

СЕКЦІЯ 1

«ЕНЕРГООЩАДНІ ЗАСОБИ МЕХАНІЗАЦІЇ ПРОЦЕСІВ ВІДНОВЛЕННЯ ОБ'ЄКТІВ І СПОРУД»

FORMATION OF ACTIVE MIXING ZONES IN A GRAVITY CONCRETE MIXER

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ABSTRACT. *The study considers active mixing zone formation process in a gravity concrete mixer during cyclic construction mixture movement within drum working volume. Influence of drum angular velocity, particle motion trajectories, and blade geometry parameters on mixture circulation movement intensity was investigated. Conditions for particle transition into the active motion phase were established and the mechanism of intensive mixing zone formation was analyzed. Relationships considering particle movement, velocity field, shear deformations, and rheological properties of concrete mixture as a viscoplastic medium were used for process description. An approach for quantitative evaluation of active mixing zones based on determination of active to passive mixture volume ratio was proposed. It was established that increased active volume fraction promotes higher concrete mixture homogeneity and shorter mixing duration.*

Keywords: *gravity concrete mixer, concrete mixture, active zone, circulation movement, particle trajectory, velocity field, tensor, mixture homogeneity.*

Introduction. Concrete mixture mixing process in gravity concrete mixers is accompanied by nonuniform component movement within drum working volume, leading to formation of active and passive mixing zones. Presence of passive zones reduces particle interaction intensity, increases mixture preparation duration, and decreases homogeneity. Accordingly, investigation of active mixing zone formation patterns and determination of factors influencing component motion intensity within the concrete mixer drum are relevant tasks. Particular attention should be given to influence of blade design parameters and drum motion modes on construction mixture particle movement character and mixing process efficiency.

Concrete mixture homogeneity is one of the main factors determining physical mechanical characteristics of ready concrete, including strength, density, and durability. Insufficient mixing intensity leads to nonuniform distribution of cement paste, water, and aggregates within mixer working volume, negatively affecting ready material quality. In gravity concrete mixers, process efficiency largely depends on mixture motion character within the drum and capability of working bodies to ensure active particle movement throughout the entire mixture volume.

Passive zone formation within concrete mixer working volume is especially characteristic of operating modes with insufficient mixture circulation movement intensity. In such regions, mixture components move slowly or remain practically motionless for a long period, worsening the mutual mixing process. As a result, uniformity of cement paste and fine dispersed component distribution within the total mixture volume decreases, which can negatively influence physical mechanical characteristics of ready concrete.

Analysis of recent research and publications. Analysis of recent studies showed that higher concrete mixture mixing efficiency in gravity concrete mixers is achieved through intensification of component movement within drum working volume and reduction of passive mixing zones [1-2]. Considerable attention in modern studies is devoted to investigation of particle motion trajectories, shear zone formation, influence of blade design parameters, and drum rotation modes on mixture homogeneity. It was established that traditional mixing methods do not always ensure sufficient component movement intensity throughout the entire drum volume, leading to formation of local zones with low motion activity [3].

Research objective. Determination of active mixing zone formation patterns in a gravity concrete

mixer and establishment of influence of drum design and kinematic parameters on construction mixture particle motion intensity, component distribution uniformity, and mixing process efficiency.

Main part. In a gravity concrete mixer, active mixing zone formation occurs due to cyclic movement of construction mixture particles within drum working volume under action of gravitational and inertial forces [4]. During drum rotation, blades capture mixture particles and lift them to a certain height, after which the particles separate from the surface and enter a free fall regime. At this moment, zones of intensive circulation movement arise within the drum, forming active mixing zones. These zones provide the most effective redistribution of concrete mixture components and destruction of local material accumulations [5].

Active zone formation is accompanied by continuous particle movement between different mixture layers, resulting in higher interaction intensity and lower probability of local stagnant region formation. During circulation movement, particles repeatedly change motion direction, promoting uniform redistribution of concrete mixture components within drum working space and improving mixing conditions.

Condition for particle transition into the active motion phase is determined by equality between centrifugal force and gravitational force projection onto the radial direction

$$\omega^2 R = g \cos \varphi_0, \quad (1)$$

where ω – drum angular velocity, rad/s;

R – drum radius, m;

φ_0 – particle separation angle from the drum surface.

After separation, the particle moves along a trajectory whose height is determined by the following relation

$$h = R(1 - \cos \varphi), \quad (2)$$

where h – particle lifting height, m;

φ – particle lifting angle.

Particle lifting height directly influences energy of subsequent motion and mixing intensity within the drum. Increased lifting height leads to higher particle falling velocity and stronger particle interaction intensity, promoting activation of local material accumulation destruction process. At the same time, excessive increase in lifting height can lead to nonuniform mixture movement and higher energy consumption of the mixing process.

Active zone formation intensity is determined by mixture volume participating in circulation movement. A mixing activation coefficient is used for evaluation of this process

$$k_a = \frac{V_a}{V_p}, \quad (3)$$

where V_a – active mixing zone volume, m³;

V_p – passive zone volume, m³.

The mixing activation coefficient enables quantitative evaluation of drum working volume utilization efficiency during the mixing process. Increased coefficient values indicate involvement of a larger mixture portion in active circulation movement and reduction of passive zone volume. Such an approach enables evaluation of influence of blade design parameters and concrete mixer operating modes on active zone formation intensity.

Determination of the mixing activation coefficient also enables evaluation of efficiency for different gravity concrete mixer design schemes. Increased active mixture volume fraction improves material circulation conditions within the drum, promoting more uniform component distribution and higher efficiency of mixer drive energy utilization.

Within the formed active zones, local regions of intensive shear motion arise, characterized by significant velocity gradients and complex concrete mixture flow structures. A velocity gradient is used for description of the particle velocity field

$$\nabla v = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}, \quad (4)$$

where v_x , v_y , v_z – particle motion velocity components in corresponding directions.

Presence of significant velocity gradients within formed active zones indicates intensive momentum exchange between mixture layers. These regions create conditions for the most effective concrete mixture component mixing, since particle motion velocities differ substantially in neighboring flow layers.

Intensive mixing zones are characterized by occurrence of shear deformations described by the shear rate tensor

$$D = \frac{1}{2} (\nabla v + (\nabla v)^T), \quad (5)$$

where D – shear rate tensor.

Occurrence of shear deformations within concrete mixer working volume ensures destruction of local particle accumulations and intensifies the mixing process. The highest shear rate tensor values are observed in near wall regions close to the blades, where the most active mixture flows are formed.

Since concrete mixture exhibits viscoplastic medium properties during the mixing process, the Bingham model is used for description of its flow

$$\tau = \tau_0 + \mu \frac{dv}{dy}, \quad (6)$$

where τ – shear stress, Pa;

τ_0 – yield shear stress, Pa;

μ – dynamic mixture viscosity, Pa·s.

Application of the Bingham model enables consideration of concrete mixture rheological properties during movement within the mixer drum. This is especially important for investigation of active zone formation processes, since mixture viscoplastic properties substantially influence circulation movement intensity, particle motion character, and shear zone formation conditions.

Thus, active zone formation process in a gravity concrete mixer represents a complex multifactor system determined by interaction between drum kinematic parameters, blade geometry, and concrete mixture rheological properties. Rational combination of these parameters enables intensive component circulation movement, reduction of passive zone volume, and higher mixing process efficiency.

Performed analysis showed that active mixing zone formation depends on drum angular velocity, blade geometry, and mixture circulation movement intensity. Increased active volume fraction promotes improved concrete mixture homogeneity, shorter mixing duration, and higher gravity concrete mixer operating efficiency.

Conclusions. As a result of the performed studies, active mixing zone formation patterns in a gravity concrete mixer during cyclic construction mixture movement within drum working volume were established. It was determined that active zone formation intensity depends on drum angular velocity, particle motion trajectories, and blade geometry parameters. It was shown that particle transition into a free fall regime ensures formation of circulation flows promoting effective mixture component redistribution and reduction of passive zones.

An approach for quantitative evaluation of active mixing zones based on determination of active volume fraction within total mixture volume was proposed. It was established that increased active volume is accompanied by higher shear deformation intensity, improved concrete mixture homogeneity, and shorter mixing process duration. The obtained relationships can be used for justification of rational operating modes for gravity concrete mixers and improvement of working body design parameters.

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MODELING OF CONSTRUCTION MIXTURE MIXING PROCESS BASED ON A STOCHASTIC APPROACH

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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