises of road transport are relatively new types of structures, the occurrence of which is associated with the rapid development of the car park, freight and passenger transport. Change of market potential of services for motor vehicles depends on time and external factors: the traditional approach, habits, cultural values, income, technology, prices, legislation, etc.

3. We have provided methods of marketing management for the successful operation of the company for maintenance of motor vehicles for personal use.

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Способы использования традиций при формировании системы технического обслуживания в Украине

Ольга Петруня

Аннотация. Размер территории, расчетная численность населения города, количество автомобилей индивидуального пользования, планировочные условия, конфигурация сети магистральных улиц и дорог – основные составляющие, которые имеют влияние на особенности размещения системы технического обслуживания легковых автомобилей в городах Украины.

Разработана структура распределения городов по типам, факторам, видам выполняемых функций в соотношении с экономическим уровнем та значением города в составе страны. Проанализированы критерии влияния на формирование традиционной системы ведения хозяйства и жизнедеятельности населения Украины. Выявлены традиционные подходы к формированию системы технического обслуживания в Украине.

Ключевые слова: города Украины, традиции, народные промыслы и ремесла, транспортная и планировочная структуры города, уровень автомобилизации, система технического обслуживания легковых автомобилей индивидуального пользования, методы маркетингового управления.

Mathematical approaches to the optimization of the functional and planning location of primary collection points of waste management collection according to city planning criteria

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Abstract. The main city planning criteria of residential area sanitation organization aimed at optimizing the location of primary collection points of waste management in residential areas are examined.

The trends in the development of residential areas waste collection systems and disposal to provide comfortable living environment for the population and to satisfy their household requirements are confined to the following trends: progressiveness of household waste collection automation, aesthetic, sanitary-and-hygienic, engineering solutions of equipping the primary waste collection points to ensure the technological and organization-and-technological methods for waste collection.

Further planning of the waste collection and disposal is impossible without taking into account the city planning and development. A decision on the technological or organization-and-technological method for the household waste collection is taken on the third or second technological level is based on the city planning and development standards, the territory analysis and is taken in accordance with a number of conditions and limitations specifying the territory.

The main city planning limitations when selecting a waste collection method are: the territorial limitation, the residential density within the limits of the streets, or the zone of influence of a waste transfer station, planning limitations of the existing site planning etc. The main requirement to the residential areas waste management and collection system envisaged by the city planning is optimization of the location of the primary waste collection points on the residential territories.

The locations of planned hubs of the primary waste collection point are determined by the planning scheme of the territory waste collection system.

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Keywords: household waste, primary collection point, waste collection systems, planning module, planned hubs, criteria, residential areas.

INTRODUCTION

The planning scheme of the waste collection points is developed for a territory at the stage of a detailed master plan of the territory at a scale of 1:2000, and is limited by the zone of influence of a waste transfer station, the city block area, or by the district of residential area in accordance with the distribution of the social and cultural services provided to the inhabitants. The main city planning criteria defining the territorial location of primary waste collection points are:

- walking distance
- differentiation of the functional zone at the stage of the primary waste collection point planning
- lay of the land and landscaping
- economic models of planned hubs location
- residential density.

STATEMENT OF BASIC MATERIAL

The principle of the functional-and-planning organization is created according to the scheme shown in Fig.1.

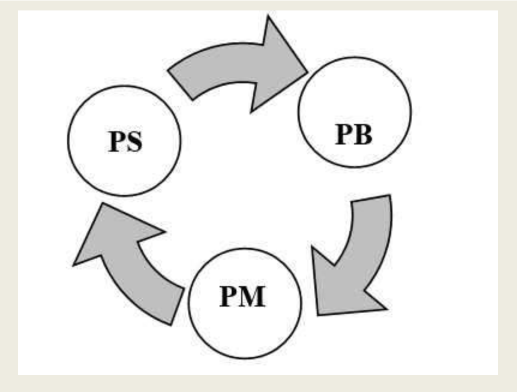


Fig.1. Scheme of organization of the residential area waste collection system planning structure

PS – *planning scheme* (at a 1:2000 scale) of the waste collection system is based on the city planning requirements and residential area limitations. In the area planning scheme the places of planned hubs of the primary waste collection point are defined. The area of the planning blocks influence is limited by the radius of walking distance and defines the territorial limits for calculation of the number of planning units (modules) of the primary waste collection point, see Fig.2.

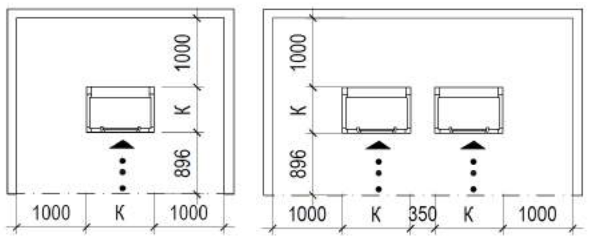
PB – *planning blocking* or embedding the planning modules in the primary household waste collection point in a cartilage. The planning block area is calculated in accordance with the household waste volume in the influence zone and the working area of the primary waste collection point, see Fig.4 Blocking the planning modules.

Fig.2. A fragment of a planning scheme of location of the primary waste collection points with the definition of their influence zone on the example of a residential area in Kyiv

PM – *planning module* (loading equipment) is the primary element in the waste collection and disposal system. The calculation of the planning module area depends on the equipment for the household waste collection system adopted according to [1] and pursuant to the determined waste collection method for the residential area, its constructive features and is defined in accordance with the principle planning scheme, see Fig.3.

A planning block is the smallest planning and organization unit of the waste collection system. In accordance with the Order of the Ministry of Regional Development, Construction and Housing, and Communal Services [2], a planning block corresponds to the first, second, third and fourth process flows. It is approved by the Order and is designed for one or two containers which, when a planned hub is formed, are blocked in accordance with the requirements of the area and the established technology.

The planning of the arrangement of a container [3] includes the distance between the equipment and fencing and the area under the fencing. The state standards do not provide the area of a module necessary for an individual to dispose of the household waste; this area is defined by the anthropometric measurements and is located on the side of the equipment opening [4, p.141-151], for PM2 the territory between the equipment is also included.



a *b*

LEGEND

− equipment for the household waste collection points

– direction of the household waste loading

− borders of a module area

Fig.3. Planning modules of the primary household waste collection point: *a* – planning module of the primary household waste collection point per one piece of equipment (PM1); *b* – planning module of the primary household waste collection point per two pieces of equipment (PM2)

The length of the PM1 module for the land-based method is calculated according to the formula (1) [3]:

$$L = 2b + K\ .$$

The length of the PM2 module for the land − based method is calculated according to the formula (2),

$$L = 2b + 2K + 0{,}35\,.$$

The width of the modules PM1 and PM2 for the land – based method is calculated according to the formula (3) [3], with the addition of anthropometric measurements:

$$B = b + K + 0{,}875,$$

where: K − the overall dimension of the container (length or width), m; b − the distance from the container to the module fencing in line with the State Standard of Ukraine N.B.B.2.2-7:2013 (1 m is accepted); B − the width of the module, m.

When defining the length and width of a module for the underground method, the dimensions of the underground container are taken into account at calculation. Collection and transporting of the household waste by the land-based and underground method are the technically interconnected processes, whereas the reloading of the household waste from the equipment to the waste collection vehicle is carried out mostly mechanically and, only occasionally, manually. Both the land-based and the underground method of container emptying provide for the top, rear or side reloading to the waste collection vehicle [5, p.235-245].

It is important that the equipment fixing and size correspond to the technical capability of the waste collection vehicle [5, p.235-245]. The containers and the waste collection vehicle have special outlets for equipment, which clutch the equipment by special auxiliary handles thereon and with the help of the waste collectors holding it up (if necessary) from the opposite side when the container is being emptied.

The experience of technological method [6, 7] of the household waste collection system in residential areas in Ukraine is not represented, the household waste is mostly disposed by the land-based (Fig.5) and sometimes underground [8, 9] organizational and technological waste collection method. The equipment for the waste collection points is adopted in accordance with [1].

The morphological composition of the household waste puts a number of requirements as to the equipment form and to its material:

- food waste may attract stray animals, rats etc., therefore they have to be collected in the equipment with a lid, molded, and not of grid structure
- paper, plastic waste, PET bottles, rubber, fabric etc. are collected into the equipment of the molded, not grid structure with a lid, to avoid the waste scattering by wind in the territory

- glass waste is collected into the equipment with the molded or grid structure
- batteries, accumulators and suchlike are collected into a specially allotted container of molded structure with a lid.

Depending on the volume of the household waste in the territory, the number of planning modules for the primary waste collection point is determined. For the household waste collection in Ukraine the containers with the volume of 1,1 m^3 and 0,4 m^3 are used, therefore a planning module has been developed for this type of equipment. Table 1 determines the area of a planning module for the equipment already in use in 90% of the cases of the household waste collection in residential areas in Ukraine.

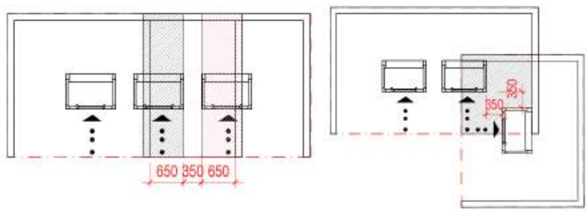
Table 1. Area of a planning module for 0,4 m^3 and 1,1 m^3 volume equipment

Waste collection method	Planning module area, m^2			
	1PM		2PM	
	0,4 m^3	1,1 m^3	0,8 m^3	2,2 m^3
Land-based	7,47	9,86	10,80	15,97
Underground, vacuum	3,43		5,40	

A planned hub is the second level of the organizational – and – planning structure of the waste collection system. *Blocking the primary modules into a planned hub is carried out using two types*: the front and off-center. The front blocking of planning modules envisages placing containers in one line, where the loading is carried out on one side or on two sides. The off – center location of containers envisages blocking with offset of the one planning module respective to the other, and loading is carried out from two or more sides.

The number of planning modules shall correspond to the limitations indicated in Chapter III of the Order of the Ministry of Regional Development, Construction and Housing, and Communal Services On Separate Household Waste Management [2]. It is achieved by taking into account the process flow of the household waste collection system in residential areas where the maximum planned hub number of equipment on the enclosure may vary from two to five.

The blocking of planning modules into a hub is based on the principle of decreasing their area while interoperating on the average per 2…5 m^2 (see Fig.4). Principle scheme of blocking the planning modules into hubs of two types: front and off-center.



a *b*

LEGEND

– equipment for the household waste collection points.

– direction of the household waste loading

– borders of the module area

Fig.4. Principle scheme of PM blocking into hubs of two types: with front and off − center location: *a* – principle scheme of PM blocking into planned hubs with front location; *b* – principle scheme of PM blocking into planned hubs with off-center location

The decision on combining the planning modules into a planned hub is taken locally in accordance with city planning conditions and the planning scheme of the waste collection system, which is prescribed in technical requirements:

- the square footage for the primary waste collection point;
- the location of the primary waste collection point in the planning organization of the city block area.

The number of planning modules in a planned hub is 3 to 5 in accordance to the process flow of the Order of the Ministry of Regional Development, Construction and Housing, and Utilities Services [2], as well as aesthetic, sanitary-and-hygienic norms. Negative experience of blocking hub (see Fig.5).

Fig.5. Blocking of planning modules of the primary waste collection points, on the example of Odessa city

After the method for the household waste collection and the planned hub type (its blocking) have been established, the functional zone of the primary waste collection point is determined which meets the function of the household waste accumulation. The functional planning dependence of the type of planned hub blocking is expressed through comparison of the functional zone area of the primary waste collection point with its accumulation volume in different disposal methods (see Fig.6). The criterion for optimizing the primary waste collection points blocking is shown below, where

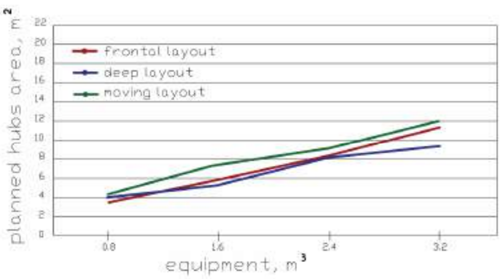
$$Sf \to \min,$$

Sf – is the functional zone area.

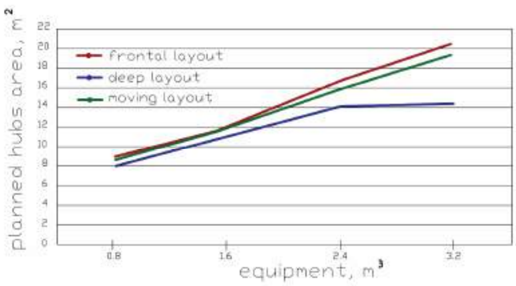
The planned hub functional zone provision can be expressed through the theory of sets, Fig.7:

$$A \in C; \; B \in C;$$

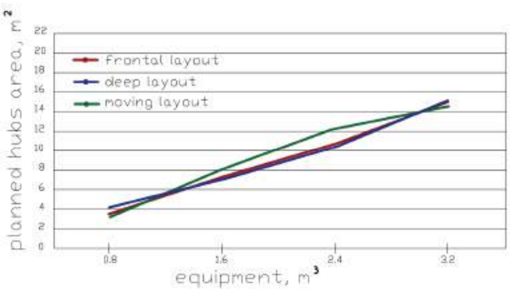
$$A / B; \quad B / A,$$



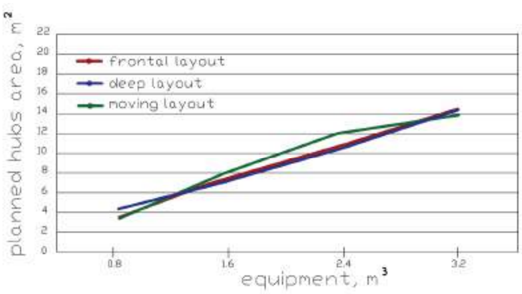
a



b

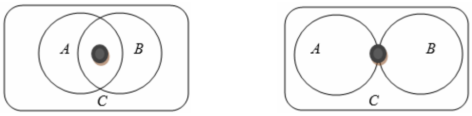


c



d

Fig.6. Functional planning dependence of the type of the primary waste collection point planned hub blocking: *a* – land-based method; *b* – land-based method with vegetal zone; *c* – underground method; *d* – vacuum method



LEGEND

– planned hub

A – loading zone (pedestrian area)

B – disposal zone (working area)

C – planned hub functional zone

Fig.**7**. Functional planning of the primary waste collection point planned hub blocking: *a* – planned hub with zone overlapping; *b* – planned hub differentiation

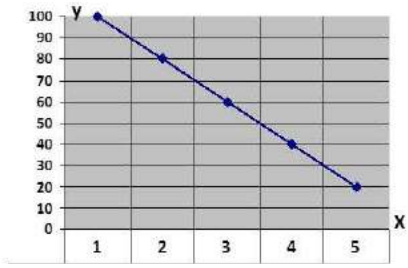


Fig.8. Distance to planned hubs in accordance with comfortable walking distance scheme: *x* – resident comfort index on a scale from 1 to 5, where 5 being the highest comfort index; *y* – distance from the apartment block entrance to a planned hub

where: A – the household waste planned hub loading zone (pedestrian area); B – the planned hub household waste disposal zone (waste collection vehicle working area); C – the planned hub functional zone.

The walking distance (l) determines the influence zone of the primary waste collection point and the area of planned hub influence. A maximum walking distance from a building entrance to the primary waste collection points is defined by the city planning norms and does not exceed 100 meters:

$$l \leq 100 .$$

To determine the primary waste collection point influence zone, the walking distance of 100 meters is accepted and expressed with due consideration of the nonlinearity coefficient as a radius of the primary waste collection point influence zone [10, p.107-112]. Location of the primary waste collection point planning hubs determining the borders of a maximum influence zone has to be optimal.

The criterion for optimization of the planned hub of the waste collection points is comfortable residential area for all inhabitants. Its provision indicators are expressed by the equal walking distance from the building entrances to the places of the waste collection disposal points with the equal utility payment rates for the waste collection services for all inhabitants of the residential area.

Determination of planned hubs of waste collection points for a residential area on a planning scheme is expressed by the equidistance parameter after the service apartment blocks have been defined.

$$l_1 = l_2 = l_3 = l_n .$$

With the increase of the distance from a building entrance to the primary waste collection point the comfort index and accessibility of the planned hub for the residents' decreases, see Fig.8. The plotting of the planned hubs location is based on the parameter of decreasing the distance for a person to be covered to the primary waste collection point in order to improve the living convenience through the walking distance:

$$l \rightarrow \min .$$

In practical application these two functions have a series of contradictions, as it is practically impossible to provide a minimum equal distance from all entrances covered by the primary waste collection point influence zone with due consideration of the city planning conditions.

Therefore, the optimization of the location of planning hubs with the aim of increasing the living convenience through walking distance is based on the parameter of decreasing of the distance from the building entrances to the planning hub within its influence zone. In order to provide the minimum distance to the primary waste collection point it will be expedient to minimize the net distance from all the buildings to the planning hub:

$$\sum l = l_1 + l_2 + l_3 + l_n \rightarrow \min .$$

City block area (quarter) perimeter and buildings: depending on the territory configuration, lateral length in the plan and the planning type, the primary waste collection points may be located in the recess of the quarter – on the main driveways and along the perimeter of the quarter without entering the residential area. In the city historical environment and when the streets are crossed more often than in 400 m the approach to the quarter area is forbidden. The primary waste collection points have to be located along the perimeter of the quarter area. Architectural objects of the residential, cultural and social purpose, which under this condition are located at a distance exceeding 100 m, are serviced by the vacuum waste collection method. Location of the primary waste collection points allows to distinguish two major functional and planning types:

- the differentiation of the loading zone and the disposal zone with delimitation of the pedestrian and transport flow to the planning hub
- the combination of the loading zone and the disposal zone with crossing the pedestrian and transport flow.

The criterion by which the planned hub location is optimized is the equal living convenience for all the residents, the provision of which for population is expressed through the planning division of a hub into a waste load zone and a waste disposal zone.

Urban road network system of resident area in accordance with [11] imposes a series of requirements to the household waste planning hub location within the red lines [12]. In accordance with Annex B, p.44-47 [11], the most commonly used typical cross sections of streets and roads, the following requirements may be distinguished:

- location on the type I and IV trunk lines, see the scheme at p.44, Annex B [11], may only take place in zones allotted for the landscaping, and servicing and removal may be fulfilled through the local (side) service roads;
- location on the type II and III trunk lines is possible on the rumble and safety margin strips, as well as on the barrier railings strip providing their sufficient width.

The same requirements are imposed to location of the planned hubs on other cross sections of the trunk roads and housing streets, the main passages and local streets. When disposing the household waste by the underground method (container or vacuum), taking into account the layout of utilities is obligatory. The criterion by which the planned hub location on the streets and roads is optimized is the provision of unimpeded pedestrian and traffic flow. The planning charting of the planned hubs location is based on the parameter of optimization of location of separation of the traffic and pedestrian flow to the planned hub.

Area lay of the land and landscaping: one of the criteria of the comfortable living of the population is the city territory landscaping and public amenities. In [13], certain requirements to the enclosures for the household waste collection are given, with the recommendation of their landscaping, and in the State Sanitary Rules and Regulations [14] and in [1] and [3], the recommendations on the equipment selection are provided.

Having analyzed the standard efforts to regulate the residential area landscaping and public amenities, one can affirm that the waste management system requires more significant attention as it belongs to one of the population's primary needs. The waste management system is an integral part of landscaping of its residential environment and does not take into account the existing lay of the land, the territory landscaping, the waste collection system technology.

At the stage of the planning charting, when locations of planned hubs and waste collection method are determined, it is important to take into account the natural and climatic factors, wind direction, temperature range and lay of the land.

The lay of the land influences the waste collection and disposal system if a curtilage is located on a challenging lay of the land or on one that is unfavorable or adverse for residential planning [15, Table 1.1]. In a curtilage on a lay of the land where the battering walls, bent surfaces, hills and barrows, junctions of three plains [15, Fig.1.3] with the drop exceeding 2 meters are present, the primary waste collection points are built into the land with due organization of the working and functional zones. The walking distance to the primary waste collection point where the challenging lay of the land or a particularly adverse hill or steps occur has to be decreased. When locating the primary household waste collection points, it is necessary to take into account the solutions of the curtilage lay of the land organization to provide rinsing of containers and the wastewater disposal for the public utility site.

The landscaping in the territory has to be compulsory and not recommended for the land-based enclosures as its additional isolation from the household.

The wind direction and the curtilage aeration influences the location of the primary waste collection points and is a compulsory factor to be considered for the land-based method.

The temperature range influences the processes running in food waste; therefore, for a temperate climate zone it is necessary to consider this factor to calculate the periodicity of the household waste disposal. However, this factor does not influence the planning location of the primary waste collection points.

Economic models of planned hub location: one of the principles of economically and rational location of the primary waste collection points is its compactness principle. The compactness principle is expressed through the economic models of locating the primary waste collection point and the volume of household waste in its influence zone, see Fig. 9, *a* and *b*, the maximum influence zone of the primary waste collection point equals the area of the circle with a 100 m radius:

$$S_{\inf l.z} = \pi r^2 ,$$

where $S_{\inf l.z}$ – is the maximum influence zone according to the walking distance radius = 3,14 hectares. Fig.9 show the developed economical models of the primary household waste collection points location for a residential area within the maximum radius of accessibility of the primary waste collection point which constitutes an influence zone of 3,14 hectares. The residential density of the area determines the economic effectiveness of each of the location models:

- in the centrally separated model and in the centrally integrated economic model under the condition of such population concentration it is difficult to find a territory in a city to block 4 containers with a volume which would satisfy all the requirements to the organization of a functional and working zone of the primary waste collection point
- the centrally separated and the centrally integrated economic models under the condition of such residential density may function only on condition that the household waste would be removed twice a day, which increases the cost of the system operation and decreases the residents' comfort

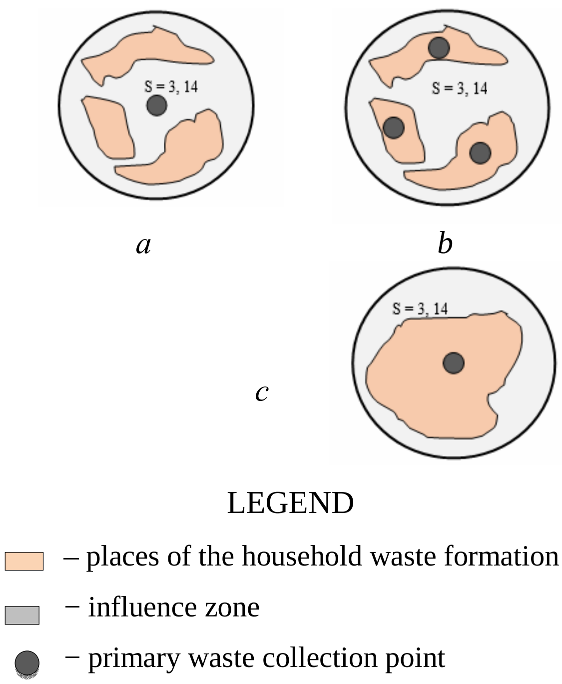


Fig.9. Economic models of planning block location in influence zone: *a* – centrally separated; *b* – fragmentary; *c* – centrally united

- the fragmentary model, on condition of the population's density in the territory requires additional primary waste collection points that increases the cost of the system construction and operation.

At the maximum residential density in the influence zone of 1200 − 1400 persons at the rate of 400 − 450 persons per hectare the household waste volume will reach 6…9 m^3 per day. The land-based method: such residential density in the influence zone gives evidence of the fact that location of one household primary waste collection point is not enough, as the maximum load on one primary waste collection point through the land-based method is 5,5 m^3 per day (4 containers with the volume of 1,1 m^3). Thus, in order to satisfy the household waste disposal by the land-based method the additional expenses in any economic model type are required.

The underground method: such residential density in the influence zone gives evidence of the fact that such centrally separated and centrally integrated economic models may be used without any additional expenses if this does not contradict technical provisions. The fragmentary model if population is dense on the territory requires additional primary waste collection points that increases the expenses for the system construction and operation and increases inhabitants' comfort by decreasing the walking distance. When the residential density is moderate, in the influence zone of 470 − 600 persons at the rate of 150…200 per hectare the household waste volume will amount to 2…4 m^3 per day.

The land-based method: such residential density in the influence zone gives evidence of the fact that locating one primary household waste collection point is enough, as the maximum load on one primary waste collection point by the land-based method is up to 5,5 m^3 per day (4 containers with the volume of 1,1 m^3). The fragmentary model, under the condition of the moderate residential density in the territory requires additional primary waste collection points, which increases expenses for the system construction and operation.

The underground method: such residential density in the influence area gives evidence of the fact that such centrally separated and centrally integrated economical models may be used without any additional expenses if this does not contradict technical provisions. The fragmentary model, if the population is dense in the territory, requires additional primary waste collection points that increases the expenses for the system construction and operation and increases the inhabitants' comfort by decreasing the walking distance.

Based on the analysis of the models of the primary waste collection points location and the residential density it is necessary to stress that the land-based method is not of economic benefit for a territory with high residential density (mostly central and historical city parts), therefore there the underground method can be used efficiently.

Generally, for a territory with high residential density it is better to use the fragmentary model, as these are the zones of compact planning and it is quite difficult on the conditions of such planning to find a significant territory area to equip an enclosure for 4 containers, to isolate it from the inhabitants and to provide a working and functional service zone for it; besides, such enclosures look unaesthetic in the central and historical city parts. For a territory with low residential density, the centrally separated or the centrally integrated models are more appropriate, as they are rational from the economic point of view.

$$Vp.f. \rightarrow \max.$$

The economic criteria by which the location of the planning hub is optimized the provision of maximum accumulation of the household waste.

CONCLUSION

The functional and planning location of the primary waste collection points is provided by a number of criteria. To optimize their location two major city planning factors are taken into account: the minimization of the walking distance from the buildings' entrances and the location of the primary waste collection points in the concentration places (places of high residential density) in the influence zone. This is meeting the economic efficiency criterion (maximum volume accumulation in the primary waste collection points) and comfortability for the largest part of the population in the influence zone.

This way of optimization may be provided if the primary waste collection point can be viewed as an attraction center. The second optimization criterion is the use of the planning conditions and territory limitations,

where $Sf \rightarrow \min$

when $Vp.f. \rightarrow \max$.

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Математические подходы оптимизации функционально-планировочного размещения первичных пунктов сбора санитарной очистки по критериям городского планирования

Людмила Золотарь

Аннотация: рассмотрены основные градостроительные критерии организации санитарной очистки жилых территорий для оптимизации размещения первичных пунктов сбора на жилых территориях.

Тенденции развития санитарной очистки жилых территорий для обеспечения комфортного проживания населения и его бытовых нужд ограничивается направлениям: прогрессивность автоматизации сбора бытовых отходов, эстетическое, санитарно-гигиеническое, инженерное решение оборудования первичных пунктов сбора бытовых отходов для обеспечения технологического или организационно-технологического способа сбора.

Дальнейшее развитие санитарной очистки невозможно без принципиального учета градостроительства. Решение по технологическом или организационно технологическом способе сбора бытовых отходов принимается на третьем или втором технологическом уровне и базируется на градостроительных требованиях и анализа территории, принимается в соответствии с рядом условий и ограничений, характеризующих территорию.

Основные градостроительные ограничения при выборе способа сбора: территориальное ограничение, плотность населения территории в пределах улиц, или зоне влияния мусороперегрузочной станции, планировочные ограничения существующей застройки и др.

Основное требование к санитарной очистки жилых территорий, которую ставит градостроительство − оптимизация размещения первичных пунктов сбора на жилых территориях.

Ключевые слова: бытовые отходы, первичная точка сбора, способы сбора бытовых отходов, планировочный модуль, планировочный узел, критерии, жилые районы.

The reasons for architectural monuments destruction and methods of capacity reinforce for bases and fundaments

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Abstract. The main problem of monuments’ emergency state is poor condition of the bases and foundations often due to their moisture. Uneven foundations subsidence leads to redistribution of efforts in bearing constructions and static instability of the base-foundation-building system. That’s why any restoration starts with the removal of their emergency state.

Using the example of Mykola Pritisk’s Church on Podil, where groundwater underflooding caused the collapse in the south-eastern part of the building, describes how the restoration works on the monument, which began with the reinforcement of damaged foundations and framework for static recovery of base-foundation-building system, measures to protect foundations and basements from underflooding, ensuring reliable vertical and horizontal waterproofing for the basement walls and floors, and all the underground part of the church, and works for antiseptic treatment of bio-damaged and saline walls and plaster surfaces. After that, the organization of reliable geodetic control for the structure deformation was ensured.

Keywords: bases and fundaments, groundwater, intensification

INTRODUCTION

The problems of the alert condition for bases and foundations of buildings are the main problems of monuments restoration. That is why all the work prior the restoration measures require liquidation of alert condition for the bases and foundations [1 − 5].

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The ways of overcoming these problems should be considered using the example of the church of St. Nicholas the Wonderworker (Mykola Pritisk’s Church − architectural monument of XVII − XVIII c. of National importance in Kyiv at the Podil (security Nr.19), where southeastern structures collapsed in May 1983 due to groundwater underflooding of basis and foundations resulting that the car-

Fig.1. General view of Mykola Pritisk’s church

Fig.2. Alert condition of the Mykola Pritisk's church (Photo May 1983)

Fig.3. Part of Mykola Pritisk's church octagonal drum

rier pylon and two reinforcing arches, which were based on it, cylindrical vaults and three sides of an octagonal drum were destroyed (Figs.2, 3).

MATERIALS AND METHODS

The purpose of the article is as follows: to illustrate the consequences of moisturizing bases and foundations using the example of particular architectural monuments, and how these problems are solved by experts of the "Ukrrestavratsiya" corporation. The methods of architectural and comparative analysis were used in the article. The details were provided for the elimination of the alert condition for the foundations and basements moisture by groundwater [6 − 10].

RESULTS AND DISCUSSION

The main reasons for the alert condition of the monument were raising the level of groundwater in recent years after the construction of the subway at Podil, which was like a dam and blocked the flow from Tarasivska and Zamkova mountains in the Dnieper, uneven subsidence of foundations that caused redistribution for efforts in carrying structures, which destroyed previously established balance in the base-foundation-building system.

Previously, during the centuries of facilities exploitation, the issue of infiltration water derivation, leading to periodic waterlogging of soils of the basis and material of the foundation, was not solved.

Consequently, full or partial degradation of the mortar and bricks appeared.

Given the fact that also, a bus station and market were for many years located near the church, and the traffic of large trucks and buses caused vibrating load on the foundation and basis.

To elucidate and clarify the reasons for the alert condition of the church, Ukrainian main state institute of engineering studies (UkrDIINTD) performed a complex field, laboratory and cameral geological studies technical report in 1983 [11]. In 1984, 9 pits were made in addition to the previous studies to clarify the soil structure of the base and foundation material (Fig.4).

Soil conditions at the construction site are summarized in the Tables 1 and 2.

At a depth of laying the foundation, bearing layers for the base are soils 2, 3 and 5.

The foundation material, as it is seen from the pits, is uniform. In the pits number 1, 4 and 5, the foundation is made of bricks on limestone mortar. In the pits number 2, 3, 6 and 7, the foundation is made of rubble masonry (slab and granite boulders of 100 cm). The sole rubble foundations are located at a depth of 2,4 to 3,55 meters. After the rubble masonry, the brick masonry, which goes to the surface, is made. Sand and brickbat are used as a filler in the masonry. The masonry within the foundation in the pits 5, 8, and 9 has a vertical crack of 2 cm wide. Sections see Figs.5 – 8.

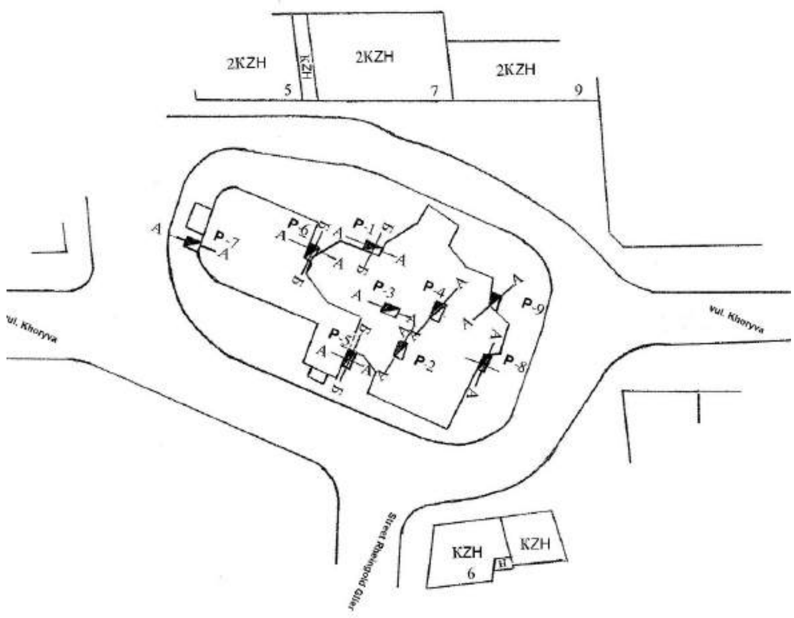


Fig.4. Layout for pits

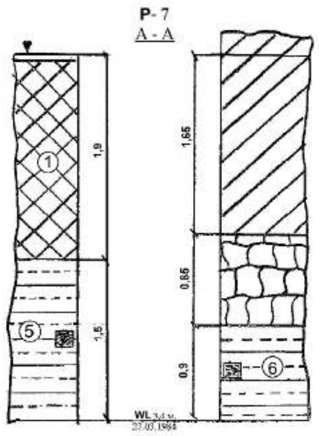


Fig.5. Section for the pits Nr.7

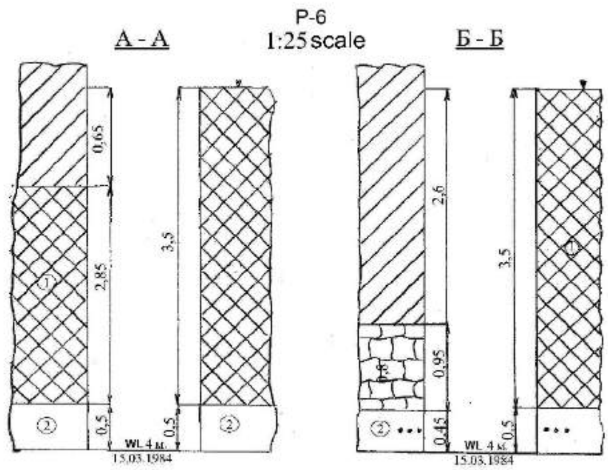


Fig.7. Section for the pits Nr.6

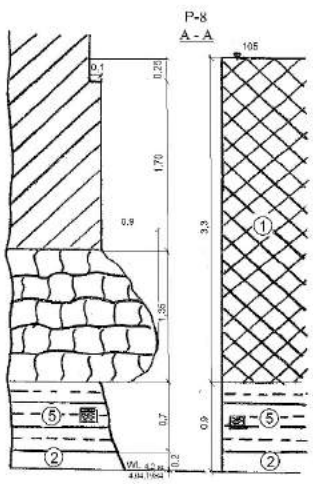


Fig.6. Section for the pits Nr.8

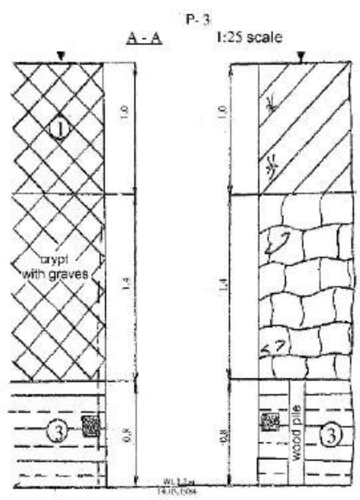


Fig.8. Section for the pits Nr.3

Table 1. Consolidated engineering-geological with a table for normative and calculated indices of soil properties

No.	Conditional marks and ground designation	Soil name (in accordance with SNiP-II-15-74) GOST 25100 - 82	Normative values								Calculated values						Additional information	
			Natural humidity	Plasticity index	Plastic limit	Liquidity index	Porosity factor	Degree of humidity	Volume weight	Total deformation modulus	Volume weight		Specific cohesion		Angle of internal friction		Sequence number with classification	Projected fluidity
			W	J_P	W_P	J_L	e	G	γ	E	$γ_I$	$γ_{II}$	C_I	C_{II}	$φ_I$	$φ_{II}$		J_L
			Unit fraction						гс/см²	кгс/см²	gf/cm²		kgf/cm²		degrees			Unit fraction
1	(1)	Bulk ground - sandy loam, sand with plant residues, and inclusion of solid construction debris up to 30% of the burial															24a	
2	(2)	Fine, quartz, dense sand with sandy loam layers, wet yellow-gray dusty sand of average size.	0,13	-	-	-	0,55	0,64	1,93	360	1,93 ±0,04	1,93 ±0,03	0,03	0,04	33	36	27в	
3	(3)	Sandy loam plastic with thin interlayers and lenses of dark gray sand with admixture of construction debris and household waste, yellow-gray.	0,22	0,03	0,21	0,46	0,80	0,73	1,01	120	1,81 ±0,11	1,81 ±0,06	0	0	23 ±6	26 ±3	34в	>1
4	(5)	Sandy loam with an admixture of plant residues, construction waste, household waste, sand interlayers, dark gray.	0,23	0,05	0,24	<0	0,99	0,59	1,64	60	-	1,64	0,05	0,07	17	19	34б	>1

The table gives the values for normative and calculated indices of soil properties by monoliths selected from under the base of the church foundation above the groundwater level.

Table 2. Soil conditions construction site

No.	Depth of bottom, m	Stratum depth, m	Soils description	Conditional marks and designations of soils	Groundwater level
1	2,30	2,30	Bulk ground, sandy, sand with plant residues, the inclusion of domestic waste up to 30%	(1)	0,00 1,00 2,00
2	4,20	1,9	Fine, quartz, dense sand with an admixture of yellow-gray wet dusty sand	(2)	3,00 WL 4,00
3	6,70	2,5	Sandy loam plastic with thin interlayers, dark gray, with an admixture of garbage and household waste	(3)	5,00 6,00
4			Sandy loam solid with interlayers of dark gray sand	(5)	7,00 8,00 9,00 10,00

State scientific and technological center for the conservation and restoration of monuments conducted studies for building material of foundations and walls of the church to determine their composition, strength, salinity, moisture, and biological damage.

It was found that brick walls were made of yellow and dark red brick on lime-sand mortar with the lime to sand ratio 1:5. Brick has a fragile structure, and water absorption more than 19%. The testing of the strength in compression rate showed the result of more than 25 kg/cm^2.

The main measures for the elimination of alert condition foresaw:

- strengthening damaged foundations and framework for establishing base-foundation-building equilibrium;
- developing measures to protect the base and foundation from underflooding;
- providing reliable vertical and horizontal waterproofing for the basement walls and floors, and for the entire underground part of the church;
- works on the antiseptic treatment for the surfaces affected by Micromycetes fungi complex and eliminating salinity from the brickwork and plaster of the walls;
- establishing a reliable geodetic control for the structure deformation [12 − 15].

STRENGTHENING OF THE DESTROYED BASIS AND FOUNDATIONS OF THE CHURCH

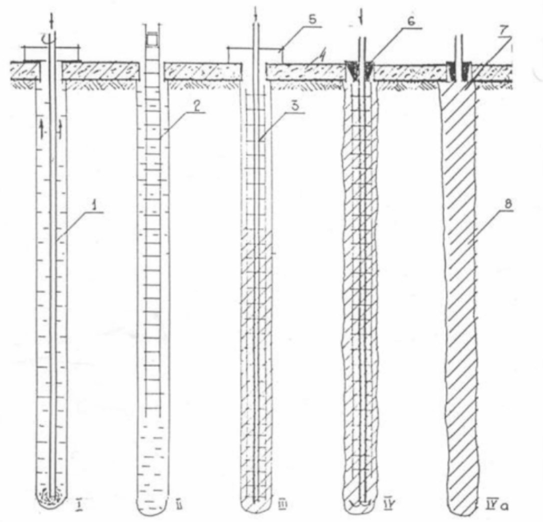
When the project of monument restoration was considered, several options to strengthen the foundations and bases were discussed, including eyeliner foundation pillars to expand the sole foundation, strengthening the soil by injection, amplification using bored and pressed piles, placing a solid base plate [16-19].

Analysis of the considered options showed that during strengthening the foundation pillars in wells, establishing outrigger bored and pressed piles under the existing foundations, uneven efforts will appear in structures that need to be carried out in sections, as the efforts cannot be passed to the basis. The disadvantages of the above options are also the strengthening, complexity, and laboriousness, the cost of these works within a construction site.

Comparing the technical and economic parameters, as well as the considered options, the most rational was the use of root piles (Figs. 9 − 15).

The main advantages of this method were the following:

- the possibility of arranging piles through existing structures reinforcing the foundations with the injection under pressure;
- the preservation of authentic exterior of the architectural monument;
- pressing the mortar in well with simultaneous resume of its pressure, which provided filling cracks in the construction of the foundation, compacted surrounding soil, provided roughness around piles surface, which increased their carrying capacity;
- settling of root piles due to their pressing usually no more than a few millimeters even for loads close to the threshold of the material strength;
- static equilibrium is not disturbed for existing foundations because of the arrangement of piles is performed using small-sized equipment with high speed without vibration transmitted to the foundation.



Technological scheme for arrangement of root piles with wells washing by concrete mortar: I – boring with chisel drilling bits; II − installing reinforcement cages; III − installation of injection pipe and filling the hole with a mortar; IV − tampons and establishing pressing of wells; IVa − pressing of wells at the mouth of the pile. 1 − drilling pipe; 2 - reinforcing cage; 3 − injection pipe; 4 - reinforced foundation; 5 − mouth tray; 6 − swab with gland; 7 − extended part of the pile; 8 − finished pile.

Fig.9. Flowsheet of root piles use

The total number of root piles was 506 pcs., diameter 132 mm, the length of the pile was 16 m, the angle 15 − 19 degrees.

The structure of the strengthening works also included cement injection under pressure to the foundations and rubble masonry. Arranging of piles was performed by SKB-4E cutting chisel (Fig.12). Drilling of masonry was conducted by blowing air and soil drilling with flushing by pre-cast concrete using hydrocyclone pumping unit УСГУ-2. Construction deformation was stopped after strengthening the monument of architecture.

MEASURES FOR PROTECTION THE BASE AND FOUNDATION OF THE CHURCH FROM UNDERFLOODING

Scientific and technological inspection [20] performed in 1998, was intended to establish the real picture of the moisture state for the church, identify the causes of soaking for the

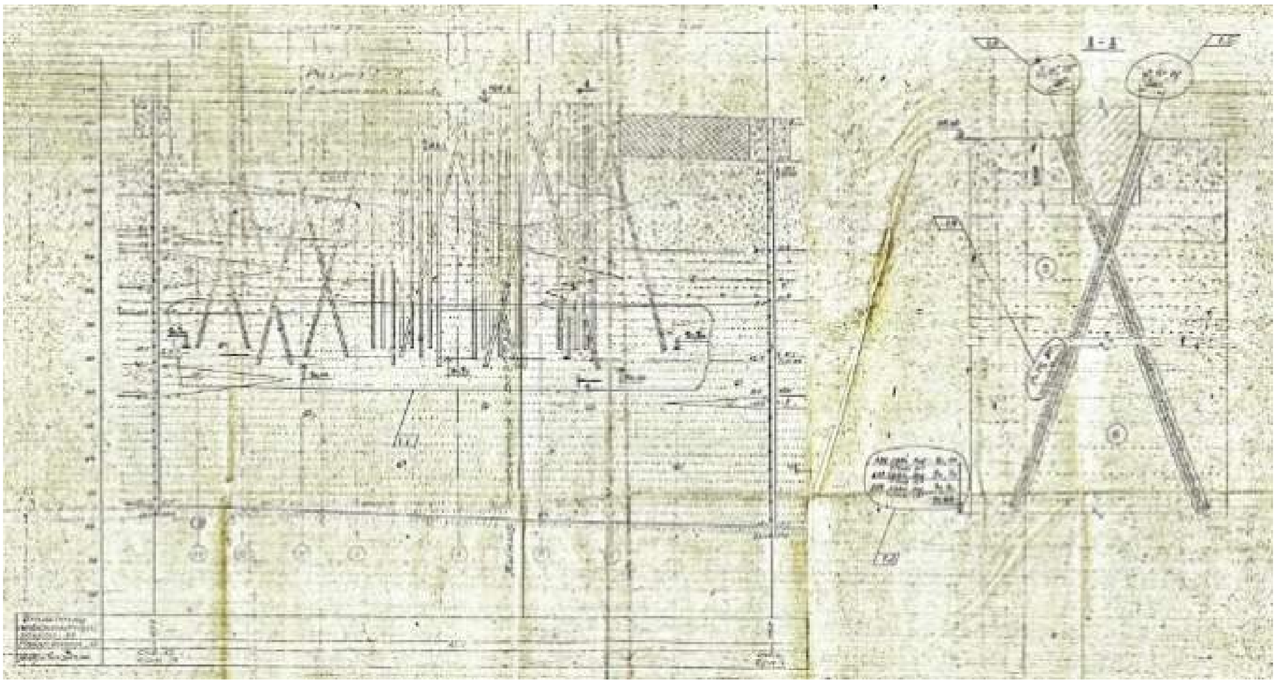


Fig.10. Scheme for putting building on the geological section

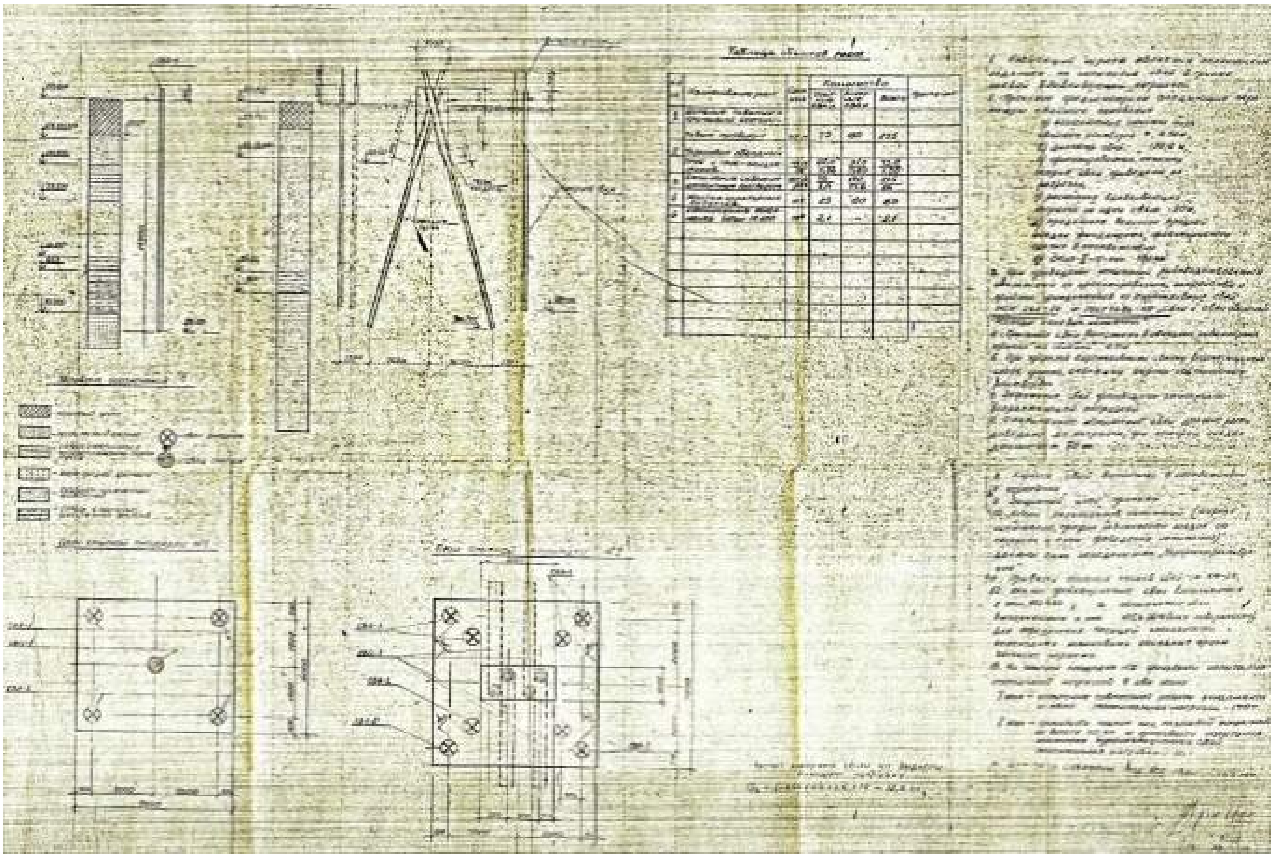


Fig.11. Test for the pile in the soil by axial load

basement, and to develop technologies of waterproofing, as well as other repair and restoration works.

The samples of building materials were taken during the inspection to determine their composition, strength, salinity at the surface of the plaster and brickwork; measurements of moisture for the brickwork and air samples were conducted; the samples of biological damages were taken. Separately, an analysis of the water, which was in the basement, was conducted.

Basement moisture condition (Fig.16) was unsatisfactory, the basement was underflooded all the time and water was always there. The water level rose to a height of 40…50 cm from the floor and depended on changes in the level of groundwater. Moisture of the plaster exceed permissible limits, plaster was covered with efflorescence. In some places, there was peeling, breaking, and some heavy losses of laying bricks. In the north wall, bricks inrush amounted to 15 cm, cracks in walls and arches reached up to 30 mm.

Analysis of the moisture condition for the laying lower sections of the walls testified that the moisture for the walls was significantly higher than the permissible limits and reached above 12…14%, resulting in lesions of building materials with Micromycetes fungi complex and caused the plaster and brickwork destruction. Moisture indicators in the interior walls of the church basement were lower and showed existing capillary suction of moisture.

Fig.12. Drilling machine СКБ-4Е

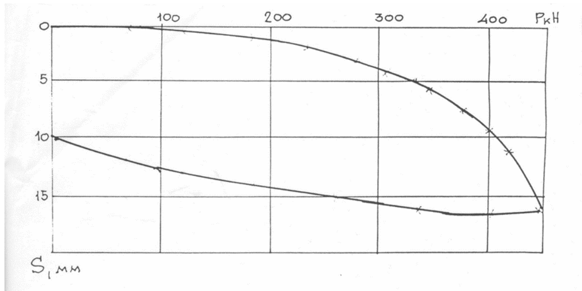


Fig.13. $S = f(P)$ plot for the studied root pile DP-1 at strengthening the foundations of the Mykola Pritisk's church in Kyiv

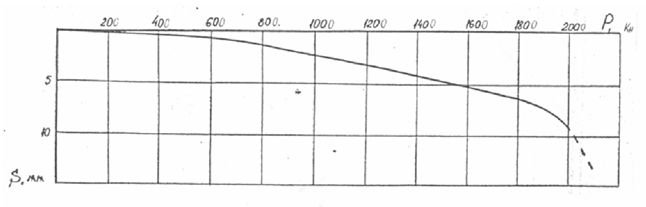


Fig.14. $S = f(P)$ plot for the studied cluster of four root piles, connected with DR-1 rostverk at strengthening the foundations of the Mykola Pritisk's church in Kyiv

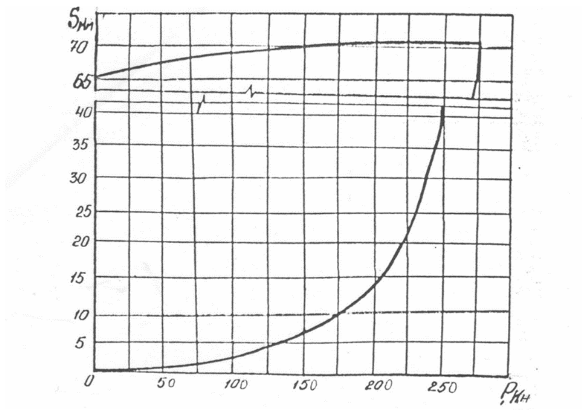


Fig.15. $S = f(P)$ plot for the studied root pile DP-1 on the break at strengthening the foundations of the Mykola Pritisk's church in Kyiv

Fig. 16. Basement before the work

Conducted chemical analysis of water in the interior of the basement testified that the ground water source is wetting. This is consistent with the fact that the water level in the basement reduced in summer.

Increased groundwater level is typical for Podil and caused underflooding in many houses in this area.

Analysis of the water-soluble salts content in the walls of the church basement showed their significant availability and salts crystallization on the material surface. Over time, crystals grow in size, are beginning to put pressure on the building material, leading to its destruction.

Tests on the water absorption and strength for wall brick were performed, and the results of these studies for water absorption averaged more than 19%, and the strength in compression − 25 kg/m^2.

Based on technological research of the church, it was concluded and the following recommendations were issued:

1. The main reason for the church basement becoming soaked is the high level of groundwater.
2. At a height of 1,5 meters from the floor, high moisture of the church walls is caused by capillary suction of ground water.
3. To normalize moisture and the state of the walls, and to prevent the ingress of water into the basement, vertical and horizontal waterproofing must be performed.
4. The church walls and basement are affected by Micromycetes fungi complex and require antiseptic treatment of surfaces.
5. Plaster salinity is very high and should be decreased.
6. It is urgent to perform landscaping, reconstruction of skirting for the drainage of surface rainwater from the church.

In order to develop a reliable, durable and cost-effective technology for waterproofing of the church walls, technological schemes of several companies were considered: the Dutch «Dry works», Spanish «Drizoro», German «Remmers» and «Deitermann».

These projects differ in cost, cost of materials, their durability and guarantees having the same technological schemes.

Due to the warranty over 10 years, the lowest cost of materials for complex work, and that the walls not only get a protection from moisture, but also are strengthened, the technology of German company «Remmers» was chosen.

Performing a full complex of works on drainage and protection for the walls from moisture was divided into three main stages:

1. Horizontal waterproofing and applying sanifying plaster for the walls in the church basement in the interior and on the façade;
2. Work on drainage and waterproofing for the basement walls and floors;
3. Repair of paving around the church.

The work was carried out using waterproof materials and sanifying plaster of the «Remmers» company according to the company technology.

1. Drainage for the moisture of the basement (Fig.17).

The technology included the following steps:

- removing destroyed plaster;
- destructive laying disassembly;
- surface dedusting;
- replacing for the lost bricks with the new;
- crack injection with the mortar;
- bricklaying mortar restoration and joints filling with AISIT Grundputz;
- dust cleaning for the holes;
- filling holes by 2 − 3 injection with AIDA KEISOL;
- two antifungal treatments for the walls;
- holes treatment with AIDA Borlochsuspension;

Fig.17. Basement before the work

Fig.18. Drilling holes in the basement facade

- applying preparatory plaster AISIT Special-Vorsspritzmortel;
- applying plaster AISIT Sanierputz Spezial;
- plaster smoothing;
- leveling with AISIT Grundputz coating;

Horizontal waterproofing.

2. Drainage of walls and vaults of the basement moisture.

Arrangement of horizontal and vertical waterproofing.

Walls and vaults:

- pumping water out of the basement;
- removal of plaster;
- removal of debris;
- destructive laying disassembly;
- room dedusting;
- replacing for the lost bricks with the new;
- crack injection with the mortar;
- drilling holes with a diameter of 30 mm;
- dust cleaning for the holes;
- filling holes by 2 − 3 injections of AIDA KEISOL;
- two antifungal treatment for the walls;
- holes treatment with AIDA Borlochsuspension;
- applying preparatory plaster
- AISIT Special-Vorsspritzmortel;
- strengthening and alignment of brickwork and joint filling with AISIT Grundputz;
- protection against moisture by applying a slurry saltproof AIDA Sulfatexschlamme;
- applying preparatory plaster layer on the entire surface of the wall;
- applying plaster base layer;
- plaster grinding;
- painting walls.

Drilling of holes was performed according to the technology (Figs.18 − 22).

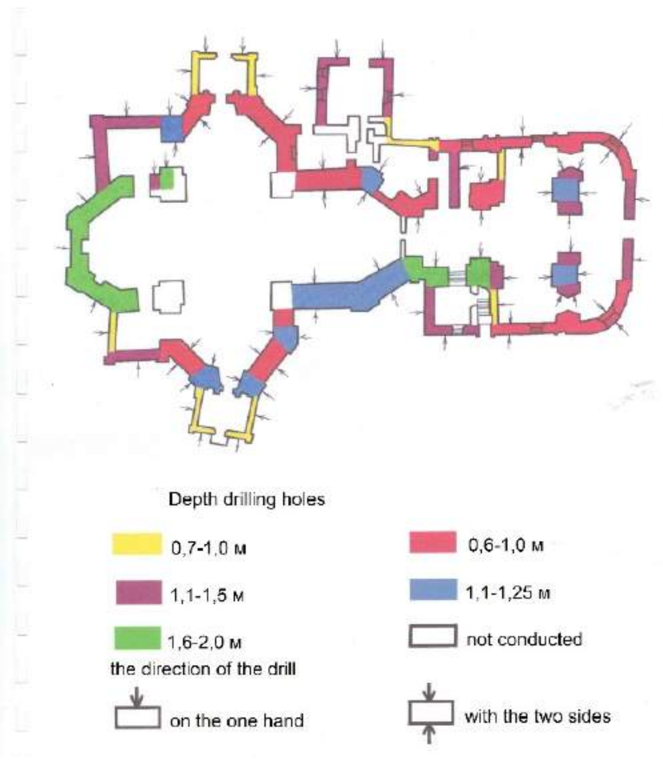


Fig.19. Layout for the holes drilling

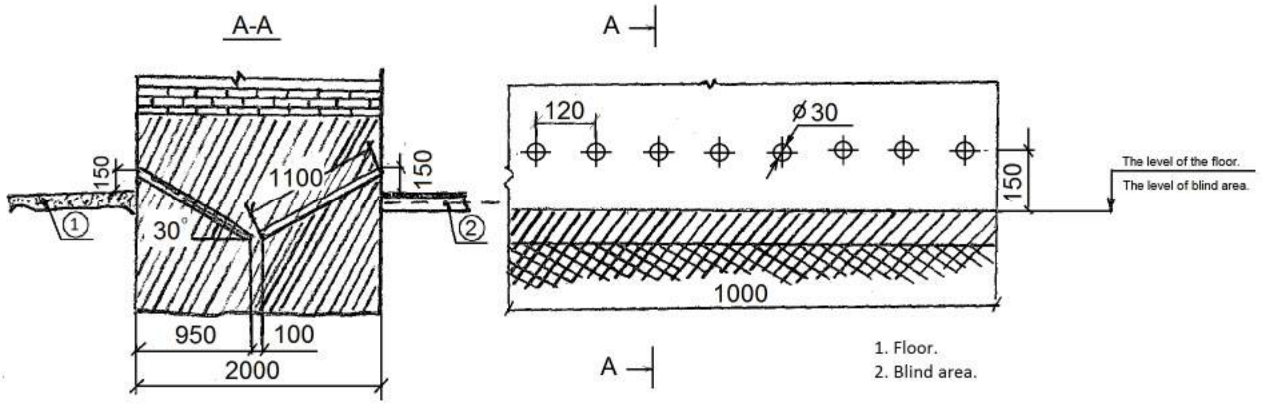


Fig.20. Layout for the holes

Fig.21. Drilling holes in the basement facade

Holes were drilled in the walls around the perimeter of the church outside the basement (see Fig.19), in places, where the wall thickness is more than 2 m − on both sides. At the altar, the drilling was performed only from outside. The depth of the holes and their location are shown at the layout (see. diagrams at the sheets).

After drilling holes, the dust removal was performed.

After the full technological cycle of vertical and horizontal waterproofing arrangement, the moisture of the church walls, both outside and inside, become normal (Fig.23).

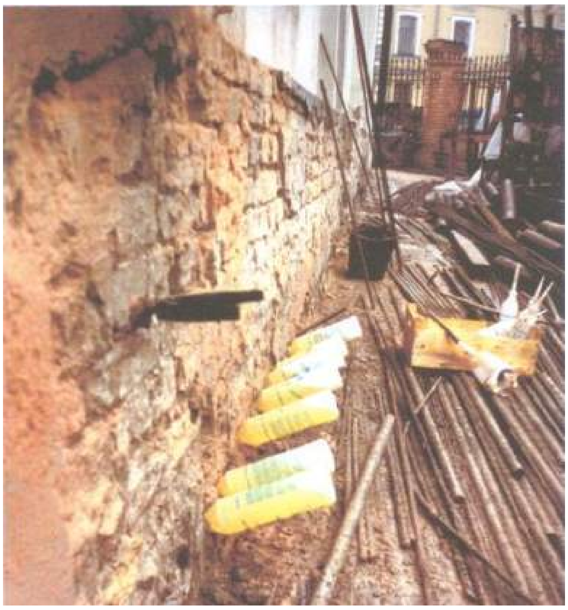


Fig.22. Fill in drilled holes with Aida KIESOL solution

Fig.23. Basement after the work

CONCLUSIONS

1. Architecture monuments, which are in the state register and protected by the state according to the Art. 54 of the Constitution of Ukraine and the Law of Ukraine "On Protection of Cultural Heritage of 08.06.2000. № 1805-III, should be monitored for their correct operation.

2. For the early detection of monument degradation, it is necessary to provide geodetic deformation monitoring for the buildings, as well as for the changes in the hydrogeological conditions of the monument location.

3. To take timely measures to drain surface water and protect the base and foundation of the monument from the raising level of groundwater.

4. Do not agree new construction projects in the protected area of the architectural monuments, which can lead to underflooding and increasing groundwater level.

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Причины разрушения достопримечательностей архитектуры и градостроения и способы усиления несущей способности основ и фундаментов

Николай Орленко

Аннотация Основной проблемой аварийного состояния достопримечательностей является неудовлетворительное состояние основ и фундаментов, часто в результате их увлажнения. Неравномерные просадки фундаментов приводят к перераспределению усилий в несущих конструкциях и нарушению статики системы основа−фундамент−сооружение. Поэтому любые реставрационные мероприятия начинают с ликвидации их аварийного состояния. На примере церкви Николая Притиски на Подоле, где подтопление грунтовыми водами повлекло обвал юго-восточной части сооружения, описан порядок реставрационных работ на достопримечательности, которые начались с усиления разрушенных фундаментов и основы для возобновления статики системы основа−фундамент−сооружение, мероприятий по защите основы и фундаментов от подтопления, с обеспечением надежной вертикальной и горизонтальной гидроизоляции стен и полов подвала и всей подземной части церкви и работ по антисептической обработке поверхностей биопораженных и засоленных стен и штукатурки. После этого обеспечивалась организация надежного геодезического контроля за деформацией сооружения.

Ключевые слова: основания и фундаменты, грунтовые воды, усиление.

Fractality of concentric structures in space of ecologic-urban planning systems

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Abstract. Conditions and stages of formation of the fractally embedded set of concentric zones of accessibility of cities on the example of Kiev are considered. The number of "levels of embedding" of such a set depends on the attractiveness and status of the city.

It was established that discontinuity of space developing is associated with economic development and engineering and transport networks. A rapid growth of these networks leads to the transformation of the traditionally central type of irregularity of developing the space into the multinuclear clustered systems of settlement.

In the zone of Kiev influence, there are five qualitatively differed by intensity of socio-economic links and speed of movement belts are distinguished. On the base of quantitative characteristics of these belts, it was established that in successive transition of developmental processes from local to regional and interregional levels of integrity of the ecologic-urban planning system − "population↔environment", the expansion of its spatial boundaries and peculiar "compression" of temporary ones occur that is manifested by intermittent increase in the radius of city's influence area – the center of system of settlement expressed in kilometers.

For analysis of processes of multi-level development of ecologic-urban planning systems, the dynamics of indices of development is not as much important as characteristics of their accelerations.

Keywords: sustainable development, fractality, spatial structures, ecologic-urban planning systems, areas of cities influence.

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INTRODUCTION

Under contemporary conditions, the effectiveness of city's functioning becomes, more and more, dependent on the speed of city's transport. However, in the up-to-date world of means of mass communications that allow people to contact without moving in space, the problem arise whether it will lead to the radical restructures in the spatial organization of life activities of population?

Usually the intensity of traffic in the cities changes dependent on the distance to the city's center that is the objective reflection of general heterogeneity of city's space. In this non-uniformity prevails a directed to the center tendency of city's activity and appropriate to it type of spatial organization. Along with this, the increase of significance of transport communication network and in particular systems of high-speed communications, leads to a certain transformation of traditional central type of spatial non-uniformity. This process shows itself in the formation of multi-clustered planning structures and group systems of settlement [1, p.62-66].

MATERIALS AND METHODS

The objective of investigation is in determination of fundamental principles of constant development of ecologic-urban planning systems (EUPS).

In the course of carrying out this work, a system approach, methods of modelling and comparative analysis were used. The analog method was chosen as the basic one that is the instrument of comparative analysis and is widely applied in ecology.

STARTING POSITION

In comprehension of modern science, development of any system – it is, first of all, the changes in its states that are determined by a set of values of basic characteristics of the system. For a town planning system – it is dimensions of the area of its territory, the number of population, functional-and-planning structure, engineering-and-transport network and form of settlement.

Development is a motion without which the nature cannot exist even for an instant. On the scale of planet, the acceleration of tempos of this movement is observed to which a development of any system is obeyed, including a town planning one [2 − 5].

FORMS OF SETTLEMENT

Problems mentioned had been studied with many Ukrainian scientists-urbanists, in particular Yu.Belokon, M.Dyomin, G.Zablotsky, G.Filvarov, I.Fomin.

According to I.Fomin's studies, "...for great cities, a concentric development in lo-cal set of inhabited localities is typical. How-ever, in case of their excessive growth, a need arises in dispersal of planning structure …up-to-date phase of development of the greatest cities required to return to group forms, but already on the larger scales not only on a lo-cal, but on the regional level as well" [6, p. 51-53].

«There are two typical varieties of the process of agglomeration for inhabited localities: concentration – growth in the central direction that leads to combining settlements; dispersal – growth in the direction from the center that is completed in the group form of settlements.

These two forms of development are inherent in the same city's agglomerations. Under certain conditions, arises a group form in the arrangement of cities, then due to intensifying functional links and development of general infrastructure, preliminary conditions are created for their planned unifying. With time, again preliminary conditions may be created for the new phase of dispersal" (Fig.1) [6, p.49, 50].

ARAREAS OF INFLUEENCE

In this plane, «...development of cities should be considered taking into account a

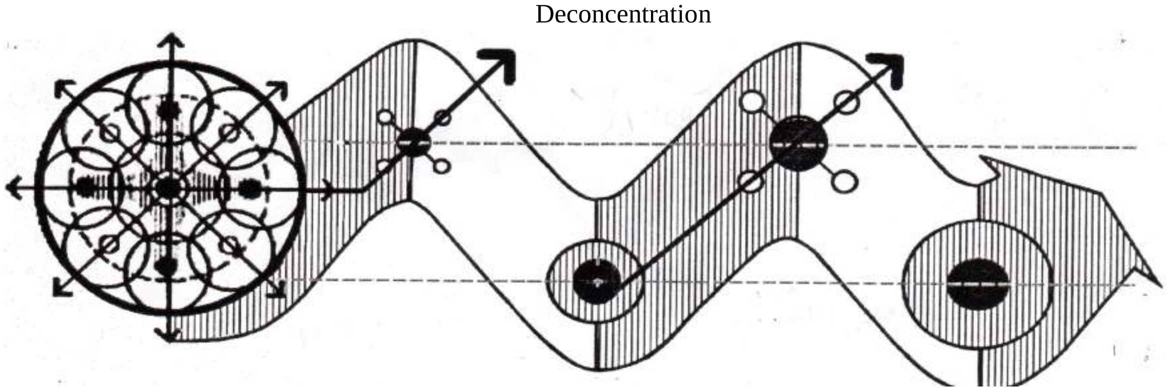


Fig.1. Cyclicity of forms of development of inhabited localities according to I.Fomin

possible alternate transition from one structural form to the other. Development of planned structure in its certain form as if it comes to a certain critical point – boundary when its advantages become minimal and drawbacks – hypertrophied. In this period, new radical measures must be undertaken for its implementation on the greater scale and at the higher level of structural complexity» (see Fig.1) [6, p.54-55].

As the criterion of estimation of spatial interaction level in the group systems of settlement of different level of their spatial integrity, M. Dyomin considers mobility of population. In this sense, he proposes to adopt "relation of population movability" to the institutions of everyday and periodic usage as the index that characterizes "power of influence" of the city-center [7, p.71]. Probably, it is this difference of powers of influence of city-centers of local, regional and world levels causes the origin of the set of concentric zones in the cities' accessibility (Fig.2).

FRACTALITY OF SPATIAL STRUCTURES

Fractality of concentric structures in the multi-level developing of ecologic space, we have considered on the example of formation and development of areas of influence in Kiev according to the data of studies conducted by M.Dyomin and Yu.Bilokon' [7, 8]. As M.Dyomin notes, «in structural relation on the territory of areas of influence of the largest cities, we can with sufficient certainty to single out a number of belts qualitatively notable for the nature and intensity of socio-economic links" [7, p.71]. As for the areas of Kiev influence, its «first belt that directly adjacent to the city is created, for the most part by agricultural and working townships", that «...are located at the distance of 10…12 km from the city. The second belt covers the territory with settlements the inhabitants of which regularly make use of services of city's institutions of periodical and episodic service" [7, p.72].

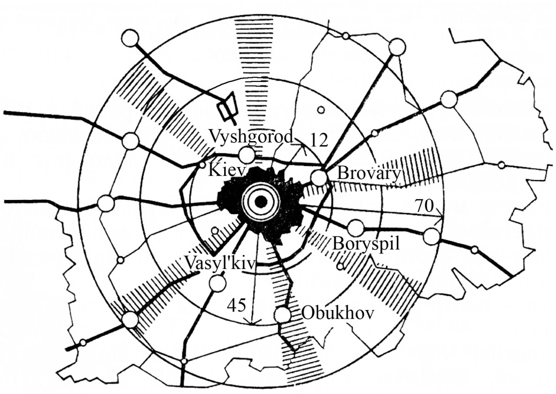
Intensity of trips to the city-center is determined by «the outer boundary of the second belt of great cities" that allows consider it as "the boundary of labor attraction" – 45 km". The third – outer belt of the area of recreational and everyday influence depends on the size of the city-center, its administrative functions, character of national-economic and town planning development of district territory, nature of external transport communications" – 70 km (Fig.2, *a*) [8, p.73].

Metropolitan status of Kiev determined the appearance of the fourth – interregional belt that covers the territory of Kievs'ka, Zhitomirs'ka, Chernigivs'ka and Cherkas'ka regions (see, Fig.2, *b*) [8, p.98-99]. Parameters of belts indices of areas of Kiev influence are shown in Table 1.

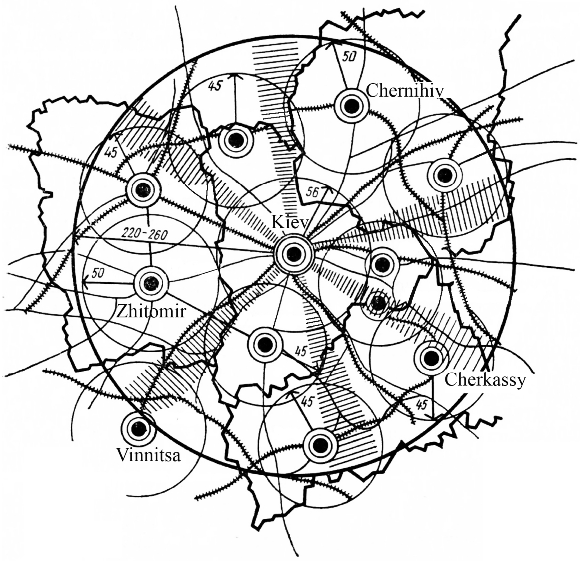
The fifth belt of area of Kiev influence (transnational) is being formed nowadays. As Yu.Bilokon' notes, a new significance of Ukraine in European space and multi-sectoral ties with countries of Western Europe urge "...the need of not only political and economic integration of all countries of European continent, but in spatial-planning aspect as well" [9, p.107].

Taking into consideration a geographic location of Ukraine and a zone of three-hour accessibility of Kiev airports that practically covers the whole Europe and the north of Africa, Yu. Bilokon' puts forward a conception of "…planned integration of countries of Eastern Europe into a general European territorial structure…it is a question of the urbanistic conception of organization of "expanded" European space for a faraway perspective taking into account general trends of integrational political and economic processes" (Fig.2,*c*) [9, p.107].

In the context of our studies, the area of influence of city-center has been considered as a multi-level space of support of life activities of the ecologic-urban planning system −"population↔environment" [9 − 11]. Data shown in Table 1 allowed obtain additional indices of degree of development and perspectives of continuous development of this system (Table 2).



a



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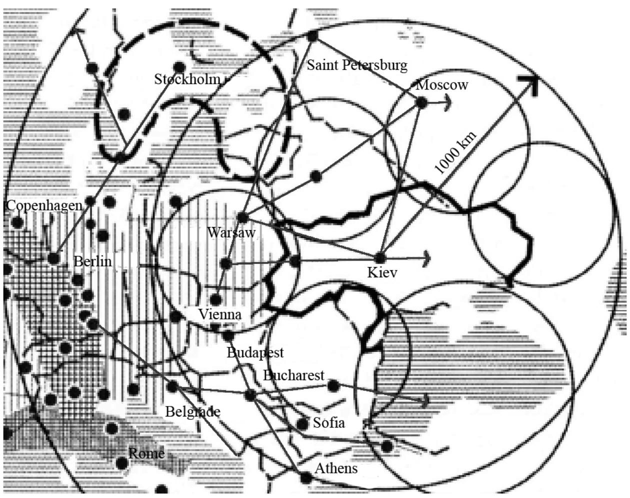

c

Fig.2. Space-donut development of Kyiv city agglomeration (*a*) and Kyiv capital region (*b*) by M.Dyomin. Ukraine in structure of European space by Y.Bilokon (*c*)

Table 1. Parameters of indices by the levels of spatial integrity of urban planning system according to M.Dyomin [7, p.89].

Indices and their measurements	Level of integrity			
	primary	topical	local	regional
Number of population of city-center, (P_c, ths. persons)	1-2	5-7	50-150	1000-2000
Number of population in the area of influence, (P_{ai}, ths. persons)	0,3-1	8-20	50-90	2000-5000
Area of territory, (S, ths.km^2)	0,08…0,12	0,3…0,7	3…5	70…120
Radius of area of influence in space, (L, km)	5…7	10…15	30…40	150…200
Radius of area of influence with time, (T, min)	15…20	30…40	60…90	120…150

Table 2. Averaged parameters of indices according to the levels of integrity of ecologic-urban planning system “population↔environment”

Indices and their measurements	Level of integrity			
	primary	topical	local	regional
Number of population EUPS: city-center – area of influence, ($P_{\sum}$, ths. persons)	2,2	20	170	5000
Population density, (ρ, persons/km^2)	21,5	40,0	42,5	52,6
Module of space of human life activities, (M, ha/person)	0,5	0,3	0,2	0,2
Average speed of movement, (V, km/hour)	20,6	21,4	27,9	77,8

However, for the analysis of constancy of developmental processes not as much “the external” characteristics of dynamics of EUPS components that are caused by a change of indices taking into account the levels of its integrity as “the internal” characteristics that are caused by the change of their speed and accelerations [10, 11].

MULTI-LEVEL ACCELERATION OF PROCESSES OF DEVELOPMENT

Having based on the data of Tables 1 and 2, “triangles of spatial changes” of rates and accelerations of indicated indices are constructed in Fig.3 in consecutive “transition” of processes of EUPS development to the higher territorial level of integrity of ecologic space [2, 9 − 11].

In Fig.3 all vertical triangles (solid line) have scales of relative accelerations of the rate of changes (″) considered indices. Here, the internal vertical triangles (more saturated shade) characterize the rate of relative accelerations in changes of indicated indices in the transition of developmental processes from topical to local level, in relation to those that have occurred in the transition from primary to topical level. The external vertical triangles characterize the rate of relative accelerations of changes of the same indices in the transition of developmental processes from a local to regional

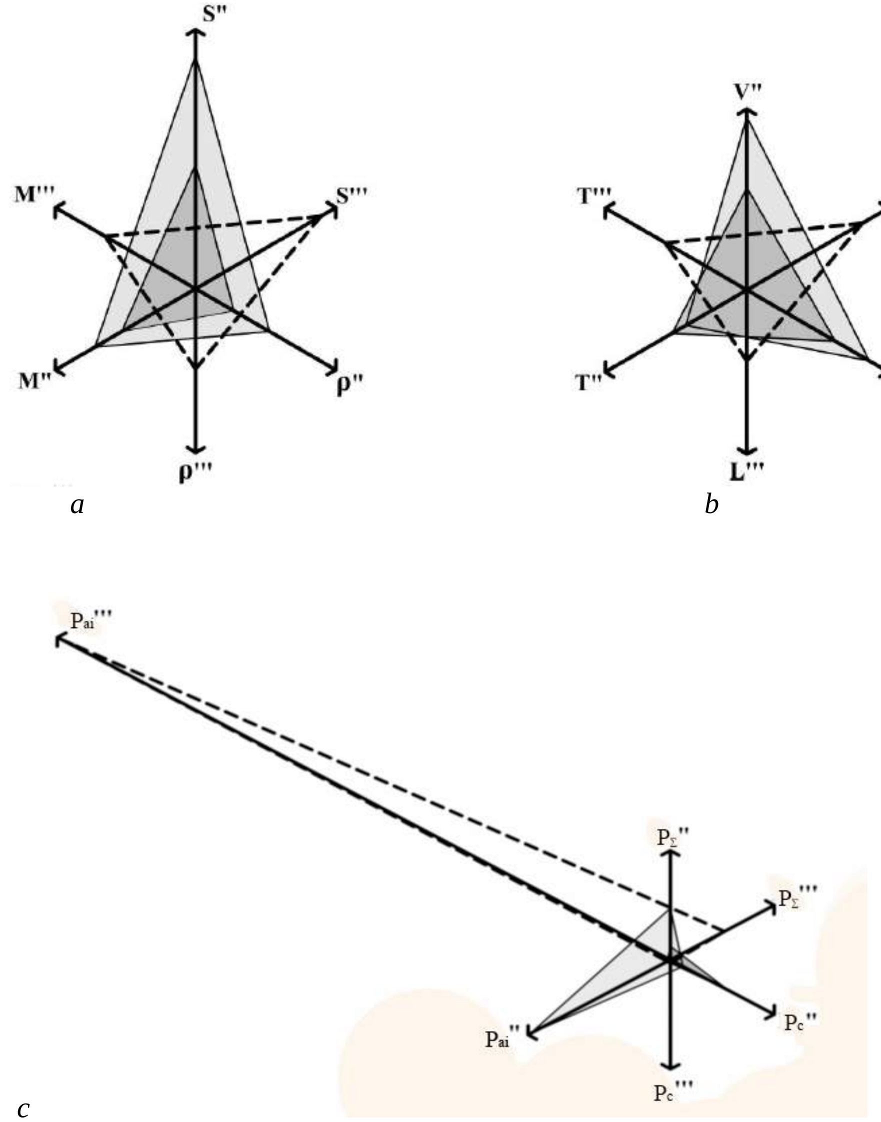

Fig.3. Changes of rates and accelerations of developmental processes of ecologic-urban planning systems in “the transition” of spatial levels

level in relation to those that have occurred in the transition from topical to local level. In its turn, horizontal triangles (dotted line) have scales of changes of relative accelerations of considered characteristics (□) that characterize angular acceleration of relative changes of wave process (see Table 1, 2; Fig.3).

In the group of indices of the territorial area increase acceleration (S), population density (ρ) and spatial module of human life-support – the inverse value to the population density (M), in the transition of levels most likely the rate of EUPS area increase (S'', index) and its acceleration (S''', index) (Fig.3,*a*) are changed.

In the group of acceleration indices of the area of influence radius increase of the city-center in the space (L) and time (T) as well as the rate of movement (V) in the transition of developmental processes for the levels of EUPS, spatial integrity, the rate (V'', index) and the acceleration of the rate of movement (V''', index) increase most rapidly (Fig.3,*b*).

In Fig.3,*b*, a certain inversibility in the directions of acceleration of changes in the radius of area influence of the city-center in space and time is traced. Thus, in the process of increase, in the consecutive spatial expansion of the radius of area of influence of the city-center in kilometers, occurs a reduction of radius of the area of its influence in hours. «Time compression» is shown by the fact that in Fig.3,*b* the external triangle by the scale «T"» «enters» into the middle of the internal one. Noted above may be a peculiar manifestation of toral structures dynamics of the space-time continuum when "the exterior shows itself inside of the interior" [11 − 13].

In the group of indices of acceleration of the increase in the total number of population (P_{Σ}), the number of population in the city-center (P_c) and the number of population in the area of its influence (P_{ai}) in the transition of developmental processes in accordance with the spatial levels of integrity, the rate (P_{ai}'', index) and acceleration of relative increase in the number of population in the area of influence (P_{ai}''', index) are most likely changed (Fig.3, *c*).

In Fig.3,*c*, a jump-like transition of significance of changes in the increase of the number of population is traced. So, in the internal vertical triangle that characterizes the rate of relative changes of the considered characteristics in the transition from topical to a local level, in relation to the transition from a primary to the topical level prevails the rate of increasing the number of population of the city-center (proportion between P_c'' and P_{ai}'' is equal to 18 : 1).

In the external vertical triangle that characterizes the rate of relative changes in the same characteristics, in the transition of processes of development according to spatial levels from the local to regional in relation to the transition from topical to local level, the inversed change in the direction and location of action of the urbanization process is observed, in which the rate of increase in the number of population of the area of influence in considerably less significance of dynamics in the number of population in the city-center (proportion between P_{ai}'' та P_c'' is equal to 11 : 1) becomes dominating.

Space-time transitions of urbanization processes of development can be considered at various points of view: in the aspect of elaboration of principles of the underwater urban planning [14], reconstruction of centers of historical places [15] or social history [16].

RESULTS AND EXPLANATIONS

The result, that is obtained, coincides with the results of I. Fomin's studies and, to the certain extent, describes the above dynamics of toral structure that this time shows itself in the varieties of agglomeration process, where the forms of "to the center and from the center" development are inherent in one and the same city's agglomerations. Dynamics of this structure reflects a concentration of population and spatial development directed to the center at the primary-topical level of development of urbanization process; dispersal of population and such development directed from the center in the transitions of developmental processes from a local to a regional level (see Figs.1 − 3; Tables 1, 2).

Process, directed from the center, yet more graphically reveals a horizontal triangle in Fig.3.c that characterizes the acceleration of relative changes in the number of population in the area of influence, in the transition of processes of development from local to regional level and in relation to the transition of processes of development from topical to local level (see, Table 1). This triangle reveals significant dominance (by two orders) of acceleration of increase in the number of population in the area of influence (P_{ai}''', index) over the acceleration of increase of population in the city-center (P_c''', index). Proportion between P_{ai}''' and P_c''' is equal to 198:1 (see, Fig.3, *c*).

It should be noted that in the space-time [LT] system of measurement [3, 17] of parameters of development of ecologic-urban planning systems P" has the value $[L^3T^{-4}]$, that according to our studies corresponds to the angular acceleration of mass [2, 12, 13]. Relatively angular acceleration. According to O. Kuznetsov, this acceleration is the cause of gravitation [3, 17]. In this sense, cities can be considered as "gravitation" centers, "the power of influence" of which extends concentrically in the space of ecologic-urban planning systems (see Fig.2). In the process of urbanization, the author investigated and other physical parallels [2, 18 − 20].

From the mentioned above, it follows that cyclically wave character of development of cities and city's agglomerations (see Fig.1) is caused by the change in the rates and accelerations of changes in the EUPS basic parameters: number of population of the city-center (P_c) and the area of influence (P_{ai}), radii of the areas of influence of cities-centers in hours (T) and in kilometers (L) at the primary, sectional, local and regional levels (see Fig.3).

That is in the multi-level transitions of developmental processes, agglomeration form of group settlement gains the signs of the system that reduces the time interval (1,1→0,9) and significantly expands it in space (1,3→1,8) (see Fig.3, *b*). Indicated changes in the multi-level dynamics of space-time boundaries of ecologic-urban planning systems and modern world of Internet communications that synchronizes processes in time and overcome bounds in space, can lead to the structural reconstruction of settlement.

CONCLUSIONS

1. Non-uniformity in developing of space and formation of group systems of settlement are associated with economic progress and development of engineering and transport, information and communication networks.
2. Index that characterizes "the power of influence" of the city-center of group system of settlement is "the relation of mobility" of population to the establishments of everyday and periodic usage.
3. In consecutive transition of processes of development from local to regional and inter-regional levels of integrity of the ecologic space, some inverse changes of space-time boundaries of ecologic-urban planning system occur.
4. For the analysis of processes of multi-level development of ecologic-urban planning systems are important not only measurements of dynamics of their indices, but characteristics of changes of this dynamics and their acceleration.

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Фрактальность концентрических структур в пространстве эколого-градостроительных систем

Ирина Устинова

Аннотация. Рассмотрены условия и этапы формирования фрактально вложенного множества концентрических зон доступности городов на примере Киева. Количество «уровней вложенности» такого множества зависит от привлекательности и статуса города.

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Установлено, что неоднородность освоения пространства связана с экономическим развитием и развитостью инженерно-транспортных сетей. Быстрый рост этих сетей ведет к превращению традиционно центрального типа неравномерности освоения пространства в многоядерные групповые системы расселения.

В зоне влияния Киева выделяется пять качественно отличающихся по интенсивности социально-экономических связей и скорости передвижения поясов. На основе количественных характеристик этих поясов установлено, что при последовательном переходе процессов развития от локального к региональному и межрегиональному уровням целостности эколого-градостроительной системы «население↔среда», происходит расширение ее пространственных границ и своеобразное «сжатие» временных, что проявляется скачкообразным увеличением радиуса зоны влияния города-центра системы расселения в километрах.

Для анализа процессов многоуровневого развития эколого-градостроительных систем важны не столько динамика показателей развитости, сколько характеристики их ускорений.

Ключевые слова: устойчивое развитие, фрактальность, пространственные структуры, эколого-градостроительные системы, зоны влияния городов.

Influence of historical events on construction of temples in Kyiv till 1917

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Abstract. Kyiv is ancient city with a unique history. A huge role in its development the temples have played [19]. Down to XX of century they influenced formation of city structure, appearance of building, general impression from urban environment and life of the population.

In XX century the most part of temples was destroyed, the ancient town-planning structure is destroyed too [3]. But the historical past continues to influence life of modern Kyiv today.

In a history of Kyiv it is possible to allocate three periods, which differently formed a religious situation in life of the city and process of temples construction. The period Kyivan Rus was characterized by intensive town-planning activity and construction of temples. In the Polish-Lithuanian period the building activity was less active. During conquest by the Russian empire the active construction of temples has brought new styles and types of temples into Kyiv [12, 13].

Generally such different history of Kyiv has resulted in formation of specific types of sacral objects and urban environment, in which they located down. In the combination with the peculiarities of natural environment, rich events of the past have created that unique look of Kyiv, which many contemporaries admired with [2].

Keywords: history, Kyiv, influence of historical events, period, a temple.

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INTRODUCTION

Kyiv is the city, in which the religion has played a huge role of its development. The religion influenced formation of the city plan, appearance, construction of new buildings; it has created to city the special status, which attracted everyone, who wanted it to subdue and to subordinate to itself. The religion, as the important component of city development, was not studied enough. The scientists considered temples by the separate periods. There are no researches, which would show a history of religions and temples of Kyiv as a whole. The history of religions and construction of temples in Kyiv is necessary for studying for better understanding a role of historical temples on territory of modern city.

THE PURPOSE OF RESEARCH

Likewise, it is necessary to research a history of religions and construction of the Kyiv temples, in order to characterize the main periods of temples construction, and to identify more detailed periods, specific only for territory of Kyiv, to define principles and tendencies in construction of temples.

METHODS OF RESEARCH

In order to get scientific result of researches, it is necessary to apply such methods. The first method is the analysis of a history of Kyiv and choice of those events, which influenced on religion of Kyiv, both temples and their architecture. The second method is the consideration of historical events influencing religions and temples of Kyiv in a sequence in time. This method is revealing and analysis of the certain periods in religious life of city and construction of temples, characteristic only for territory of Kyiv.

RESULTS AND EXPLANATIONS

The Kyivan Rus period. The Slavs occupied territory of Kyiv in the beginning of its history. Paganism was their religion. It was the first religion in territory of Kyiv. Then Christians appeared among the Slavs. The first mentions about Christianity in Kyiv appeared 866 (Table 1). The patriarch Fotiy in the letter to east bishops wrote, that the local inhabitants profess Christianity and had accepted bishop and priest. When Kyiv became the centre of Slavic territories, approximately 100 years, pagans and Christians peacefully lived in the city, where the places of pray to the pagan gods and even temples were located. A pagan temple of Perun above Borichev lovering was mentioned in the documents. The Christian churches built in city also. Missionaries of many religions came to Kyiv, as mentioned in the documents per 989. But the Christianity gradually became stronger among the inhabitants of city.

The important period for Kyiv came per 988. This year prince Vladymyr has accepted christening in Korsun (Khersones) and became the Christian. He destroyed the pagan gods and christened the population of Kyiv in the river, when had returned home. From this moment paganism had disappeared in Kyiv. Kyiv became the centre of Christianity, whence Christianity was distributed to territory of residing by Slavic tribes.

At Kyivan Rus there was a strong political connection with Byzantium. The Kyiv governors tried to imitate it in all. Later prince Yaroslav in Kyiv constructed structures similar to the main structures of the city of Constantinople. Constantinople was one of major cities of the Christian world and had the large importance for the Christians. Therefore Kyiv was built similar on Constantinople – the spiritual centre of east Christians. As well as in Constantinople, the main state temple of St. Sofia, monasteries St. Heorhiy and St. Iryna, palace, Golden gate (entrance gate in city) were constructed in Kyiv. It was the period of intensive construction in ancient Kyiv.

Kyivan Rus was the strong state. Its governors actively were engaged in construction. The large means put in construction of capital of the state – city of Kyiv. Feature of Kyiv was that the city was the administrative and religious centre simultaneously. Its temples were richly decorated and were best in the state. Kyiv was small on the area, but there were many temples in it. In addition, temples and monasteries were stopped up round Kyiv on hills along the Dnipro River. The most part of these objects further became a basis for development of the large monasteries and religious complexes.

The architectural style of Kyivan Rus structures came from Byzantium. Also the influence of local building traditions and architectural school was visible in the Kyiv structures. The first Kyiv temple was Desyatynna church constructed near the princely palace. All temples in Kyiv, which built later during Kyivan Rus, had common features [1].

Brick temples, since the first constructions, had a cross-domed structure, a semicircular apse in the chancel, semicircular domes. Their walls spread from a thin brick with addition of stones. Cement solution by means of that connected bricks haddifficult composition and was pink color. The walls decorated arches, niches and thin vertical columns. Inside the temples were painted by frescos and decorated with mosaics made from small pieces of colored glass and stone. The features of the Kyiv School were shown in a plenty of domes and other details.

Kyiv settled down on several hills. The craft area was below. The top part of city set-

Table 1. Religions of historical Kyiv and their origin

№	Historical Religion	Name of religious organization	Type of religion	Date of origin of religion	Country of origin of religion	Date of the appearance of religion in Kyiv	Name of the temple
1	Paganism	Pagan community	polytheism	VI	Kievan Rus, modern Ukraine	VI	temple
2	Orthodoxy	Orthodox Byzantine Church	monotheism	38	Byzantium, modern Turkey	866	chapel, church, cathedral
3	Orthodoxy	Orthodox Russian Church	monotheism	1448	Russia	1686	chapel, church, cathedral
4	Orthodoxy	Orthodox Armenian Church	monotheism	68	Armenia	1433	chapel, church, cathedral
5	Orthodoxy	Old Believer Church	monotheism	1653	Russia	1811	church
6	Greek Catholicism	Greek Catholic Church	monotheism	1596	Rzeczpospolita, contemporary Ukraine	1596	chapel, church, cathedral
7	Catholicism	Roman Catholic Church	monotheism	1054	Italy	1320	chapel, church, cathedral
8	Lutheranism	Lutheran Church	monotheism	1517	Germany	1765	church
9	Judaism	Jewish community	monotheism	X BC	Judea, modern Israel	XIII	temple, synagogue
10	Karaimism	Karaite community	monotheism	VIII	Golden Horde, modern Ukraine, Crimea	1850	kenas
11	Islam	Islamic community	monotheism	VII	Arab Caliphate, modern Saudi Arabia	XIX	mosque

tled down at tops of hills. The form of hills dictated the form of city. The city consisted of separate areas, which freely adjoined one to another. The city had no precise geometrical structure. Each of areas had from one up to several temples. There were main temples, the biggest streets and main square in the city. The temples settled down in urban building through different composite principles. They could stand on one, till two, till several temples in a line, till three as a triangle. On the general plan of Kyiv it is possible to see axes, on which the different temples stand. The temples on this axis settle down at different height in city – in the bottom of hills, in the middle and above. Probably the ancient builders visually focused on already constructed objects at construction of new temples. Then there were no perfect drawings and tools so precisely to arrange temples on curve surfaces of the Kyiv hills.

In the middle of XI centuries the tragic period began in Kyiv. Natural disasters – drought, fires, earthquakes and solar eclipse had resulted in famine, illnesses and mass destruction of the city dwellers. Internal wars in the state to take a city ended with fires and robberies. In 1237 the Mongolian army has attacked Kyiv. People of Kyiv were courageously protected, but could not defend the city. It was the period of destruction and robbery of the Kyiv temples. In this tragic period there came the new inhabitants − Jews to the city. They have brought to Kyiv new religion – Judaism. The period of destructions and wars in Kyiv was finished by transformation of beautiful temples into ruins. The ruins of churches stood as early as long years in desolation (Fig.1).

The period Kyivan Rus in Kyiv was time, when in city the Orthodox religion dominated. Kyiv was capital of the strong state. It was incorporated and many temples and monasteries were constructed in the city and around of it [17, 18, 21].

The Polish−Lithuanian period. In 1320 Lithuanian prince Hedimin conquered Kyiv. Since 1054 the Roman Church was separated from other Christian churches and has generated a Catholic direction in Christianity [14]. The Lithuanian governors appeared in Kyiv, which were the Catholics (see Table 1). From now on inhabitants – Catholics appeared in Kyiv. The Lithuanian governors tried to subordinate Orthodox – the local population – to the Roman Church. Orthodox were oppressed in comparison with the Catholics. The orders to not repair existing and to not build new Orthodox churches were issued. Restrictions to present ground monasteries were entered. Kyiv periodically attacked by the Tatars to plunder and to set fire to city. But the Orthodox temples were not destroyed up to the end. The pilgrims visited them. One of the Lithuanian princes was Orthodox. He constructed the church of ruins in the monastery of Kyievo-Pecherska Lavra. Many Catholic temples were built in Kyiv. The Armenians lived at the city too. The Armenian church was constructed for them in 1433 (see Table 1).

In the XVII century Kyiv became the centre of the voivodership West Russian Duchy of Lithuanian – since 1471. The Orthodox governors had headed of Kyiv and Orthodox became easier to live in city. The destroyed temples and the monasteries restored, the attention has given to the Orthodox temples. In 1569 the Polish constitution was authorized. The equal rights were given to Orthodox inhabitants and Catholics. Kyiv had many royal privileges, but it influenced well-being of city a little. In 1605 the decree issued, according to which they have forbidden for Jews to settle in Kyiv. Therefore only Orthodox and the Catholics lived at city. The Catholics tried to impose the religion Orthodox. For this purpose it was created the Greek-Catholic branch of Christianity. The sense of new religion was to that subordinate Orthodox to Roman Catholic Church. The Greek-Catholics tried to grasp all Orthodox churches of Kyiv and monastery Kyievo-Pecherska Lavra, occupied the castle, which belonged to the Kyivan metropolitans.

Then Kyiv got in the complement of the Polish state. Poland was the Catholic state, so struggle between the Catholics and Orthodox became stronger. In 1632 − 1648 the city head divided into two parts. The Catholic chapter owned one part with the Cathedral temple. The townspeople lived at other part, the temples of different religions settled down there. In Kyiv the Catholics owned four temples; Orthodox owned ten temples according to the description of the French engineer Boplan. An ancient state temple St. Sofia also belonged to the Catholics and Greek-Catholics. Orthodox used any indulgences on the part of Poland to improve a situation with the religion. But the attacks to Orthodox religion on the part of the Catholics became more and more severe. In 1621 the Poles plundered the churches, monasteries and Brotherhood School. In 1630 the Poles have attacked the monastery Kyievo-Pecherska Lavra, which was saved from a robbery with unusual events.

In conditions of interreligious struggle Petro Mohyla made the huge contribution to Orthodox religion. He returned an ancient temple Sofia Orthodox; he transformed Brotherly school to Academy. He had the large incomes and support of the Russian kings. Petro Mohyla could build new temples. But he restored the old destroyed churches, which stored memory about an outstanding history of Orthodox religion on territory of Kyiv. Petro Mohyla received money and gifts from the Russian kings. For these means he constructed the destroyed main monasteries of Kyiv:

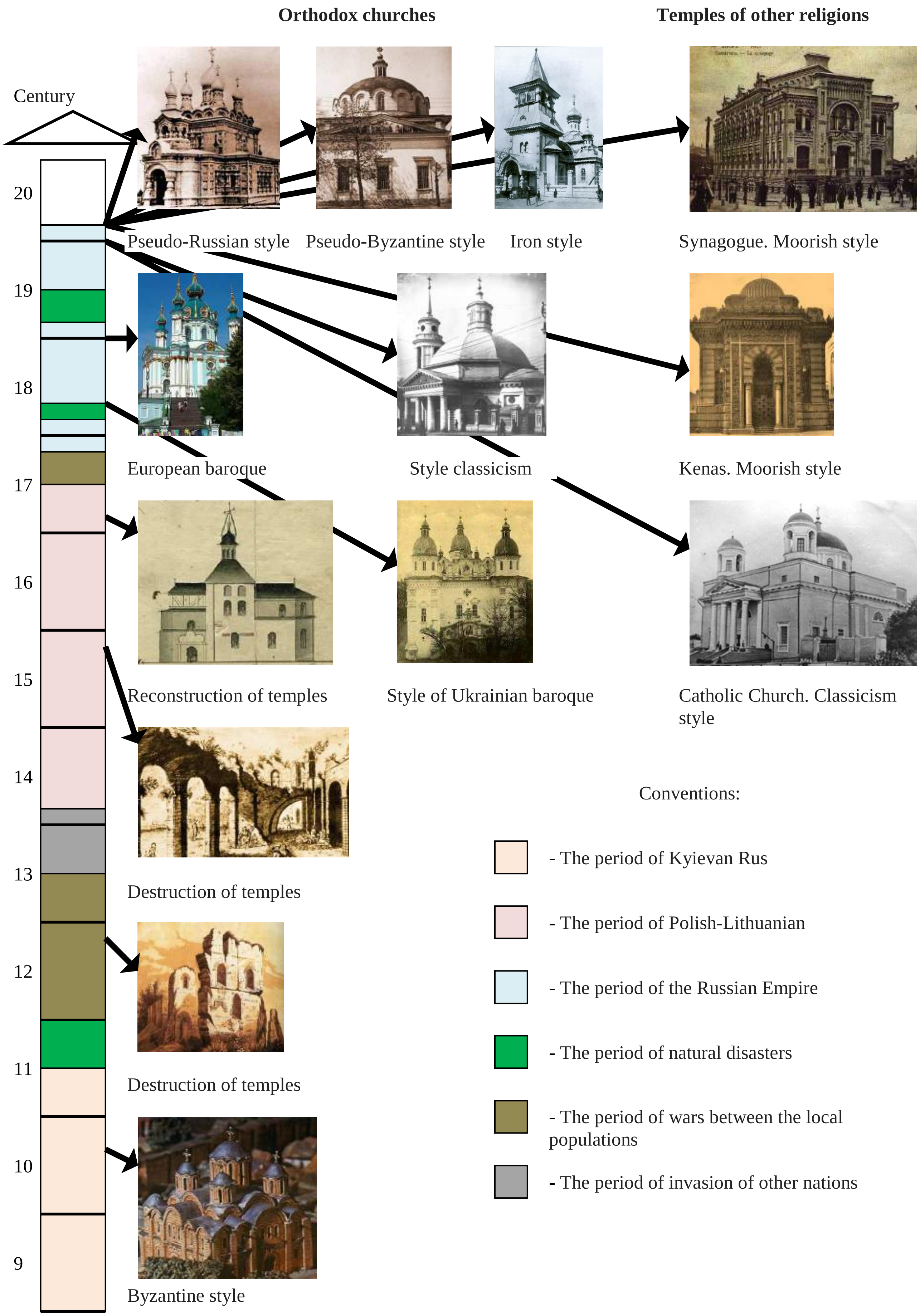

Fig.1. Periods in the construction of churches in Kyiv

Kyievo-Pecherska Lavra, St. Sofia, Vidubitsky, Nicholas, Bratsky Monastery. But the prosecution of the Orthodox Kyiv inhabitants of proceeded despite of Orthodox religion support. In 1648 the war between the Cossack army and the Polish army begun. Kyiv was conquered by both one army and the other. The war brought ruins both Catholic temples and Orthodox temples too.

In this period there were two main religions – Orthodox and Catholics in Kyiv. The Catholics tried to subordinate to themselves Orthodox. They grasped Orthodox temples and built Catholic temples. Orthodox used any opportunity to keep the ancient religion. The law, which forbade to build and to repair existing temples, resulted in the further destruction of temples, injured of wars. In such conditions the political and religious figure Petro Mohyla had appeared who put all means to restoration of ancient orthodox temples. The Orthodox temples were kept due to him [18, 21].

The Russian period. In 1666 Kyiv came into a structure of the Russian state. The connection with the Orthodox state affected positively on Kyiv. The Catholics could not unpunished plunder urban monasteries and temples. But the temples and monasteries were destroyed still some time. Since 1686 Kyiv did not submit to Constantinople and the Church of Constantinople hierarchy, as Orthodox city. The Moscow church hierarchy and the Moscow kings subordinated of Kyiv (see Table 1). Russian kings and emperors understood importance of city and its religious history. The Kyiv monasteries and the temples have begun to revive. The new churches, refectory, bell towers built for money of the rich people. They gave their means to cover of a dome of churches with gold, ordered iconostases also. The Kyiv Brotherly Academy became the best educational university in the state. The pilgrims visited Kyiv. For them the city remained sacred, despite of all destructions. “We have seen the glorified city of Kyiv; it stands on high mountains; and we were glad; we were lowered from the horses and have bowed to sacred city to Kyiv and praised the God”, “the City of Kiev stands on the Dnipro River, on the right bank, on the high mountains; the city is very perfect; in the Moscow and Russian state such city does not find” – the pilgrim from Moscow, the wise old man Leontiy had written down so, when he travelled to Jerusalem through Kyiv in 1701.

The Russian kings and emperors visited the Kyiv: since 1706 Peter I was three times in city; Empress Elizaveta Petrovna, Emperor Paul I with the wife Empress Maria Feodorovna, Empress Catherine II, Emperor Alexander I, Empress Alexandra Feodorovna, Emperor Nicholas I, the Emperor Alexander II was two times and second time with his wife Empress Maria Alexandrovna visited our capital. Also Emperor of Austria Joseph II visited Kyiv. During visits of Russian kings and emperors the time for worship sacred places was allocated necessarily. In the Russian state Kyiv returned meaning of the orthodox centre, which has lost during gains.

In the beginning XVIII centuries Kyiv suffered from natural disasters. In 1710 – 1711 epidemic of a plague happened. The inhabitants of Kyiv escaped from the city; the churches and monasteries became empty. Then invasion a locust happened, in result the crop on fields, in gardens and kitchen gardens was gone. Per 1713 – 1716 the Turkish armies nearly have not grasped Kyiv. In 1718 the extensive fire captured two areas of city Kyievo-Pechersk monastery and Podil with churches (see Fig.1). Despite of troubles the city gradually developed and was under construction. New structures and the churches decorated city. “Kyiv had a perfect look on the part of the Dnipro River and settling down on a mountain; the set of churches was finished by hills and made a landscape charming” − the doctor of medicine the having high grade Ioann Lerkhe had written down during visiting Kyiv in 1770. The foreigners settled in Kyiv. They had brought new religions. Per 1770 − 1771 the first Protestant Lutheran church was constructed in city (see Table 1). In 1786 Orthodox churches and the monasteries were ordered in united system. Classification of building was entered, named "classes". Positions for implementation of different duties were entered under the name "clerical positions". The financing of monasteries has improved their material situation.

At the end of XVII centuries the arrival Empress Catherine II created a push of development for the city. The industry began to develop in Kyiv; the standard of living was improved after her arrival. The people of different nationalities lived at Kyiv: the Polish noblemen, Armenians, Kirghiz Tatars. When there was a revolution in France, the French emigrants had arrived to Kyiv. The Jews lived at Kyiv also. Since 1827 for 1858 they were forbidden to live in city. But then interdictions were softened, and the Jews again settled at Kyiv. In 1797 46 wooden and stone temples were in Kyiv. Natural disasters were destroying city. In 1811 the fire burnt out almost all Podil area. The wooden temples completely burned down together with building. Podil was of the beginnings to revive only after 1815. In 1831, 1847, 1853, 1855 epidemic of cholera was in the city. In 1839, 1848, 1849 strong rains flooded of a Kyiv streets and the hurricane created destructions. In 1844, 1845, 1853 the Dnipro River was widely spilled and has flooded all lowered parts of the city (see Fig.1). But the city continued to be under construction. The negative influence of a nature pushed necessity of the city beautification. The transport infrastructure began to develop. Educational universities, museums and theatres were built in city. They laid the railway and constructed the first railway station. The large and beautiful Orthodox temples have decorated of Kyiv (see Fig.1). The city territory was of a beginning to extend. The new quarters built up with houses. The churches constructed in new quarters too. There were open the ancient frescos during repair in temples of St. Sofia, St. Cyril's and Savior on Berestov churches. The old images caused the large interest. In 1900 Kenais – Karaite community prayer house – was constructed (see Table 1). In Kyiv the representatives of different religions lived, but the city kept the status of the Orthodox religious centre.

After Kyiv got in the Russian empire, they began to build actively Orthodox temples in it. At first they built temples in monasteries - churches, refectory of churches, hospital churches. The old and wooden churches were replaced by new stone, on the same place. The separately worth urban churches were built less. But all constructed urban churches were large and represented complexes from several structures. From first one third XVIII centuries it was begun the construction of urban churches and occasionally temples of monasteries. The urban churches were large and small. Among them, there were outstanding objects of world importance – St. Andrew's Church, Vladimir Cathedral. From the end XVIII century’s chapels have appeared in Kyiv. From the second half XIX centuries of church at hospitals, educational institutions and military institutions appeared in Kyiv [6, 16]. The types of churches were different. The styles used in bilging, also different, since Ukrainian baroque, classicism and finishing pseudo- and neo- by styles eclecticism XIX centuries – Pseudo-Russian, Neo-Byzantine, Neogothic [18, 20, 21] (see Fig. 1). The city developed, the building grasped new territories. The city developed from two centres [4, 5]. One centre became ancient Kyiv with temples. The second centre became Kyievo-Pechersk monastery, which was transformed into a military fortress. The city incorporated to a monastery by an earth road, since autumn till spring it was difficult to pass on a road. So lengthways roads specially built urban structures to connect two parts of Kyiv. When the city became large enough, its temples were not uniform compositions. Each area had the temples, which settled down depending on the form of area, chosen site necessary, quantity of temples.

The Russian period was a period, when Orthodoxy again became dominant religion [11, 15] in the city. Many new temples had constructed; had ordered system of churches and monasteries. The new religions had appeared (see Table 1). But Kyiv remained sacred city [7, 10]; its importance only was increased.

THE CONCLUSIONS

The history of Kyiv is unique. Religion greatly influenced its development [8, 9]. Temples were the main buildings of the city.

An analysis of the construction history of the sacral buildings of Kyiv showed:

1. The historical events that took place on the territory of Ukraine strongly influenced the life of Kyiv, its development, planning. The smaller periods of Kyiv development can be identify. Among them there are periods in which the city actively developed and built, and there are those in which wars and natural disasters devastated Kyiv. Different periods alternated in the history of Kyiv, the period of active development was followed by a period of destruction. This was the reason why Kyiv developed less than other cities located close to it. At a later time, the destruction was pushed to a new construction of buildings in the city.

2. The city received a high status of the capital in ancient times, which influenced its future life. Other states often tried to subdue it. When they conquered the city, they tried to keep life in it, as in an important local center. But at the same time they forced the local population to accept the traditions and religion characteristic of the conquering state.

3. As a result of its position and permanent conquests, Kyiv had many religions. But the Orthodox religion, established in ancient times, as a state religion, has survived. Other states could not destroy Orthodoxy. The memory of the time when the city was the capital and religious center after the model of Constantinople, the capital of Byzantium, is preserved. As a result, Kyiv became a city in which pilgrims came and also visited it when they went on pilgrimage to Jerusalem. The city was considered a saint, which greatly influenced its life and development. Its holiness was recognized by Russia, which conquered the city later. It was Russia that began to actively develop the religious function of Kyiv – to build churches, monasteries, to finance their development.

4. As a result, Kyiv, like the ancient capital, was one of the first cities to build temples. It was the main city of the state, and its temples were the main in the state, and therefore they were to be the largest and most beautiful. As a result of wars, conquests, natural disasters, many temples were destroyed and restored later from the ruins. There were a lot of temples in Kyiv, which were parts of the buildings of different eras, combined together. To the walls that survived as a result of the destruction, they built up pieces in a later era to create the whole building. Or they built a new object on the site and the foundations of the destroyed church. This also affected the new building, since the site of the new building already had its own important history, which could not be ignored.

5. The period of conquests and destruction influenced on the temples of Kyiv so that for some time it did not build Orthodox churches. Therefore, not all the historical styles that were on the territory of Ukraine are represented in the architecture of the Kyiv temples. The first style in which temples were built was Byzantine. As evidenced by historical documents, there was a pause in their construction, during which many Orthodox churches turned into ruins. Petro Mogila began the reconstruction of destroyed Orthodox churches. Only when Russia conquered Kyiv, intensive construction of churches not only Christian, but also other religions was started.

Thus, the monasteries and temples, which were laid in antiquity, became the basis for the development of sacral complexes in the next centuries. As the city developed from two centers, the sacred buildings – monasteries and temples – were the main ones in each of them.

6. In the structure of Kyiv, the temples played an important role; they dominated the construction and towered over one-story or two-story houses. One of the reasons for this was that the city developed slowly. Only at the end of the nineteenth century did appear high houses in Kyiv. The study of the master plan made it possible to identify the axes when several temples were located on the same line. But they were at different heights in the space of the city – some temples were located on a hill, others were under a hill. This can be explained by the fact that when constructing new churches, builders visually oriented on existing buildings. Therefore, there were such axes in terms of the city. There were many temples, and they formed groups in the structure of the city. It is possible to single out different prin-

ciples for the creation of such groups. Approaches of the location of the temples: one temple, two churches side by side, three temples formed a triangle, several temples stood a straight line and several temples were built along a broken line. These principles were laid back in Kyivan Rus and developed in subsequent centuries.

7. The principles incorporated in the Kyivan Rus, in many respects have defined development of city and its history per the further centuries. Their influence is felt on a history of Kyiv till now.

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Влияние исторических событий на строительство храмов в Киеве до 1917 года

Бачинская Ольга

Аннотация. Киев – древний город с неповторимой историей. Огромную роль в его развитии сыграли храмы. Вплоть до XX века они влияли на формирование структуры города, внешнего вида застройки, общего впечатления от городской среды, жизни населения.

В XX веке большая часть храмов была уничтожена, древняя градостроительная структура разрушена. Но историческое прошлое продолжает влиять на жизнь современного Киева и сегодня.

В истории Киева можно выделить три периода, которые по-разному формировали религиозную ситуацию в жизни города и процесс строительства храмов. Период Киевской Руси характеризуется интенсивной градостроительной деятельностью и строительством храмов. В польско-литовский период строительная деятельность была менее активной. В период покорения Российской империей активное строительство храмов принесло новые стили и типы храмов в Киев.

В целом такая разная история Киева привела к формированию специфических типов сакральных объектов и городской среды, в которой они располагались. В соединении с особенностями природной среды богатое событиями прошлое создало тот неповторимый облик Киева, которым восхищались многие современники.

Ключевые слова: история, Киев, влияние исторических событий, период, храм.

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