

2. Nazarenko Ivan, Klymenko Mykola (2020). Application of general energy assessment criteria for preparing building mixtures. KHNADU Bulletin, 2 (88), pp 37–42. <https://doi.org/10.30977/BUL.2219-5548.2020.88.2.37>
3. Rudyk, R., Salnikov, R. (2024). Analysis of the mixer geometry and rheology impact on concrete mixture mixing efficiency. Construction Engineering, Vol. 41, pp. 77–84. <https://doi.org/10.32347/tb.2024-41.0409>
4. Rudyk R. Y., Virchenko V. V., Salnikov R. Y., Kuzub Y. O. (2025). Mathematical modeling of the working body's oscillatory motion in a concrete mixer. Journal of Engineering Sciences (Ukraine), Vol. 12(2), pp. D45–D54. [https://doi.org/10.21272/jes.2025.12\(2\).d4](https://doi.org/10.21272/jes.2025.12(2).d4)
5. Rudyk, R., & Virchenko, V. (2025). Increasing the efficiency of gravity mixing for concrete mixtures. Construction Engineering, (42), 50–60. <https://doi.org/10.32347/tb.2025-42.0506>

MODELING OF CONSTRUCTION MIXTURE MIXING PROCESS BASED ON A STOCHASTIC APPROACH

Yurij Kuzub, postgraduate student¹ (ORCID: 0009-0006-8463-3914),

Viktor Virchenko, candidate of technical sciences, associate professor¹ (ORCID: 0000-0002-5346-9545)

¹ National University “Yuri Kondratyuk Poltava Polytechnic”, Vitaliia Hrytsaienko, 24, 36011, Ukraine

ABSTRACT. *The study considers construction mixture mixing process in a forced action mixer using a stochastic approach for description of component movement within working volume. Mixer working space is represented as a system of interconnected cells between which probabilistic mixture particle transitions occur under action of screw blades, shear deformations, and circulation flows. A transition matrix describing component redistribution patterns between separate mixer zones during the mixing process was developed. The mechanism of gradual homogeneous material distribution achievement within working volume is described and influence of transition parameters on mixing intensity is established. Possibility of proposed model application for mixing process evaluation efficiency and justification of rational design and operating parameters for mixing equipment is demonstrated.*

Keywords: *construction mixture, mixing, transition matrix, mortar mixer, cell model, screw blades, mixture homogeneity, stochastic modeling.*

Introduction. Construction mixture mixing process is one of the decisive stages of the technological cycle for concrete and mortar composition preparation, since ready material quality and efficiency of subsequent technological operations depend on component distribution uniformity. Insufficient construction mixture homogeneity can lead to deterioration of ready material physical mechanical characteristics, nonuniform component distribution, and lower construction work quality. Therefore, improvement of mixing process efficiency and determination of component movement patterns within mixer working volume are important tasks of modern construction machinery engineering. In forced action mixers, mixing is accompanied by complex spatial particle movement under influence of screw blades, shear deformations, inertial forces, and gravitational forces [1–2]. Under such conditions, application of stochastic approaches enabling description of mixture component redistribution process within mixer working volume becomes expedient. One such approach involves application of a probabilistic model in which material movement between separate drum zones is considered as a system of probabilistic transitions. This enables evaluation of mixture homogeneity achievement dynamics and establishment of influence of mixer design and operating parameters on mixing process efficiency. Application of mathematical models for investigation of mixing processes is especially relevant, since conducting a large number of experimental studies requires significant time and resource expenditures. Use of stochastic approaches enables evaluation of mixture component movement character and prediction of homogeneous state achievement rate depending on mixer design and operating parameters.

Analysis of recent research and publications. Analysis of modern studies showed that most scientific works devoted to construction mixture mixing processes focus on determination of mixer energy characteristics, influence of working body geometry, and medium rheological properties on mixing intensity [3–5]. Hydrodynamic, kinematic, and discrete element models are mainly used for description of

component movement in mixers [6]. At the same time, application of stochastic and probabilistic models for description of mixture particle movement within mixer working volume remains insufficiently investigated, especially considering local component redistribution between separate working space zones.

Research objective. Investigation of a stochastic model for construction mixture mixing process in a forced action mixer and determination of component redistribution patterns within working volume through description of probabilistic transitions between separate mixing space cells.

Main part. During stochastic model development, mixer internal volume is considered as a discrete system of separate cells between which mixture component movement occurs under action of screw blades. Each cell characterizes a local working volume zone containing a portion of material at a given time moment. Discrete representation of mixer working volume enables consideration of local mixture movement features in different drum zones. Under real conditions, the mixing process occurs nonuniformly, since regions of intensive circulation and shear deformations are formed near screw blades. At the same time, component movement velocity is lower in remote zones, influencing overall mixing intensity.

System state is described by a component distribution vector

$$X(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_n(t) \end{bmatrix} \quad (1)$$

where $x_i(t)$ – relative mixture fraction in the i -th cell at time moment t .

To ensure preservation of total material mass, the normalization condition is satisfied

$$\sum_{i=1}^n x_i(t) = 1 \quad (2)$$

Physically, this means that during the mixing process the material does not disappear from the working volume and does not accumulate outside the system boundaries, but only changes its position between separate cells. Component movement occurs under action of screw blades, gravitational forces, and inertial effects arising during mixing body rotation.

The mixing process is described as a sequence of component transitions between neighboring cells. After each mixing cycle, material redistribution occurs according to transition probability matrix N . Then the system state at the next step is determined by the following relation

$$X(t+1) = N \cdot X(t) \quad (3)$$

The transition process between neighboring cells reflects real physical movement of construction mixture components inside the mixer. During each mixing cycle, particles repeatedly change their spatial position, forming circulation flows within working volume. Such repeated component position variation ensures gradual mixture concentration equalization.

During the mixing process, continuous mass exchange of mixture components occurs between separate working volume zones. Intensity of such mass exchange is determined by circulation flow velocity formed under action of mixer working bodies. The more active the exchange between neighboring cells, the faster the system approaches a homogeneous state.

The transition matrix characterizes probability of mixture component movement between separate mixer zones. The model assumes that a material portion can move to the previous cell, remain in the current cell, or move to the next cell. For this purpose, the following coefficients are introduced as

$$p + q + r = 1 \quad (4)$$

where p – backward transition probability,

q – probability of remaining in the current cell,

r – forward transition probability.

Transition coefficient values depend on mixer operating modes and physical mechanical properties of the construction mixture. Increased mixing body rotation speed raises intensity of component movement between neighboring cells, promoting faster achievement of a homogeneous mixture state. In addition, transition processes are substantially influenced by screw blade geometry parameters.

An important factor is also the number of cells into which mixer working volume is conditionally divided. Increased cell quantity enables more detailed description of local material redistribution processes, but simultaneously complicates the mathematical model and increases calculation volume during mixing process simulation.

Considering the local mixing character, the transition matrix acquires a band structure:

$$N = \begin{bmatrix} q & r & 0 & \cdots & 0 & p \\ p & q & r & \cdots & 0 & 0 \\ 0 & p & q & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ r & 0 & 0 & \cdots & p & q \end{bmatrix} \quad (5)$$

The proposed band structure of the transition matrix corresponds to the local interaction character between neighboring working volume zones. Such an approach enables adequate description of gradual material movement inside the mixer without necessity for complex continuous flow description throughout the entire drum volume.

Such a structure corresponds to the physical process of mixture movement under action of screw blades, when primary material exchange occurs between neighboring working volume zones. Periodic boundary conditions are used for a closed drum, under which extreme cells interact with each other, ensuring cyclic mixing character.

Periodic boundary conditions correspond to closed mixer geometry in which the material continuously circulates within working volume. Due to this, extreme cells interact with each other, enabling avoidance of isolated stagnant zone formation and ensuring continuous mixture component redistribution.

Initial component distribution in the mixer is nonuniform, since after loading the material is localized within specific drum zones. During multiple transitions between cells, the distribution gradually equalizes. At the initial stage, mixture component concentration is localized within separate drum zones after material loading. During multiple transitions between cells, local concentration differences gradually decrease, leading to formation of a more homogeneous component distribution within mixer working volume.

The criterion for mixture homogeneity achievement is convergence of values in all cells to the same level

$$x_1 = x_2 = \cdots = x_n = \frac{1}{n} \quad (6)$$

The proposed stochastic approach can be used as a basis for computer simulation of construction mixture mixing process. Model implementation within a software environment enables investigation of component redistribution dynamics, analysis of transition matrix parameter influence, and evaluation of efficiency for different mixer operating modes without conducting a large number of experimental studies.

The obtained results can be used for further investigation of construction mixture mixing processes with varying consistency and density. In addition, the proposed approach creates possibilities for evaluation of efficiency of different mixing body designs and determination of rational equipment operating modes depending on technological mixture preparation conditions.

Thus, the stochastic model enables description of construction mixture mixing process as a sequential probabilistic redistribution of components between separate working volume zones, making it possible to evaluate mixing intensity and determine influence of mixer design and operating parameters on the rate of homogeneous mixture state achievement.

Conclusions. As a result of the performed studies, a stochastic model of construction mixture mixing process was developed, in which mixer working volume is represented as a system of interconnected cells with probabilistic component transitions between them. It was established that application of a transition matrix enables description of mixture redistribution process within the mixer and evaluation of homogeneous material state achievement dynamics.

It was shown that component distribution equalization rate depends on transition probability values between cells determined by screw blade design and mixer operating modes. The obtained model can be used for evaluation of mixing process efficiency and further justification of rational operating parameters

for mixing equipment.

References

1. Virchenko, V. (2011). Mixing of construction mortar solutions with the effective mixers. Bulletin of the Mykhailo Ostrohradskyi KNU, 1(66), 71–74.
2. Anishchenko, A., Aleinikova, A., Kovalenko, A., Nesterenko, M., & Nesterenko, T. (2023). Technological package of the small-sized equipment for preparation of products from polystyrene-concrete mixture. AIP Conference Proceedings, 2490(1), 050027. <https://doi.org/10.1063/5.0143912>
3. Blazhko, V. V., Anishchenko, A. I., Saienko, L. V., & Hryhorkiv, O. B. (2024). Small-sized complexes for the production of building mixtures for various purposes. Bulletin of Kharkiv National Automobile and Highway University, 104, 70–74. <https://doi.org/10.30977/BUL.2219-5548.2024.104.1.70>
4. Salnikov, R., & Virchenko, V. (2025). Comparative analysis of mathematical models for the screw unit in small continuous-operation plastering machines. Construction Engineering, (42), 27–35. <https://doi.org/10.32347/tb.2025-42.0503>
5. Kuzub, Y., & Rudyk, R. (2025). Influence of spiral tape parameters mixer for mortar homogeneity. Scientific Bulletin of Construction, (112), 37–44. <https://doi.org/10.33042/2311-7257.2025.112.1.37>
6. Rudyk, R., & Salnikov, R. (2024). Analysis of the mixer geometry and rheology impact on concrete mixture mixing efficiency. Construction Engineering, 41, 77–84. <https://doi.org/10.32347/tb.2024-41.0409>

INCREASING OPERATION EFFICIENCY OF EQUIPMENT FOR CONSTRUCTION MIXTURE PREPARATION

Viachelsav Polezhaiev, postgraduate student¹ (ORCID: 0009-0007-2010-9088),

¹ National University “Yuri Kondratyuk Poltava Polytechnic”, Vitaliia Hrytsaienka, 24, 36011, Ukraine

ABSTRACT. *The study considers features of construction mixture preparation and transport processes in mixing feeding equipment combining a forced action mixer and a screw conveying unit. The influence of physical mechanical and rheological properties of construction mixtures with varying consistency on mixing and subsequent transport conditions is analyzed. It is shown that efficiency of the technological process depends on coordination between working body design parameters, operating modes, and movement conditions of the mixture within the mixer working volume and conveying channel.*

Analytical relationships describing construction mixture particle movement under blade working body action, circulation flow formation within the mixing chamber, and subsequent axial movement of the prepared mixture by the screw conveying unit are presented. The obtained relationships consider the influence of working body kinematic parameters, blade geometry, screw helix parameters, and mixture viscosity on mixing and transport conditions within a unified technological process. The presented results can be used for justification of rational design and operating parameters for construction mixture preparation and transport equipment.

Keywords: *construction mixture, forced action mixer, screw conveying unit, mixing, transport, working body, technological process, construction equipment.*

Introduction. Construction mixture preparation and delivery processes are an important component of modern construction, since they determine material technological property formation conditions and efficiency of construction and finishing operations. Construction and finishing operation quality largely depend on mixture homogeneity, preservation of structural mechanical characteristics, and continuous material delivery to the application location. Accordingly, improvement of mixing equipment capable of ensuring intensive component mixing with minimal energy consumption and coordination between mixture preparation and transport parameters within a unified technological process becomes especially important.

Construction mixtures, depending on liquid phase content and physical mechanical properties, can exhibit different mobility, internal friction, and component cohesion, which directly influence mixing conditions and subsequent movement within technological channels. Under such conditions, equipment operation efficiency is determined not only by mixing body design parameters but also by coordination between conveying device operating modes and medium properties. A promising direction for technological system efficiency improvement involves application of universal mixing feeding units in