IRSTI 50.47.31; 67.15.35; 87.53.13 **https://doi.org/10.58805/kazutb.v.1.26-808**

AUTOMATION OF SELECTION OF CONSTRUCTION MIX WITH ADDITIVES OF TECHNOGENIC RAW MATERIALS

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Today, there are a large number of programs (calculators) on the market for calculating concrete mixtures, proportions, and composition, all of which somehow calculate only traditional mixtures consisting of cement, sand, and crushed stone. Stocks of traditional raw materials are being depleted, while the amount of man-made raw materials is growing. In this regard, the additives of man-made raw materials in the composition of building mixes are increasing from year to year, which suggests that the need for them is in demand. Unfortunately, the composition of the construction mix with additives of man-made raw materials is still determined only manually, followed by calculating the mass of an ingredient, without taking into account the density of the material. In this regard, the relevance of the study lies in the need to automate the process of selecting a building mix with additives of man-made raw materials. Considering that the problem is not only practical, but also scientific, interest in it is quite high.

The purpose of the research is to develop a methodology for an automated system for selecting building mixes with additives from man-made raw materials based on the use of information technology.

The developed program allows you to select the composition of the construction mix, which includes man-made raw materials (metallurgical slag, bauxite sludge, fly ash).

Calculation results: optimal composition of the construction mix, weight, total cost of the construction mix in tenge. The calculation results are displayed in Excel form. The parameters cost, density, and number of ingredients of the construction mix can be updated using artificial intelligence technologies.

The program allows you to analyze calculation data based on visualization in the form of graphs, diagrams, and subsequent management decisions. The resulting compositions of building mixes need laboratory experiments, depending on the purpose. The efficiency of using the developed program ensures the selection of a large number of building mix formulations that are simply not possible to perform manually. The scientific novelty of the developed program consists in the development of an original algorithm and the absence of analogues of the source code, which allows obtaining both practical and scientific results.

The developed program ”Automated system for selecting the composition of a building mix with additives from man-made raw materials” can be used for practical purposes in business processes of small and medium-sized businesses, during scientific experiments (master’ s degree, doctoral degree), in the educational process of the educational program ”Information Technology”, Automation and Control, ”Building Materials”.

Keywords: automated system, artificial intelligence, construction mix, man-made raw materials, program, algorithm

АВТОМАТИЗАЦИЯ ПОДБОРА СТРОИТЕЛЬНОЙ СМЕСИ С ДОБАВКАМИ ТЕХНОГЕННОГО СЫРЬЯ

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Сегодня на рынке присутствует большое количество программ (калькуляторов) для расчета бетонных смесей, пропорций, состава, все они так или иначе рассчитывают только традиционные смеси в состав которых входят цемент, песок и щебень.

Запасы традиционного сырья истощаются, а количество техногенного сырья наоборот растет. В этой связи добавки техногенного сырья в состав строительных смесей год от года увеличиваются, что позволяет говорить о том, что потребность в них востребована. К сожалению, состав строительной смеси с добавками техногенного сырья до сих пор определяется только ручным способом, с последующим вычислением массы того или иного ингредиента, при этом не учитывается плотность материала. В этой связи актуальность исследования состоит в необходимости автоматизации процесса подбора строительной смеси с добавками техногенного сырья. Учитывая, что проблема не только практическая, но и научная, интерес к ней довольно высок.

Цель исследования заключается разработке методологии автоматизированной системы подбора строительной смеси с добавками из техногенного сырья, на основе применения информационных технологий.

Разработанная программа, позволяет подобрать состав строительной смеси в состав которой входит техногенное сырье (металлургический шлак, бокситовый шлам, зола уноса).

Результаты расчетов: оптимальный состав строительной смеси, масса, общая стоимость строительной смеси в тенге. Результаты расчета выводятся в Excel форме. Параметры стоимость, плотность, количество ингредиентов строительной смеси, могут обновляться с использованием технологий искусственного интеллекта.

Программа позволяет проводить анализ данных расчетов, на основе визуализации в виде графиков, диаграмм, с последующим принятием управленческих решений. Полученные составы строительных смесей нуждаются в лабораторных экспериментах, в зависимости от назначения. Эффективность использования разработанной программы, обеспечивает подбор большого количества рецептур строительной смеси, которые ручным способом, просто не возможно, выполнить.

Научная новизна разработанной программы состоит в разработке оригинального алгоритма и отсутствии аналогов исходного кода, позволяющего получать, как практические, так и научные результаты.

Разработанная программа «Автоматизированная система подбора состава строительной смеси с добавками из техногенного сырья», может использоваться для практических целей в бизнес процессах субъектов малого и среднего бизнеса, при проведении научных экспериментов (магистратура, докторнатура), в учебном процессе по ОП «Информационные технологии», Автоматизация и управление», «Строительные материалы».

Ключевые слова: автоматизированная система, искусственный интеллект, строительная смесь, техногенное сырье, программа, алгоритм

ТЕХНОГЕНДІК ШИКІЗАТ ҚОСПАЛАРЫ БАР ҚҰРЫЛЫС ҚОСПАСЫН ІРІКТЕУДІ АВТОМАТТАНДЫРУ

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Бүгінгі таңда нарықта бетон қоспаларын, пропорцияларын, құрамын есептеуге арналған көптеген бағдарламалар (калькуляторлар) бар, олардың барлығы цемент, құм және қиыршық тасты қамтитын дәстүрлі қоспаларды ғана есептейді.

Дәстүрлі шикізат қоры таусылып, техногендік шикізат мөлшері керісінше өсуде. Осыған байланысты құрылыс қоспаларының құрамына техногендік шикізат қоспалары жылдан жылға артып келеді, бұл оларға деген қажеттілік сұранысқа ие екенін айтуға мүмкіндік береді. Өкінішке орай, техногендік шикізат қоспалары бар құрылыс қоспасының құрамы осы уақытқа дейін тек қолмен анықталады, содан кейін белгілі бір ингредиенттің массасын есептейді, ал материалдың тығыздығы ескерілмейді. Осыған байланысты зерттеудің өзектілігі техногендік шикізат қоспалары бар құрылыс қоспасын таңдау процесін автоматтандыру қажеттілігінен тұрады. Мәселе тек практикалық емес, сонымен қатар ғылыми екенін ескере отырып, оған деген қызығушылық өте жоғары.

Зерттеудің мақсаты ақпараттық технологияларды қолдану негізінде техногендік шикізаттан қоспалары бар құрылыс қоспасын таңдаудың автоматтандырылған жүйесінің әдіснамасын әзірлеу болып табылады.

Әзірленген бағдарлама құрылыс қоспасының құрамын таңдауға мүмкіндік береді, оның құрамына техногендік шикізат (металлургиялық қож, боксит шламы, алып кету күлі) кіреді.

Есеп айырысу нәтижелері: құрылыс қоспасының оңтайлы құрамы, салмағы, құрылыс қоспасының теңгедегі жалпы құны. Есептеу нәтижелері Excel формасында көрсетіледі. Параметрлері құны, тығыздығы, құрылыс қоспасының ингредиенттерінің саны жасанды интеллект технологиясын қолдана отырып жаңартылуы мүмкін.

Бағдарлама графиктер, диаграммалар түрінде визуализация негізінде есептеулердің деректерін талдауға, содан кейін басқару шешімдерін қабылдауға мүмкіндік береді. Алынған құрылыс қоспаларының құрамы мақсатына байланысты зертханалық тәжірибелерді қажет етеді. Әзірленген бағдарламаны пайдалану тиімділігі құрылыс қоспасының көптеген формулаларын таңдауды қамтамасыз етеді, оларды қолмен орындау мүмкін емес.

Әзірленген бағдарламаның ғылыми жаңалығы-түпнұсқа алгоритмді әзірлеу және практикалық және ғылыми нәтижелерге қол жеткізуге мүмкіндік беретін бастапқы кодтың аналогтарының болмауы.

Әзірленген ”техногендік шикізаттан қоспалары бар құрылыс қоспасының құрамын іріктеудің автоматтандырылған жүйесі” бағдарламасы шағын және орта бизнес субъектілерінің бизнес процестерінде, ғылыми эксперименттер (магистратура, докторнатура) жүргізу кезінде, ”ақпараттық технологиялар”, Автоматтандыру және басқару”, ”құрылыс материалдары”ББ оқу процесінде практикалық мақсаттар үшін пайдаланылуы мүмкін.

Түйін сөздер: автоматтандырылған жүйе, жасанды интеллект, құрылыс қоспасы, техногендік шикізат, бағдарлама, алгоритм

Introduction. Research related to automation of control of technological processes for the production of building materials with additives from industrial waste is described in [1-4].

Unfortunately, the scientific foundations and methodology for the production of building mixes with additives of man-made raw materials and the use of modern Industry achievements 4, information technologies have not yet been presented in Kazakhstan.

This is an urgent and demanding task that can be solved by specialists with knowledge in the field of automation and control, information technology, as well as theoretical and practical skills in using man-made raw materials in a particular industry in Kazakhstan.

The publications related to the topic of our

research are discussed below.

The article [5] examines the integration of artificial intelligence into the automated design of concrete mixes, with special emphasis on the use of computerized curves of the granulometric composition to optimize the distribution of aggregates.

Disadvantages: Lack of information on practical application and limited data on actual results.

In [6], the study is devoted to the application of optimization methods for automating the development of mixtures for 3D printing of concrete, which improves workability, strength and resistance to deformation.

Disadvantages: The difficulty in applying the proposed methods in practice and the need for specialized equipment.

[7] provides an overview of current trends in the digital transformation of concrete technologies, including the use of automation and digital tools in the process of developing mixtures.

Disadvantages: The generalized nature of the review without detailed consideration of specific technologies.

In [8], the study focuses on the use of machine learning for the probabilistic selection and design of concrete mixes, taking into account various factors, including strength and stability.

Disadvantages: The complexity of mathematical models and the need for large amounts of data for training.

The article [9] offers a holistic approach to optimizing the process from concrete mix selection to structural design, taking into account uncertainties.

Disadvantages: The high complexity of the proposed methodology and the need for an interdisciplinary approach.

The article [10] provides an overview of the application of operational research methods for the design and proportionation of concrete mixtures, suggesting a classification structure.

Disadvantages: Theoretical orientation without practical implementation examples.

The article [11] examines various aspects of 3D printing of concrete, including automation of the process and features of the selection of mixtures for printing.

Disadvantages: A generalized overview without a detailed analysis of specific technologies and methods.

In the article [12], the main comments are related to the fact that there are no detailed descriptions of technical solutions and automation methods; there is insufficient information about potential problems during implementation.

The research in the article [13] is theoretical in nature; it lacks practical examples of the implementation of artificial intelligence in real conditions.

The solutions presented in the article [14] require large computing resources; integration into existing production lines may be difficult.

The article [15] describes the general provisions related to the design work of a construction company, but does not show the ways of practical implementation of tasks.

The analysis of publications on the research topic revealed the need to develop software tools to automate the selection of building mixes with additives from man-made materials, as no solution to this problem has yet been presented. In this regard, the relevance of the research lies in the development of methodological approaches for automating the selection of building mixes with additives of man-made raw materials.

Materials and methods. The program code of the automated system for selecting building mixes with additives of man-made raw materials is developed in Python using several key approaches and technologies. The methodology covers the architecture of the code, the data processing methods used, calculation algorithms, as well as user interaction mechanisms and automatic data updates.

The code is based on a modular approach, which makes it easy to scale and modify functionality. Main components:

-Graphical interface (GUI) – implemented on the

basis of Tkinter, providing user interaction;

-Calculation algorithms – include calculations of the mass, cost and total percentage of the components of the mixture;

-Data update – Artificial intelligence simulation is used to dynamically change the cost and density of materials;

-Saving results – Supports exporting data to Excel using openpyxl.

The program code applies basic mathematical methods to calculate the mass and cost of the components of the construction mix:

Calculation of the mass of ingredients (formula 1):

$$M = \left(\frac{P}{100}\right) \times D \times V \quad (1)$$

where:

M- is the mass of the component (kg);

P- is the percentage of the component (%);

D- is the density of the component (kg/m^3);

V- is the total volume of the mixture (m^3).

Calculation of the cost of the construction mixture (formula 2):

$$C = M \times C_k \quad (2)$$

where:

C - the cost of a specific component (KZT);

C_k -is the cost of 1 kg of the component (KZT);

M- is the calculated mass of the component.

The total cost of the mixture is calculated as the sum of the cost of all the ingredients.

The program uses artificial intelligence (AI) simulation to dynamically update the cost and density of materials. This is implemented using the random value generation method (random.uniform()), which simulates fluctuations in market prices and physical properties of materials. An example of the cost update code is shown on the program code listing 1:

Listing of the program code 1:

```
def get_updated_costs():
    updated_costs = {
        'Cement': random.uniform(190, 210),
        'Sand': random.uniform(28, 32),
        'Gravel': random.uniform(48, 52),
        'Slag': random.uniform(75, 85),
        'Fly␣Ash': random.uniform(65, 75),
        'Bauxite␣Mud': random.uniform(95, 105)
    }
    return updated_costs
```

The program supports the dynamic addition of new materials. This is implemented by updating the dictionaries of cost and density of ingredients see the listing of the program code 2:

Listing of the program code 2:

```
def add_new_material(material_name, default_density, default_cost):
    densities[material_name] = default_density
    costs[material_name] = default_cost
```

The program supports exporting calculations to Excel for further analysis, see the program code listing 3:

Listing of the program code 3:

```
def save_to_excel():
```

```
    workbook = openpyxl.Workbook()
    sheet = workbook.active
    sheet.append(["Material", "Mass␣(kg)", "Density␣(kg/m³)",
                  "Percentage␣(%)", "Cost␣per␣kg␣(KZT)",
                  "Total␣Cost␣(KZT)"])
    for row_id in tree.get_children():
        sheet.append(tree.item(row_id)['values'])
    workbook.save("Construction_Mix.xlsx")
```

The functionality of the program code allows users to save calculations and use them in reports.

The program code allows you to analyze data for various parameters and provide them graphically using Matplotlib, see program code listing 4.

Listing of the program code 4:

```
plt.plot(industrial_waste_percentages, total_costs, marker='o',
         linestyle='-')
```

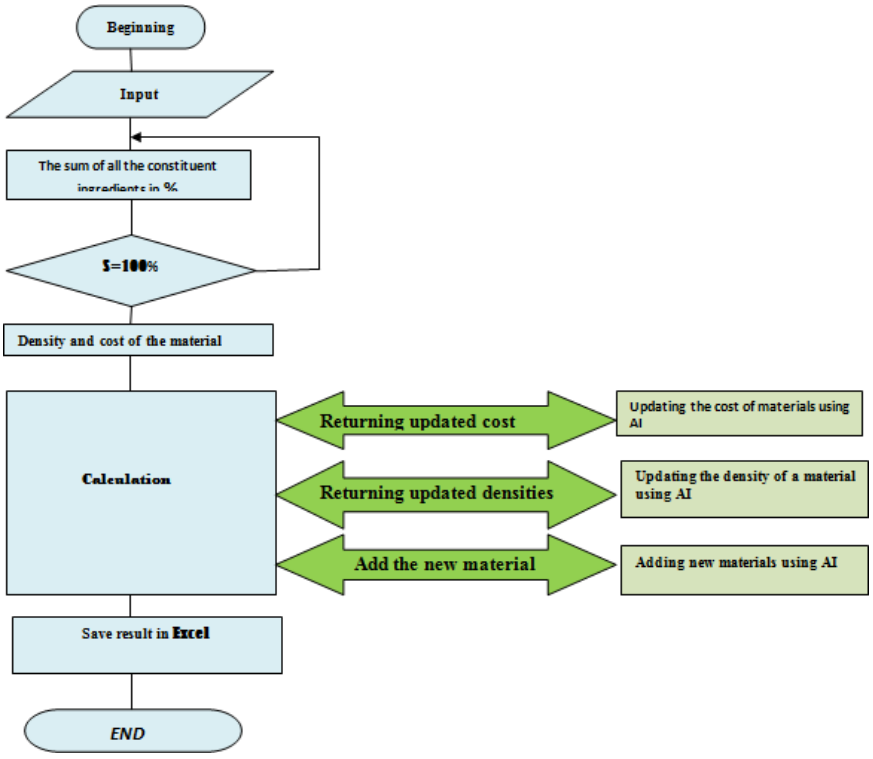

Fig. 1 - The algorithm of the program code

This procedure allows us to graphically assess the effect of the composition of man-made waste on the final cost of the construction mix and, based on it, determine the optimal proportions.

But here it must be understood that any calculations must be supported by laboratory experiments and field tests. The program code allows you to automate the process of selecting the composition of a building mix with additives from man-made raw materials, which in practice takes a lot of time.

The user menu of the program code is developed using theTkinter library:

-The main library for creating a graphical user interface (GUI), which allows you to build windows,

input forms, buttons, tables, labels and other interface elements.

Results and discussion. For the development of the program code, an algorithm was prepared, see Fig. 1, the principle of operation of which is described below.

The algorithm works as follows:

Data for each ingredient of the construction mix with additives of man-made raw materials is uploaded from the interface.

1. Data initialization:

The main() function sets the parameters for calculating the construction mix:

-the volume of the mixture (volume) in m^3;

-the density of the material (Material Densities) in kg / m^3;

-the percentage of the material (Material percentages);

-material costs (cost) per 1 kg.

2. **Mix Composition Calculation:**

-the function calculate_concrete_mix(volume, densities, percentages, costs) is called:

-a list to store mix composition data and a variable for the total cost are initialized. For each ingredient;

The function returns:

-a list of data for the mix composition;

-the total cost of the mix.

Updating data on cost, density of materials, and adding new materials is carried out using artificial intelligence.

3. Saving Results to Excel:

the function save_to_excel(data, file_path) performs:

-creates an Excel file;

-adds table headers;

-writes rows containing mix composition data.

Formats the table:

-adjusts column widths;

-highlights headers with bold text and centers the text;

-sets the print area, page orientation, and scaling to fit the table to one page width.

Saves the file to the specified path.

4. Result Display:

After saving the file, the program outputs:

-the path to the Excel file;

-the total cost of the construction mix.

5. Program Execution:

the program checks if it is the main module (if __name__ == ”__main__”:);

the main() function is called to perform the calculations and save the results.

Fig. 2-11 show the program code of the program ”Automated system for selecting the composition of a building mix with additives from man-made raw materials.”

```
import tkinter as tk
from tkinter import ttk
from tkinter import filedialog, messagebox
import openpyxl
import random

# AUTOMATED SYSTEM FOR SELECTING THE COMPOSITION OF BUILDING MIX WITH TECHNOLOGICAL RAW MATERIAL ADDITIVES
def calculate_mix():
    try:
        # Get input data from the interface
        volume = float(volume_entry.get())
        cement_pct = float(cement_entry.get())
        sand_pct = float(sand_entry.get())
        gravel_pct = float(gravel_entry.get())
        slag_pct = float(slag_entry.get())
        fly_ash_pct = float(fly_ash_entry.get())
        bauxite_mud_pct = float(bauxite_mud_entry.get())
```

Fig. 2 - Program code (Data entry)

```
        # Ensure the total percentage equals 100
        total_pct = cement_pct + sand_pct + gravel_pct + slag_pct + fly_ash_pct + bauxite_mud_pct
        if total_pct != 100:
            messagebox.showerror("Error", "Total percentage must be equal to 100!")
            return
```

Fig. 3 - Program code (Verification of compliance with the percentage of the building mix)

```
        # Material densities and costs
        densities = get_updated_densities()
        costs = get_updated_costs()

```

Fig. 4 - Program code (Functions for determining the density and cost of the material)

```
        # Calculation
        percentages = {'Cement': cement_pct, 'Sand': sand_pct, 'Gravel': gravel_pct, 'Slag': slag_pct,
                       'Fly Ash': fly_ash_pct, 'Bauxite Mud': bauxite_mud_pct}
        total_cost = 0
        for material, percentage in percentages.items():
            mass = (percentage / 100) * densities[material] * volume
            cost = mass * costs[material]
            total_cost += cost

        total_label.config(text=f"Total Cost: {round(total_cost, 2)} KZT")
    except ValueError:
        messagebox.showerror("Error", "Please enter valid numbers!")
```

Fig. 5 - Program code (Calculation)

```
# Function to get updated costs using a simulated AI model
def get_updated_costs():
    # Simulate AI-generated costs for materials
    updated_costs = {
        'Cement': random.uniform(190, 210),  # Simulated fluctuation in cost
        'Sand': random.uniform(28, 32),
        'Gravel': random.uniform(48, 52),
        'Slag': random.uniform(75, 85),
        'Fly Ash': random.uniform(65, 75),
        'Bauxite Mud': random.uniform(95, 105)
    }
    return updated_costs
```

Fig. 6 - Program code (Updating ingredients using AI)

```
# Function to get updated densities using a simulated AI model
def get_updated_densities():
    # Simulate AI-generated densities for materials
    updated_densities = {
        'Cement': random.uniform(1350, 1450),  # Simulated fluctuation in density
        'Sand': random.uniform(1550, 1650),
        'Gravel': random.uniform(1450, 1550),
        'Slag': random.uniform(1150, 1250),
        'Fly Ash': random.uniform(750, 850),
        'Bauxite Mud': random.uniform(950, 1050)
    }
    return updated_densities
```

Fig. 7 - Program code (Updating the density of the material using AI)

```python
# Function to add a new material dynamically
def add_new_material(material_name, default_density, default_cost):
    densities = get_updated_densities()
    costs = get_updated_costs()

    # Add the new material with default values
    densities[material_name] = default_density
    costs[material_name] = default_cost

    # Notify user
    messagebox.showinfo("New Material Added", f"Material '{material_name}' has been added with Density: {default_
```

Fig. 8 - Program code (Adding new materials)

```python
# Function to save results to Excel
def save_to_excel():
    file_path = filedialog.asksaveasfilename(defaultextension=".xlsx", filetypes=[("Excel files", "*.xlsx")])
    if not file_path:
        return
    workbook = openpyxl.Workbook()
    sheet = workbook.active
    sheet.title = "Construction Mix"
```

Fig. 9 - Program code (Conversion of calculation results to Excel)

```python
# Creating the main window
root = tk.Tk()
root.title("Construction Mix Calculator")
root.geometry("1000x700")

# Input fields
input_frame = tk.Frame(root)
input_frame.pack(pady=10)

tk.Label(input_frame, text="Volume (m³):").grid(row=0, column=0, padx=5, pady=5)
volume_entry = tk.Entry(input_frame)
volume_entry.grid(row=0, column=1, padx=5, pady=5)

# Cement
cement_frame = tk.LabelFrame(input_frame, text="Cement")
cement_frame.grid(row=1, column=0, columnspan=3, padx=10, pady=5)
tk.Label(cement_frame, text="Percentage (%):").grid(row=0, column=0, padx=5, pady=5)
cement_entry = tk.Entry(cement_frame)
cement_entry.grid(row=0, column=1, padx=5, pady=5)

# Similarly define frames for Sand, Gravel, Slag, Fly Ash, and Bauxite Mud...
```

Fig. 10 - Program code (Creating windows)

```python
# Run the application
root.mainloop()
```

Fig. 11 - Program code (program launch)

Figure 12 shows the menu interface of the program ”Automated system for selecting the composition of a building mix with additives from man-made raw materials.”

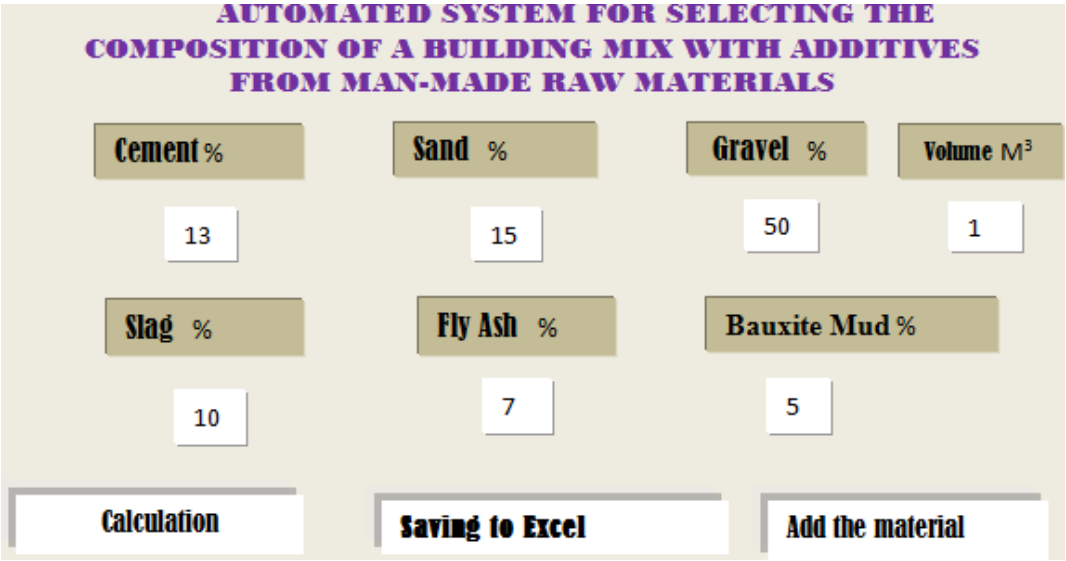

Fig. 12 - Menu interface of the program "Automated system for selecting the composition of a building mix with additives from man-made raw materials"

Table 1 - The results of calculating the selection of the building mix

Material	Percentage (%)	Density (kg/m^3)	Cost per kg (KZT)	Mass (kg)	Total Cost (KZT)
Cement	13	1400	200	182	36400
Sand	15	1600	30	240	7200
Gravel	50	1500	50	750	37500
Slag	10	1200	80	120	9600
Fly Ash	7	800	70	56	3920
Bauxite Mud	5	1000	100	50	5000

User interaction with the program

1. Program launch:

the user launches the file. A window opens with fields for data entry.

2. Data entry:

The user enters:

the volume of the mixture (m3);

the percentage of each ingredient.

If necessary, you can add new ingredients.

3. Performing the calculation:

-clicking on the "Calculate" button starts the calculation.

Saving the results:

-the user clicks the "Save to Excel" button to save the results to a file.

4. Adding new ingredients:

with the "Add Material" button, the user adds the ingredients that need to be used in calculations.

Program operation:

The user enters:

Volume: 1 m3.

-cement: 13%;

- sand: 15%;

-Crushed stone: 50%;

-slag: 10%;

-fly ash: 7%;

-Bauxite sludge: 5%.

Presses the ”Calculate” button. The program:

-verifies the correctness of the data;

-calculates the mass and cost of each ingredient.

-Determines the total cost of the construction mix depending on the percentage composition.

Clicks ”Save to Excel”:

The program:

creates an Excel file and saves the data.

The results of calculating the selection of the building mix are presented in Table 1.

If necessary, the user can add a new ingredient by clicking the ”Add Material” button. Table 2 shows the calculation results for the percentage composition with other numerical values.

Table 2 - Results of calculating the selection of the construction mixture

Material	Percentage (%)	Density (kg/m^3)	Cost per kg (KZT)	Mass (kg)	Total Cost (KZT)
Cement	14	1400	200	196	39200
Sand	16	1600	30	256	7680
Gravel	40	1500	50	600	30000
Slag	15	1200	80	180	14400
Fly Ash	10	800	70	80	5600
Bauxite Mud	5	1000	100	50	5000

The program code has the ability to analyze data for different building mix compositions. In particular, Fig. 13 shows a graph of the effect of the percentage of man-made raw materials and building mixes on its cost.

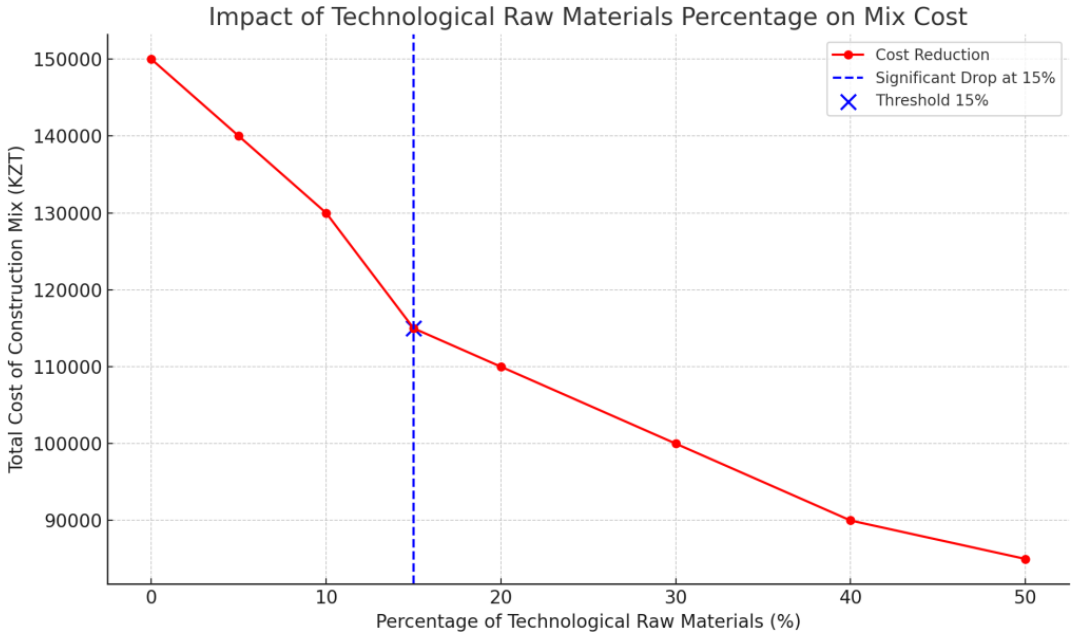

Fig. 13 - Graph of the effect of the percentage composition of the building mix on its cost

As can be seen from the graph, when the composition of man-made raw materials reaches 15%, there is a significant reduction in the cost of the construction mixture.

If necessary, various types of analysis can be obtained related to the study of building mixes obtained as a result of automated selection.

Conclusion. The proposed development methodology and the developed program code are based on a flexible and modular approach that allows automating the selection of building mixes using man-made raw materials.

The scientific approach of the proposed methodology is based on:

- the use of mathematical modeling methods that ensure high accuracy of calculations;

- realization of artificial intelligence capabilities for updating information data;

-obtaining data analysis based on graphical representation of the results of calculating the composition of the construction mixture with additives of man-made raw materials.

The scientific novelty of the developed program consists in the development of an original algorithm and the absence of analogues of the source code, which allows obtaining both practical and scientific results.

The developed program ”Automated system for selecting the composition of a building mix with additives from man-made raw materials” can be used for practical purposes in business processes, small and medium-sized businesses, during scientific experiments (master’ s degree, doctoral studies), in the educational process of the educational program ”Information Technology”, Automation and Control, ”Building Materials”.

The effectiveness of the developed program is incomparable with the manual selection of a building mix and takes this process to a new level.

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