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Investigation of construction mixture preparation processes in a universal mixer

Abstract. Modern construction conditions are characterized by increased requirements for efficiency of preparation and transport processes for construction mixtures with varying consistency within mobile technological systems. The study aims to analyze dry, semi dry, and plastic construction mixture mixing features and to justify rational mixing and conveying equipment design schemes ensuring coordinated preparation and material delivery process progression.
The study considers structural mechanical characteristics of construction mixtures with different consistency and their influence on mixing conditions within the mixer working volume. Comparative analysis covers gravity and forced action mixers considering medium particle motion character and homogeneous mixture composition formation intensity. Main methods for construction mixture transport to application point are analyzed and efficiency of screw conveying units within mixing feeding installations is determined. The obtained results can be used for selection of equipment design and operating parameters for preparation and delivery of construction mixtures with varying consistency under construction site conditions.

Keywords: construction mixture, mixing, forced action mixer, transport, screw conveying unit, preparation process mode, productivity

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Introduction.

Modern construction development is accompanied by increasing requirements for productivity, mobility, and technological flexibility of machines and equipment used for preparation, transport, and delivery of construction mixtures. Construction, repair, and finishing practice widely uses dry, semi dry, and plastic mixtures differing in liquid phase content, mobility, component cohesion, internal friction, and transport capability. Such differences significantly influence technological equipment selection, operating modes, and working body design parameters.

Construction mixtures are complex multicomponent dispersed systems with properties dependent on aggregate granulometric composition, binder type, water content, mineral or chemical additive presence, and mechanical action mode during mixing. For dry mixtures, the main technological task is uniform component distribution throughout the entire mixer working volume. For semi dry mixtures, particular importance lies in ensuring uniform material wetting and overcoming increased internal resistance to particle motion. For plastic mixtures, decisive factors include homogeneous structure formation conditions, prevention of material adhesion to working surfaces, and continuous delivery to the application point [1].

Accordingly, use of a single equipment type for all construction mixture types does not always ensure adequate preparation quality and subsequent material transport efficiency. The technological process must consider not only mixing conditions but also subsequent mixture movement to unloading or application zone. This is especially important for mobile technological systems operating directly at the construction site and ensuring autonomous execution of multiple operations within a single production cycle [2].

A promising direction for improvement of such equipment is integration of a mixing device and a conveying unit based on an Archimedes screw within a single machine. A screw conveying unit provides axial material movement in a pipeline through screw surface rotation and interaction of its flights with the mixture. Such a design scheme enables integration of construction mixture preparation and transport processes, reduces intermediate operations, shortens time losses, and increases construction work mechanization level.

Review of Research Resources and Publications. Studies on construction mixture mixing processes show that homogeneous structure formation efficiency is determined by particle motion intensity within mixer working volume, blade or screw working body geometry, mixing chamber fill level, and shaft rotation speed. Material motion character depends on inertial force to internal friction force ratio, especially during mixing of semi dry and plastic mixtures with increased component cohesion [3-4].

A separate research group includes studies focused on construction mixture transport through pipeline systems. These studies show that material delivery uniformity is governed by medium rheological properties, transport channel geometry parameters, pipeline length, and conveying unit operating modes. Considerable attention is given to analysis of pressure loss during mixture movement, material delivery nonuniformity, and influence of pumping unit design parameters on technological system productivity [5-6].

A promising development direction for mechanized construction mixture delivery systems is use of screw conveying units ensuring continuous material movement and capability to transport media with different structural mechanical characteristics. Studies show that screw mechanism productivity is determined by screw diameter and pitch, interflight space fill factor, working body rotation speed, and transported medium physical mechanical properties [7].

At the same time, results of available studies indicate insufficient attention to coordination of mixing and conveying working body parameters within universal units designed for operation with construction mixtures of varying consistency. In most cases, mixing and transport processes are considered separately without accounting for their mutual influence within a single technological cycle.

Problem statement.

Under modern construction conditions, requirements for technological parameters of construction mixture preparation and transport processes for varying consistency increase, since physical mechanical properties directly influence mixing efficiency, material delivery uniformity, and construction work quality. Application practice of mobile mixing feeding units shows that mixing parameters determine not only medium homogeneity level but also conditions for subsequent pipeline movement, passage through conveying units, and delivery uniformity to application point.

This problem becomes especially relevant during work with dry, semi dry, and plastic construction mixtures that differ significantly in structural mechanical characteristics and movement conditions within technological channels. Under such conditions, ensuring coordinated operation of mixing equipment and conveying devices, including screw mechanisms based on an Archimedes screw, requires scientifically grounded determination of design and operating parameters with consideration of transported medium properties.

Analysis results for modern technological processes of construction mixture preparation and delivery indicate necessity of research aimed at establishing relationships between mixing and transport process parameters for varying consistency mixtures to increase universal mixing feeding unit efficiency and ensure continuous material preparation process under construction site conditions.

Main material and results.

Efficiency of modern technological systems for construction mixture preparation and transport is determined by coordination between mixing and conveying working body parameters and medium physical mechanical characteristics. Ensuring continuity of material preparation process requires integrated consideration of component granulometric composition, liquid phase content, mixture structural cohesion, and mixing equipment design and operating parameters together with screw conveying unit parameters. Under such conditions, investigation of interaction patterns between construction mixtures of varying consistency and working bodies of universal mixing feeding units becomes particularly important [8].

Construction mixtures used in modern construction are classified into dry, semi dry, and plastic types based on water content and structural mechanical properties. Each listed group is characterized by specific mixing and transport conditions determining selection of mixing equipment type, conveying unit design, and drive operating modes. Mixture consistency variation is accompanied by changes in internal friction, flowability, component cohesion, and pipeline transport capability, which must be considered during design of universal units with screw conveying mechanisms [9-10].

Dry construction mixtures belong to multicomponent dispersed systems containing binders, mineral aggregates, and functional additives without liquid phase introduction during transport or storage. Homogeneous composition formation for such media is ensured through repeated particle movement within mixer working volume under action of gravitational and inertial forces. Mixing process intensity is determined by working body geometry, mixing chamber fill level, and rotation speed. Dry mixture movement through technological channels is mainly performed by screw or belt conveying devices ensuring bulk material delivery uniformity.

Semi dry mixtures are characterized by structural contacts between material particles formed under action of a limited liquid phase amount. The mixing process is accompanied by destruction of such contacts and uniform moisture redistribution throughout the entire medium volume. Increased internal friction between particles causes necessity for forced action mixing bodies and conveying mechanisms with increased drive torque. Coordination between conveying device operating modes and medium properties determines material movement character within the pipeline and delivery uniformity [11].

Plastic construction mixtures are characterized by increased component cohesion and significant resistance to shear deformation, which substantially influences mixing and transport conditions. Homogeneous material structure formation requires intensive particle interaction without stagnant zone formation within mixer working volume. During movement of such media, decisive factors include material interaction forces with conveying channel surfaces and conveying unit operating parameters [12].

Main characteristics of construction mixtures with varying consistency are presented in the Table 1.

Table 1 – Main technological characteristics of construction mixtures with varying consistency

Mixture type	Water content	Structural state	Mixing features
Dry	Minimal	Bulk dispersed system	Intensive particle movement within working volume
Semi dry	Limited	Weakly cohesive granulated structure	Destruction of structural bonds between particles and uniform moisture distribution
Plastic	Increased	Cohesive viscoplastic system	Homogeneity maintenance without stagnant zone formation

Presented behavior features of construction mixtures with varying consistency indicate decisive influence of structural mechanical characteristics on mixing process progression within mixer working volume. Homogeneous medium composition formation intensity depends on the relationship between working body motion speed, mixing chamber fill level, and material properties, including internal friction, component cohesion, and particle redistribution capability within space. Rational combination of the specified parameters determines efficiency of local structural heterogeneity destruction and mixture component distribution uniformity.

Modern construction widely uses gravity and forced action mixers differing in material mixing energy transfer principle. In gravity mixers, mixture component movement occurs through periodic material lifting by drum internal surfaces followed by free falling under gravitational forces. Such a mechanism forms medium circulation flows sufficient for mixing bulk materials and mixtures with low component cohesion. Particle interaction intensity in this case is determined by drum diameter, rotation speed, internal surface shape, and working volume fill factor.

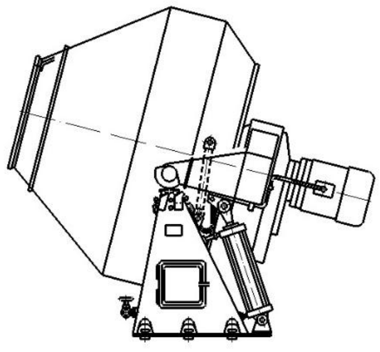

Figure 1 – Gravity Concrete Mixer

At the same time, increased material cohesion is accompanied by reduced particle movement efficiency in gravity mixers (Fig. 1), leading to formation of limited medium circulation zones and nonuniform component distribution within working volume. Under such conditions, necessity arises for mixing devices capable of ensuring forced material movement regardless of mobility level. This factor becomes especially pronounced during operation with semi dry and plastic mixtures characterized by increased internal resistance to deformation [13].

Forced action mixers (Fig. 2) ensure material movement through direct action of blade or screw working bodies on the medium, enabling shear deformation formation throughout the entire mixture volume. Such material motion promotes intensive destruction of local structural formations and uniform component redistribution regardless of medium consistency. Mixing process efficiency in forced action mixers is determined by working body geometry, mutual arrangement of their elements, shaft rotation speed, and mixing chamber fill level [14].

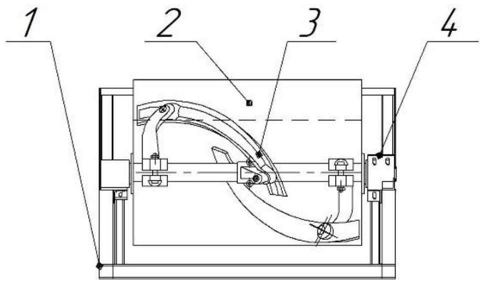

Figure 2 – forced action mixer scheme:
1 – frame; 2 – hopper; 3 – working body;
4 – drive

Particle motion trajectory within mixer working volume also significantly influences mixing process progression. Spatial material flow formation ensures intensive particle exchange between different mixing chamber zones, promoting component concentration equalization throughout the entire mixture volume. In forced action mixers, such flows are formed by working bodies and have a controlled character, whereas in gravity mixers flow structure is mainly determined by drum geometry and rotation mode.

Mixing process productivity in mixers is determined by mixer working volume, fill factor, and mixing body rotation speed and can be represented by the following relation

$$Q_{mix} = \frac{\varphi_{mix} V_w \, n_{mix}}{N_{mix}}, \qquad (1)$$

where Q_{mix} – mixing productivity, m³/s;

φ_{mix} – mixer fill coefficient;

V_w – mixer working volume, m³;

n_{mix} – mixing body rotation speed, rev/s;

N_{mix} – number of working body revolutions required to achieve specified mixture homogeneity, rev.

Analysis of mixing equipment operating conditions during preparation of construction mixtures with varying consistency shows necessity to consider relationships between mixer design parameters, kinematic operating modes, and medium physical mechanical characteristics. Establishment of such relations creates prerequisites for justification of rational mixing process parameters as a component of a unified construction mixture preparation technological cycle.

After completion of construction mixture mixing, the next stage of the material preparation technological cycle involves transport to unloading or direct application location within the production process. Mixture movement conditions are determined by consistency, granulometric composition, density, delivery route length, and working zone spatial arrangement. Transport process organization substantially influences technological equipment productivity, material delivery uniformity, and overall construction operation efficiency. Coordination between mixing parameters and subsequent mixture movement conditions within technological channels becomes particularly important, since medium structure variation during mixing determines motion character in conveying devices.

Construction practice uses various construction mixture transport methods, among which gravitational, mechanical, pneumatic, and pipeline delivery systems remain the most widespread. Gravitational transport is mainly used for short material movement sections within technological equipment or between separate production unit assemblies. This method is characterized by structural simplicity, but application efficiency is limited by material flowability and transport channel inclination angles [15].

Mechanical transport systems ensure material movement through moving working bodies interacting with the medium during delivery. Such systems include belt conveyors, bucket elevators, scraper devices, and screw conveying units used depending on mixture properties and movement route length. Belt conveyors are effective for transport of dry components and bulk mixtures along horizontal or slightly inclined sections. Bucket elevators are used for vertical material transport between technological unit levels. Scraper conveyors ensure movement of media with increased density and limited flowability within closed delivery channels [16].

Semi dry mixture movement is accompanied by increased internal friction between material particles and higher resistance to movement along transport channels. Under such conditions, transport efficiency is determined by capability to create forced medium movement through direct action of conveying device working bodies. Selection of conveying equipment design parameters is performed considering material density, cohesion level, and required delivery productivity [17].

Pipeline delivery systems with pumping equipment capable of ensuring material transport in horizontal and vertical directions over considerable distances are most widely used for plastic construction mixture movement. Such transport conditions are determined by mixture rheological characteristics, pipeline diameter, transport route length, and delivery device operating modes. Formation of the required medium structure during the mixing stage creates prerequisites for uniform pipeline material movement without component segregation [18].

Screw transport productivity for construction mixtures is determined by screw geometry parameters and rotation speed [3] and is described by the following relation

$$Q_s = \frac{\pi\left(D_{outer}^2 - d_{shaft}^2\right)}{4} S\, n_s\, \varphi_s, \qquad (2)$$

where Q_s – screw conveyor productivity, m³/s;

D_{outer} – screw outer diameter, m;

d_{shaft} – screw shaft diameter, m;

S – screw pitch, m;

n_s – screw rotation speed, rev/s;

φ_s – screw interflight space fill factor.

Pneumatic transport systems are mainly used for movement of dry construction mixtures and powder components within material preparation technological lines. Medium movement in such systems is performed by airflow within sealed delivery channels, enabling long distance material transport together with protection from environmental influence. Pneumatic system efficiency is determined by airflow velocity, material dispersity, and transport line geometry parameters.

Figure 3 – Plastering station PFT ZP 3 XL MIX

Besides separate application of mixing and conveying equipment, construction practice widely uses combined units in which construction mixture preparation and delivery processes are implemented within a single technological machine. Such technical solutions ensure reduction of material preparation technological cycle duration, decrease in intermediate transfer operation quantity, and increased efficiency of mobile equipment application during construction site operations [19].

Design schemes for such units include integration of a mixing drum or forced mixing chamber with a material delivery conveying assembly located in the lower unit section or within a separate technological block housing. Coordinated operation of mixing and delivery mechanisms ensures continuous mixture movement from preparation zone to unloading location without additional transport devices, which is especially important during finishing, installation, and repair operations.

Application of combined mixing feeding units enables implementation of compact mobile technological systems suitable for operation with construction mixtures of varying consistency under limited construction site space conditions. Integration of mixing and transport functions within a single unit creates prerequisites for coordination between material preparation parameters and subsequent delivery modes within technological channels.

Since mixing and transport processes for construction mixtures in batch mixing conveying units are performed sequentially within a single technological cycle, total unit productivity is determined considering duration of both process stages and can be represented by the following relation

$$Q_t = \frac{Q_{mix}\,Q_s}{Q_{mix} + Q_s}, \quad (3)$$

where Q_t – total productivity of mixing conveying equipment, m³/s.

The obtained relationship reflects mutual influence of mixing and conveying working body parameters on unit productivity and enables determination of rational design and kinematic parameter values depending on construction mixture consistency.

Performed analysis of construction mixture mixing features with varying consistency showed decisive influence of mixing equipment design scheme on homogeneous medium composition formation efficiency. Comparison of gravity and forced action mixer operating principles indicates expediency of forced action mixer application during operation with a wide mixture range from dry to plastic types. Direct working body action on the material ensures intensive particle movement throughout the entire mixing chamber working volume, uniform component distribution, and formation of required mixture technological properties regardless of cohesion and mobility level.

Analysis of construction mixture transport methods shows expediency of screw conveying unit application capable of ensuring material movement within closed delivery channels with coordinated flow parameters and continuous medium motion character. Such a transport method is effectively implemented during operation with mixtures of varying consistency and enables direct material delivery from the mixing assembly to the unloading location within a unified technological process.

Integration of a forced action mixer with a screw conveying assembly within a single technological unit creates prerequisites for increased efficiency of construction mixture preparation and delivery processes under production conditions. Application of such design solutions ensures reduction of material preparation technological cycle duration, decrease in auxiliary movement operation quantity, and higher construction work mechanization level.

Conclusions. Performed analysis of technological features for preparation of construction mixtures with varying consistency showed decisive influence of structural mechanical characteristics on mixing equipment design scheme selection and operating mode choice. It was established that ensuring intensive component movement throughout the entire mixing chamber working volume is a necessary condition for homogeneous medium composition formation during preparation of dry, semi dry, and plastic mixtures.

Comparative analysis of gravity and forced action mixers showed expediency of forced type mixer application for operation with a wide range of construction mixtures differing in cohesion level and internal deformation resistance. Direct working body action on the medium ensures spatial material flow formation within mixer working volume and uniform component distribution regardless of mixture consistency.

Analysis of construction mixture transport methods to the application location showed efficiency of screw conveying unit application ensuring material movement within closed delivery channels with coordinated flow parameters for media of varying consistency. Integration of a forced action mixer with a screw conveying assembly within a single technological unit creates prerequisites for increased efficiency of construction mixture preparation and delivery processes under mobile construction conditions and reduction of material preparation technological cycle duration.

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Дослідження робочих процесів приготування будівельних сумішей в універсальному змішувачі

Аннотація. Сучасні умови будівельного виробництва характеризуються підвищенням вимог до ефективності процесів приготування та транспортування будівельних сумішей різної консистенції в межах мобільних технологічних систем. Метою роботи є аналіз особливостей змішування сухих, напівсухих і пластичних будівельних сумішей та обґрунтування раціональних конструктивних схем змішувального і транспортуючого обладнання для забезпечення узгодженого перебігу процесів підготовки та подачі матеріалу. У роботі розглянуто структурно-механічні характеристики будівельних сумішей різної консистенції та їх вплив на умови перемішування в робочому об'ємі змішувача. Проведено порівняльний аналіз змішувачів гравітаційної та примусової дії з урахуванням характеру переміщення частинок середовища та інтенсивності формування однорідного складу суміші. Проаналізовано основні способи транспортування будівельних сумішей до місця використання та визначено ефективність застосування гвинтових транспортуючих органів у складі змішувально-подаючих установок.
Отримані результати можуть бути використані під час вибору конструктивних і режимних параметрів обладнання для приготування та подачі будівельних сумішей різної консистенції в умовах будівельного майданчика.

Ключові слова: будівельна суміш, змішування, змішувач примусової дії, транспортування, гвинтовий орган, технологічний режим приготування, продуктивність

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