Definisanje osnovnih parametara kompleta male opreme za pripremu suvog maltera za različitu namenu

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Na osnovu prikupljenih informacija i pregleda naučne literature, uočena su nerešena pitanja u procesu pripreme suvih građevinskih mešavina neposredno na gradilištu. Razmatrane su konstrukcije postojećih tehnoloških kompleksa za proizvodnju suvih građevinskih mešavina a njihovi glavni nedostaci su identifikovani neposredno pri primenama na gradilištu. Na osnovu izvedenih istraživanja predloženi su projekti tehnoloških setova male opreme za pripremu suvih građevinskih mešavina na gradilištu. Utvrđeno je da su osnove za kreiranje predloženih tehnoloških kompleta novi projekti betonskih miksera koji rade u kaskadnom načinu rada. Predložena je tehnika za izračunavanje glavnih parametara tehnološke opreme, zavisno od upotrebe osnovne mašine.

Ključne reči: set male opreme, suva mešavina, mikser betona, kaskadni režim, putanja kretanja čestica mešavine.

1. UVODNE NAPOMENE

Moderne suve građevinske smeše su složene kompozicije komponenti, različite u njihovim svojstvima. Mešanje ovih komponenti zajedno i stvaranje homogene smeše je težak zadatak u tehničkom smislu. Stvaranje efikasne opreme za ove svrhe predstavlja veliki problem moderne gradnje. Sa svojim rešenjem, posebnu pažnju treba posvetiti razvoju tehnološke opreme.

Trenutno, u procesu pripreme suvih građevinskih mešavina, postoji niz nerešenih problema: povećana nosivost radnih tela i miksera, dugo vremena za pripremu kompleksnih kompozicija, prisustvo segregacije tokom pripreme smeša i složenost pripreme smeša direktno na gradilištu [1 - 4].

Trenutno se koriste tehnološki kompleksi koji imaju mogućnost proizvodnje mešavina različitih vrsta za pripremu suvih građevinskih smeša [5 - 7].

Kompleksi su opremljeni visokokvalitetnim uređajima za doziranje i mešačima prisilnog delovanja sa jednim ili dve osovine, na kojima su različiti mešački uređaji [3, 9].

Međutim, savremeni mešači za beton ne dozvoljavaju uvek proizvodnju homogene smeše sa malim faktorom punjenja radne zapremine mašine. Pored toga, postojeći mikseri ne dozvoljavaju stvaranje jednog organizovanog radnog ciklusa na jednom mjestu. Sa ovih pozicija, atraktivniji su tehnološki kompleti koji omogućavaju kombinovanje svih operacija u vremenu.

Pored toga, raznovrsnost postojeće opreme, kao i tehnoloških linija i kompleta, nije usmerena na rešavanje problema stvaranja suvih građevinskih smeša direktno na gradilištu.

Stvaranje efikasne opreme malih dimenzija za pripremu suvih smeša je hitan zadatak.

Rezultati laboratorijskih i industrijskih ispitivanja novih dizajnerskih miksera koji rade u kaskadnom režimu, potvrđuju njihovu efikasnost u pripremi suvih građevinskih mešavina, što omogućava opremanje ovih mašina tehnološkim kompletima i kompleksima [8].

2. GLAVNI MATERIJALI I REZULTATI

Predlaže se izrada i uvođenje malih setova opreme za pripremu suvih građevinskih smeša na bazi novih miksera koji rade u kaskadnom režimu u proizvodnji malih količina (za pojedinačnu malu izgradnju, izgradnju u poljoprivrednom sektoru, popravku i rekonstrukciju postojećih objekata).

Kompleti tehnološke opreme prikazani su na Slici 1. Sva oprema ovih tehnoloških kompleta bazirana je na zajedničkoj osnovi i izabrana je u skladu sa performansama baznih mašina-miksera.

Tehnološki set opreme, prikazan na slici 1, uključuje sledeće komponente: 1 - mikser (osnovna mašina); 2 - mašina za punjenje 3 - bunker za pesak; 4 - silos cementa; 5 - vaga za merenje težine; 6 - rezač vlakana; 7 - transporter-dodavač 8 - bunker granita; 9 - punilica.

Osnovne mašine tehnološkog seta (slika 1) mogu biti betonski mešači novog konstruktivnog rešenja: mikser sa tri osovine, gravitacioni betonski mešač, dvostrani turbulentni mešač [5].

Karakteristika rada ovih mašina je stvaranje složenog kretanja čestica smeše u telu mašine [9]. Oprema tehnološkog skupa je ujedinjena i ima tradicionalno rešenje izvođenja.

Produktivnost skupa tehnološke opreme određuje se na osnovu tehničkih performansi bazne mašine koja se koristi u sastavu tehnološkog seta.

Slika 1: Tehnološki set opreme za pripremu suve građevinske mešavine:

- a) osnovna mašina i troosovinski mikser; b) osnovna mašina sa gravitacionim mikserom; c) osnovna mašina idvorotorni mikser

Produktivnost tehnološkog seta korišćenjem betonskog miksera sa tri osovine nalazi se prema zavisnosti [10]:

$$\Pi_{mex} = 3600 \cdot \frac{\pi}{4} \cdot (D^2 - d^2) \cdot b \cdot n \cdot z_n \cdot \sin \alpha \cdot \kappa_{sc}^{cp} \cdot \kappa_{sc}^{II} \quad (1)$$

gde su:

D – prečnik vratila na kraju lopatice, m;
 d – prečnik prosečnog vratila, m;
 b – širina lopatice, m;
 z_n – broj lopatica srednjeg vratila;
 α – ugao postavljanja lopatice, °;

κ_{sc}^{cp} – faktor opterećenja miksera u odnosu na prosečno vratilo, $\kappa_{sc}^{cp} = 0,75$;

n – broj obrtaja vratila radnog uređaja;

κ_{sc}^{II} – koeficijent vraćanja betonske mešavine u drugoj zoni.

Određivanje tehničke produktivnosti kompletne opreme, koja uključuje mikser betona gravitacionog dejstva, definisan je kao

$$\Pi_{mex} = V_{obu} \cdot Z_{II} = \frac{I}{2} \left[\pi \cdot L_k (R_k^2 \cdot k - r_e^2) - \pi \cdot r_n^2 \cdot l_n \cdot z_n - z_1 \cdot b_1 \cdot h_1 \cdot c_1 - z_2 \cdot b_2 \cdot h_2 \cdot c_2 \right] \cdot Z_{II} \quad (2)$$

gde su:

V_{obu} – ukupna zapremina mešavine u mikseru, m³;

$Z_{II} = 3600 / t_{II}$ – broj ciklusa po času (t_{II} – trajanje

ciklusa, koji se sastoji od zbira vremena potrebnog za utovar komponentata t_1 , vremena mešanja t_2 i pražnjenja mešavine t_3 ($t_{II} = t_1 + t_2 + t_3$), s);

L_k – dužina miksera, m;

R_k – poluprečnik miksera, m;

k – koeficijent koji uzima u obzir položaj mešavine;

R_n, l_n, z_n, r_e – poluprečnik, dužina, broj krakova lopatica, poluprečnik vratila, m;

$b_1, b_2, h_1, h_2, c_1, c_2$ – dužina, visina i debljina lopatica tela miksera i lopatica vratila, m.

Produktivnost tehnološkog seta sa dvorotornim turbulentnim mikserom data je preko zavisnosti

$$\Pi_{mex} = V_{obu} \cdot Z_{II} \cdot \kappa_m, \quad (3)$$

gde su:

V_{obu} – ukupna zapremina mešavine u mikseru, m³;

$Z_{II} = 3600 / t_{II}$ – broj ciklusa mašine po času (t_{II} ije trajanje jednog ciklusa, i jednako je zbiru vremena sipanja komponenti t_1 , vremena mešanja t_2 i pražnjenja mešavine t_3 ($t_{II} = t_1 + t_2 + t_3$), c);

κ_m – faktor korišćenja mašine (0.85).

U ovom slučaju, snabdevanje miksera komponentama može se prikazati na sledeći način:

$$M = \int_0^t (Q_{x_{ex}} - Q_{x_{mix}}) dt \quad (4)$$

gde je:

M – ukupna masa komponentata;

t – vreme za sipanje svih komponentata;

$Q_{x_{ex}}$ – protok komponenti nakon skladištenja;

$Q_{x_{mix}}$ – protok komponenti posle dodavanja.

Odnos ukupne mase i zapremine miksera V je dat kao:

$$\frac{M}{V} = \Delta x = \frac{Q}{V} \int_0^t (x_{ex} - x_{mix}) dt, \quad (5)$$

gde su:

M - ukupna masa komponenti

t - ivreme sipanja svih komponenti;

x_{ex} , x_{in} , x - redom, sadržaj komponenti na ulazu, izlazu i unutar miksera;

Q - kapacitet miksera pri stalnim uslovima rada.

Među glavnim indikatorima performansi malih tehnoloških setova opreme za pripremu građevinske mešavine, vredi pomenuti troškove snage.

Troškovi snage za rad tehnološke opreme namenjeni za pripremu mešavina vlakno-beton se sastoje od sume troškova snage pojedinih vrsta opreme koja je uključena u komplet (slika 1, c): mašina- alat vlakna, osnovna mašina (mikser za beton), dodavači i dozatori. Stoga, zavisnost za određivanje snage tehnološkog skupa opreme ima oblik [7]

$$N_{TKO} = N_{6.M} + N_p + N_{II} + N_o, \quad (6)$$

gde su:

N_{TKO} - ukupna potrošnja energije za rad tehnološkog seta opreme, kW;

$N_{6.M}$ - potrošnja energije osnovne mašine, kW;

N_p - potrošnja energije rezača vlakana, kW;

N_{II} - potrošnja energije dodavača, kW;

N_o - potrošnja energije dozatora, kW.

Uzimajući u obzir projektovane karakteristike osnovne mašine za beton sa tri osovine (slika 1), prilikom rada na suvim građevinskim mešavinama, N_{TKO} treba definisati kao za mikser sa tri osovine $N_{6.M}$, uzimajući u obzir rad mašina na suvim građevinskim mešavinama

$$N_{6.M} = \frac{N_1 + N_2 + N_3}{1000 \cdot \eta}, \quad (7)$$

gde su:

N_1 - potrošnja energije za mešanje sa gornjim vratilom;

N_2 - potrošnja energije za mešanje komponenti mešavine betona i transport u deo za pražnjenje sa srednjim vratilom t;

N_3 - potrošnja energije za mešanje komponenti sa donjim vratilom t;

η - stepen koristnosti pogonskog mehanizma.

$$N_1 = N_1' + N_1'', \quad (8)$$

gde su:

N_1' - potrošnja energija mešanja u prvoj zoni,

N_1'' - potrošnja energija mešanja u drugoj zoni

$$N_1' = \omega \cdot F_a \cdot C_1 \cdot f \cdot (R^2 - r^2) \cdot Z_{1.a}^I \cdot \kappa_3^e \cdot \rho_1, \quad (9)$$

pri čemu su:

ω - ugaona brzina vratila, s⁻¹;

F_a - površina lopatica, m²;

C_1 - koeficijent otpora kretanju čestica suve mešavine betona duž lopatica u prvoj zoni, $C_1 = 9$;

f - koeficijent trenja suve mešavine na lopatici, $f = 0,4$;

R - spoljni poluprečnik obrtanja lopatice, m;

r - unutrašnji poluprečnik obrtanja lopatice, m;

$Z_{1.a}^I$ - broj lopatica na gornjem vratilu u prvoj zoni mešanja;

κ_{38} - faktor opterećenja koji se odnosi na gornje vratilo;

ρ_1 - prosečna gustina suve mešavine, kg / m³.

$$N_1'' = \omega \cdot F_a \cdot C_2 \cdot f' \cdot (R^2 - r^2) \cdot Z_{1.a}^{II} \cdot \kappa_3^e \cdot \rho_2, \quad (10)$$

gde su:

C_2 - koeficijent otpora kretanju čestica suve mešavine betona duž lopatica u prvoj zoni, $C_2 = 7$;

f' - koeficijent trenja suve mešavine na lopatici, $f' = 0,1..0,2$;

$Z_{1.a}^{II}$ - broj lopatica na gornjem vratilu u drugoj zoni mešanja.

Nakon transformacija, zavisnost za određivanje potrošnje energije gornjeg vratila miksera ima oblik

$$N_1 = \left[(\omega \cdot F_a \cdot \rho \cdot (R^2 - r^2) \cdot \kappa_3) \right] \cdot C_1 \cdot f \cdot Z_{1.a} + C_2 \cdot f' \cdot Z_{1.a}' \quad (11)$$

Potrošena energija na mešanje komponenti betonske smese i transport do izlaza sa srednjim vratilom

$$N_2 = N_2' + N_2'', \quad (12)$$

gde je:

N_2' - potrošena energija na proces mešanja komponenti u prvoj zoni i njihov transport u drugu zonu;

N_2'' - potrošnja energije u drugoj zoni mešanja.

$$N_2' = m_c \cdot g \cdot W \cdot \omega \cdot R_w, \quad (13)$$

pri čemu su:

m_c - masa komponenti u zavojnom transporteru, kg;

W - koeficijent prevlačenja (kada se telo kreće u nepovoljnim uslovima $W = 4$);

ω - ugaona brzina vratila, s;

R_w - poluprečnik zavojnice, m;

g - gravitaciono ubrzanje

$$N_2'' = \omega \cdot F_a \cdot C_2 \cdot f' \cdot (R^2 - r^2) \cdot Z_{2.a}^{II} \cdot \kappa_3^{ep} \cdot \rho_2, \quad (14)$$

pri čemu su:

$Z_{2.a}^{II}$ - broj lopatica na srednjem vratilu u drugoj zoni.

Potrebna snaga za mešanje komponenti sa donjim vratilom je

$$N_3 = N_3' + N_3'', \quad (15)$$

pri čemu je:

N_3' - snaga potrebna za proces mešanja u prvoj zoni;

N_3'' - snaga potrebna za proces mešanja u drugoj zoni;

N_3' и N_3'' – definišu se na isti način kao i za gornje vratilo.

Za mikser sa gravitacionim dejstvom [5], snaga $N_{\delta, m}$ utrošena za proces pripreme mešavine suve smeše, sastoji se od snage potrebne za okretanje tela miksera i snage potrebne za okretanje vratila lopatice.

$$N_{\delta, m} = N_K + N_B, \kappa Bm,$$

gde je:

N_K - snaga potrebna za okretanje tela miksera.

$$N_K = N_K^{(1)} + N_K^{(2)} = \frac{0,85 \cdot G_{cm} \cdot h \cdot Z \cdot \omega_K}{\eta_K \cdot 1000} + \frac{F_{mp, k} \cdot V_{abc, k} \cdot z_1}{\eta_K \cdot 1000}, \quad (16)$$

pri čemu su:

G_{cm} – težina komponenti, N;

h – vertikalna koordinata pomeraja mase mešavine u telu, m;

Z – broj mešanja u telu mašine e;

ω_K – ugaona brzina obrtana tela miksera, s^{-1} ;

η_K – efikasnost pogona kućišta;

$F_{mp, k}$ – sila trenja koja se povećava kada se čestice mešavine pomeraju duž površinu lopatica tela miksera, N;

$V_{abc, k}$ – apsolutna brzina čestica smeše duž tela lopatice, m / s ;

z_2 – broj lopatica na unutrašnjoj površini tela.

Potrebna snaga za rad vesla vratila tokom mešanja data je izrazom

$$N_B = N_B^{(1)} + N_B^{(2)} = \frac{\omega_{\theta} \cdot M_{\theta}}{\eta_{\theta} \cdot 1000} + \frac{F_{mp, \theta} \cdot V_{abc, \theta} \cdot z_2}{1000 \cdot \eta_{\theta}}, \quad (17)$$

gde je:

ω_{θ} – ugaona brzina obrtanja vratila lopatica miksera, s^{-1} ;

M_{θ} – uvijanje vratila lopatica, N·m;

η_{θ} – efikasnost pogona vratila;

$F_{mp, \theta}$ – sila trenja koja nastaje prilikom kretanja čestica smeše po površini lopatica, N;

$V_{abc, \theta}$ – apsolutna brzina čestica duž lopatica, m / s ;

z_2 – broj lopatica.

Instalacijom dvorotornog turbulentnog miksera, važi izraz:

$$N_{\delta, m} = \omega_{p, o} \cdot F_{\eta} \cdot q_{cm} \cdot f \cdot (R - r) \cdot \cos \beta \cdot Z_{\eta} \cdot \kappa_3 \cdot \rho_1, \quad (18)$$

gde je:

$\omega_{p, o}$ – ugaona brzina obrtanja vratila lopatica miksera, s^{-1} ;

F_{η} – površina lopatica, m^2 ;

q_{cm} – pritisak na lopatice na strani mešanja, Pa;

$f = 0,4$;

R – spoljašnji poluprečnik rotacije lopatica, m;

r – unutrašnji poluprečnik rotacije lopatica, m;

Z_{η} – broj lopatica na gornjem vratilu u prvoj zoni mešanja;

κ_3 – faktor opterećenja mešalice betona;

ρ_1 – prosečna gustina suve mešavine, kg / m^3 ;

β – ugao lopatica.

Dakle, predloženi tehnološki setovi malih dimenzija mogu se uspešno koristiti za direktan rad na gradilištu.

3. ZAKLJUČAK

1. Predloženi su tehnološki skupovi malih dimenzija nove konfiguracije i novog projektnog rešenja za izvođenje malih količina rada u uslovima gradilišta.
2. Takođe, date su zavisnosti koje omogućavaju utvrđivanje pokazatelja performansi novih setova tehnološke opreme za pripremu suvih građevinskih smeša na gradilištu.

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The Definition of Basic Parameters of the Set of Small-sized Equipment for Preparation of Dry Mortar for Various Applications

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Based on the conducted information retrieval and review of the scientific literature, unsolved issues have been identified in the process of preparation of dry construction mixtures in the conditions of a construction site. The constructions of existing technological complexes for the production of dry construction mixtures are considered and their main drawbacks are identified in terms of application in the conditions of the construction site. On the basis of the conducted research, the designs of technological sets of small-sized equipment for the preparation of dry construction mixtures in the construction site are proposed. It is found out that the basis for creating the proposed technological kits are new designs of concrete mixers operating in cascade mode. A technique for calculating the main parameters of technological sets of equipment is proposed, depending on the use of the base machine of the kit.

Keywords: a set of small-sized equipment, a dry construction mix, a concrete mixer, a cascade regime, the motion trajectory of the mixture particles.

1. INTRODUCTION

Modern dry building mixtures are complex compositions of components, different in their properties. Mixing these components together and creating a homogeneous mixture is a difficult task in a technical sense. Creation of effective equipment for these purposes is an urgent problem of modern construction. With its solution, special attention should be paid to the development of technological kits.

At present, in the process of preparation of dry construction mixtures, there is a number of unresolved issues: increased wear of the working bodies and mixer bodies, long time for the preparation of complex compositions, the presence of segregation during the mixture preparation and the complexity of preparing the mixtures directly at the construction site [1 - 4].

At present, technological complexes, which have the ability to produce mixtures of different types, are used for the preparation of dry construction mixtures [5 - 7].

The complexes are equipped with high-quality dosing devices and forced-action mixers with one or two shafts, on which various stirring devices are fixed [3, 9]. However, modern concrete mixers do not always allow to produce homogeneous mixtures with a small filling factor of the working volume of the machine. In addition, existing mixers do not allow to create a single organized work cycle in one place. From these positions, technological kits that allow to combine all operations in time are more attractive.

In addition, the variety of existing equipment, as well as technological lines and kits, is not aimed at solving the problem of making dry construction mixtures directly on the construction site.

Creation of effective small-sized equipment for the preparation of dry mixtures is an urgent task.

The results of laboratory and industrial tests of new design mixers operating in a cascade mode, confirm their

effectiveness in the preparation of dry building mixtures, which makes it possible to equip these machines with technological kits and complexes [8].

2. MAIN MATERIALS AND RESULTS

It is proposed to develop and introduce small-size sets of equipment for the preparation of dry construction mixtures on the basis of new mixers operating in a cascade mode in the production of small amounts of work (with individual low-rise construction, construction in the agricultural sector, repair and reconstruction of existing buildings).

Technological equipment kits are shown in Figure 1. All equipment of these technological kits is based on a common base and is selected according to the performance of the base machine-mixer.

The technological set of equipment, presented in Figure 1, includes the following components: 1 - mixer (basic machine); 2 - filling machine 3 - sand bunker; 4 - silo of cement; 5 - weighing batcher; 6 - fiber cutter; 7 - auger feeder; 8 - bunker of granite grains; 9 - filler hopper

The basic machines of the technological set (Fig. 1) can be concrete mixers of a new constructive solution: a three-shaft concrete mixer, gravity-forced concrete mixer, a two-side turbulent mixer [5]. A feature of the work of these machines is the creation of a complex multi-path motion of the particles of the mixture in the body of the machine [9]. The adjacent equipment of the technological set is unified and has a traditional design solution.

The productivity of a technological equipment set is determined on the basis of the technical performance of the base machine used in the composition of the technological set.

Figure 1: Technological sets of equipment for the preparation of dry building mixtures:
a) the base machine is a three-shaft mixer; b) the basic machine is a mixer of gravitational-forced action; c) basic machine - two-rotor turbulent mixer

The productivity of the technological set with the use of a three-shaft concrete mixer is found according to the dependence [10]:

$$\Pi_{\text{mex}} = 3600 \cdot \frac{\pi}{4} \cdot (D^2 - d^2) \cdot b \cdot n \cdot z_n \cdot \sin \alpha \cdot \kappa_{3cp} \cdot \kappa_g^{\text{II}} \quad (1)$$

where are:

D - is the diameter of the shaft along the end of the blade, m;
 d - is the diameter of the average shaft, m;
 b - blade width, m;
 z_n - number of blades of the middle shaft;
 α - is the angle of installation of the blades, deg;
 κ_{3cp} - load factor of the mixer relative to the average shaft, $\kappa_{3cp} = 0,75$;

n - frequency of rotation of the shaft of the working element;

κ_g^{II} - coefficient of return of the concrete mixture of the second zone.

Determination of the technical productivity of the equipment set, which includes a concrete mixer of gravitational-forced action, is defined as

$$\Pi_{\text{mex}} = V_{\text{обм}} \cdot Z_{\text{II}} = \frac{I}{2} \int \pi \cdot L_k (R_k^2 \cdot k - r_g^2) - \pi \cdot r_n^2 \cdot l_n \cdot z_n - z_1 \cdot b_1 \cdot h_1 \cdot c_1 - z_2 \cdot b_2 \cdot h_2 \cdot c_2 \cdot Z_{\text{II}} \quad (2)$$

where are:

$V_{\text{обм}}$ - is the total volume of the mixture in the mixer, m^3 ;

$Z_{\text{II}} = 3600 / t_{\text{II}}$ - number of cycles of machine operation per hour (t_{II} - is the duration of one cycle, which consists of the sum of time for loading components t_1 , mixing them t_2 and unloading the finished mixture t_3 ($t_{\text{II}} = t_1 + t_2 + t_3$), c);

L_k - length of the mixer body, m;

R_k - is the radius of the mixer body, m;

k - is a coefficient that takes into account the position of the mixture in the body;

R_n, l_n, z_n, r_g - radius, length, number of legs of shaft blades and shaft radius, m;

$b_1, b_2, h_1, h_2, c_1, c_2$ - length, height and thickness of blades of the body and blades of the mixer shaft, m.

The productivity of the technological set when using a two-rotor turbulent mixer is found according to the dependence

$$\Pi_{\text{mex}} = V_{\text{обм}} \cdot Z_{\text{II}} \cdot k_m, \quad (3)$$

where are:

$V_{\text{обм}}$ - the total volume of the mixture in the mixer, m^3 ;

$Z_{\text{II}} = 3600 / t_{\text{II}}$ - number of cycles of machine operation per hour (t_{II} is the duration of one cycle, which consists of the sum of the time for loading components t_1 , mixing them t_2 and unloading the finished mixture t_3 ($t_{\text{II}} = t_1 + t_2 + t_3$), c);

k_m is the machine utilization factor (0.85).

In this case, the feeding of the components of the concrete mixture into the mixer will be as follows:

$$M = \int_0^t (Q_{x_{\text{ex}}} - Q_{x_{\text{bmx}}}) dt \quad (4)$$

where are:

M - total mass of components;

t - the time interval for loading all components;

$Q_{x_{\text{ex}}}$ - the flow of the components of the mixture upon leaving the storage bin;

$Q_{x_{\text{bmx}}}$ - the flow of the components of the mixture as it leaves the feeder.

The ratio of the total mass of M components to the entire working volume of mixer V is as follows:

$$\frac{M}{V} = \Delta x = \frac{Q}{V} \int_0^t (x_{ex} - x_{enx}) dt, \quad (5)$$

where are:

M - is the total mass of the components;

t - is the time interval for loading all components;

x_{ex} , x_{enx} , x - respectively, the content of the components at the inlet, outlet and inside the mixer;

Q - the capacity of the mixer under steady operating conditions.

Among the main performance indicators of a small-sized technological set of equipment for the preparation of a building mixture, it is worth mentioning the power costs.

The power costs for the operation of a technological equipment set intended for the preparation of fiber-concrete mixtures consist of the sum of the power costs of the individual types of equipment that are included in the kit (Figure 1, c): the machine-tool of the fiber, the base machine (concrete mixer), feeders and dispensers. Thus, the dependence for determining the power of the technological set of equipment has the form [7]

$$N_{TKO} = N_{\delta.m} + N_p + N_{II} + N_o, \quad (6)$$

where are:

N_{TKO} – Total costs of power for the operation of the technological set of equipment, kW;

$N_{\delta.m}$ – power costs of the base machine, kW;

N_p – power consumption of a fiber cutter, kW;

N_{II} – power consumption of feeders, kW;

N_o – power consumption of dispensers, kW.

Taking into account the design features of the base machine of the three-shaft concrete mixer (Figure 1), when working on dry building mixtures, N_{TKO} should be defined as for a three-shaft mixer $N_{\delta.m}$, taking into account the operation of the machine on dry building mixtures

$$N_{\delta.m} = \frac{N_1 + N_2 + N_3}{1000 \cdot \eta}, \quad (7)$$

where are:

N_1 – the power used to mix the components of the mixture with the upper shaft;

N_2 – the power used to mix the components of the concrete mix and transport it to the discharge port by the middle shaft;

N_3 – the power used to mix the components of the mixture by the lower shaft;

η – the efficiency of the mixer drive.

$$N_1 = N_1' + N_1'', \quad (8)$$

where are:

N_1' – the power expended on the mixing process in the first zone,

N_1'' – power costs for the mixing process in the second zone

$$N_1' = \omega \cdot F_a \cdot C_1 \cdot f \cdot (R^2 - r^2) \cdot Z_{I.a}^1 \cdot \kappa_3^e \cdot \rho_1, \quad (9)$$

where ω – angular velocity of the shaft, s^{-1} ;

F_a – Blade area, m^2 ;

C_1 – coefficient of resistance to movement of particles of dry concrete mixture along the blades in the first zone, $C_1 = 9$;

f – coefficient of friction of the dry mixture over the surface of the blades, $f = 0,4$;

R – outer radius of rotation of the blade, m;

r – internal radius of rotation of the blade, m;

$Z_{I.a}^1$ – number of blades on the upper shaft in the first zone;

κ_{38} – load factor of the concrete mixer relative to the upper shaft;

ρ_1 – average density of dry mix, kg / m^3 .

$$N_1'' = \omega \cdot F_a \cdot C_2 \cdot f' \cdot (R^2 - r^2) \cdot Z_{II.a}^1 \cdot \kappa_3^e \cdot \rho_2, \quad (10)$$

where are:

C_2 – Coefficient of resistance to movement of particles of the dry mixture along the blades in the second zone, $C_2 = 7$;

f' – coefficient of friction of the mixture along the blade surface, $f' = 0,1..0,2$;

$Z_{II.a}^1$ – number of blades on the upper shaft in the first zone.

After the transformations, the dependence for determining the power costs by the upper shaft of the mixer has the form

$$N_1 = \left[(\omega \cdot F_a \cdot \rho \cdot (R^2 - r^2) \cdot \kappa_3) \right] \cdot C_1 \cdot f \cdot Z_{I.a} + C_2 \cdot f' \cdot Z_{I.a}', \quad (11)$$

The power expended on mixing the components of a concrete mix and its transportation to the discharge port by an average shaft

$$N_3 = N_2' + N_2'', \quad (12)$$

where are:

N_2' – the power expended on the process of mixing the components of the dry construction mixture in the first zone on the process of mixing the components of the mixture and transporting it to the second zone;

N_2'' – power expended in the second zone of the mixer.

$$N_2' = m_c \cdot g \cdot W \cdot \omega \cdot R_{uu}, \quad (13)$$

where are:

m_c – mass of the components of the mixture in the auger zone, kg;

W – Drag coefficient (when the body moves in hostile environments $W = 4$);

ω – Angular speed of rotation of the shaft, s;

R_{uu} – Radius of screw, m;

g – acceleration of gravity

$$N_2'' = \omega \cdot F_a \cdot C_2 \cdot f' \cdot (R^2 - r^2) \cdot Z_{II.a}^1 \cdot \kappa_3^{ep} \cdot \rho_2, \quad (14)$$

where is:

$Z_{II.a}^1$ – number of blades on the middle shaft in the second zone.

The power required to mix the components of the mixture with the lower shaft

$$N_3 = N_3' + N_3'', \quad (15)$$

where are:

N_3' – power expended on the process of mixing in the first zone;

N_3'' – the power expended on the mixing process in the second zone of the mixer;

N_3' и N_3'' – are determined by analogy with the upper shaft.

For a gravity-forced-action mixer [5] $N_{б.м.}$, spent on the process of preparing a dry construction mix, consists of the power required to rotate the mixer body and the power required to rotate the blade shaft

$$N_{б.м.} = N_K + N_B, \text{ кВт},$$

where is:

N_K – power required to rotate the body of the mixer,

$$N_K = N_K^{(1)} + N_K^{(2)} = \frac{0,85 \cdot G_{см} \cdot h \cdot Z \cdot \omega_K}{\eta_K \cdot 1000} + \frac{F_{мп.к} \cdot V_{абс.к} \cdot z_1}{\eta_K \cdot 1000}, \quad (16)$$

where are:

$G_{см}$ – weight of the components of the mixture, H;

h – vertical coordinate of mass mixture displacement in the body, m;

Z – number of mixes circulating in the body of the machine;

ω_K – angular speed of rotation of the mixer body, s^{-1} ;

η_K – efficiency of the housing drive;

$F_{мп.к}$ – the frictional force arising when the particles of the mixture move along the surface of the blade of the mixer body, H;

$V_{абс.к}$ – absolute velocity of the mixture particles along the body blades, m / s ;

z_1 – number of blades on the inner surface of the body.

The power required to operate the paddle shaft during mixing of the components of the mixture,

$$N_B = N_B^{(1)} + N_B^{(2)} = \frac{\omega_б \cdot M_б}{\eta_б \cdot 1000} + \frac{F_{мп.б} \cdot V_{абс.б} \cdot z_2}{1000 \cdot \eta_б}, \quad (17)$$

where are:

$\omega_б$ – angular speed of rotation of the mixer's blade shaft, s^{-1} ;

$M_б$ – torque of the blade shaft, H·m;

$\eta_б$ – efficiency of shaft drive;

$F_{мп.б}$ – the friction force that occurs when a particle of a concrete mix moves along the blade surface, H;

$V_{абс.б}$ – absolute velocity of the mixture particle along the shaft blade, m / s;

z_2 – number of blades on the shaft.

When installing a two-rotor turbulent mixer

$$N_{б.м} = \omega_{п.о} \cdot F_л \cdot q_{см} \cdot f \cdot (R - r) \cdot \cos \beta \cdot Z_л \cdot \kappa_3 \cdot \rho_1, \quad (18)$$

where are:

$\omega_{п.о}$ – angular speed of rotation of the mixer's blade shaft, s^{-1} ;

$F_л$ – the area of the blade, m^2 ;

$q_{см}$ – pressure on the blade on the mixture side, Pa;

$f = 0,4$;

R – outer radius of blade rotation, m;

r – internal radius of blade rotation, m;

$Z_л$ – number of blades on the upper shaft in the first zone;

κ_3 – load factor of the concrete mixer;

ρ_1 – average density of dry mix, kg / m^3 ;

β – blade angle.

Thus, the proposed technological kits of small-sized equipment can be successfully used to work directly on the construction site.

3.CONCLUSION

1. Technological sets of small-sized equipment of a new configuration and a new design solution are proposed to perform small volumes of work in the conditions of a construction site.

2. Dependencies are given allowing to determine the performance indicators of new technological equipment sets for the preparation of dry building mixtures in the construction site.

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