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Technological Package of the Small-Sized Equipment for Preparation of Products from Polystyrene-Concrete Mixture

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Abstract. The design of the small-sized equipment package is presented, where the base machine was a gravity-forced mixer for the preparation of high-quality polystyrene-concrete mixture with the addition of fiber elements and its further use in production. All equipment included in the package works with the same production when combining operations over time. The design of the basic machine - the mixer working in the cascade mode is resulted. Dependencies to determine the main performance of machines (production, power), which show their relationship to each other are also given.

FORMULATION OF THE PROBLEM

Products made of polystyrene-concrete mixture are used in the construction of low-rise buildings, or houses of non-standard shape in the modern world. The mixture is used to make both individual blocks and entire sections of the house in the form of insulation. Most often, these are large machines that operate in the enterprise, and then the finished mixture or blocks are transported to the construction site. This creates inconvenience in the time between operations, thereby reducing the production of construction work.

Therefore, it is necessary to create a technological package of equipment that will work at the same pace, thus not reducing the quality of the finished mixture and polystyrene concrete product. Creating a technological package of equipment will reduce machine downtime, increase line production, and most importantly - get quality products.

ANALYSIS OF EXISTING DESIGNS OF MIXERS AND PACKAGES FOR THE PRODUCTION AND PREPARATION OF POLYSTYRENE CONCRETE BLOCKS

Analyzing the types of mixers for the preparation of polystyrene-concrete mixtures [1-6], we can conclude that the main and most common are gravity or forced mixers (one-shaft or two-shaft) [7-8].

The simplest option for the preparation of the mixture is a gravity cyclic concrete mixer of a typical design, which is used for the preparation of the mobile concrete mixtures.

The forced-action mixer is an RSG-1000 installation – a hermetic horizontal-type mixer designed for preparation and transportation of the foam concrete, polystyrene-concrete mixture of different density to the place of pouring [9].

The mixing mechanism of installation consists of two differently directed screws that provides high-quality mixing of components and homogeneity of mix.

The design of the mixer allows to refuse use of additional pumps for transportation of the mix. The supply of the mixture to the place of pouring is due to overpressure in the mixer created by the compressor. The mixer has a safety valve, which allows you to adjust the overpressure when unloading the mixture. The mixture can be transported at a distance of up to 20-30 m horizontally and up to 5-6 m vertically.

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The semi-automatic high-performance foam generator of installation allows to receive uniformly porous foam mix with a possibility of adjustment of the density.

The control panel mounted on the mixer case gives the chance to operate all functions of the installation to one operator. The installation can be installed in production complexes with an automated control system.

Technological complexes for the manufacture of products from polystyrene-concrete mix are different depending on the configuration of the base machine, line production and type of product.

Conveyor type complexes are maximally automated [10]. Involvement of manual labor is practically not required. This complex has a high cost and maximum production. Products made on such equipment will have accurate geometric dimensions, high quality, due to the exact dosage of components and adherence to technology.

The complex consists of hoppers for storage of components of mix, the mixer for preparation of polystyrene concrete, the manual vibropress, the crusher for crushing of polyfoam.

Thanks to the above technologies, it is possible to make blocks and bricks from polystyrene concrete [11]. An example of the use of polystyrene concrete are domed houses from SunHouse (Fig. 1) [12].

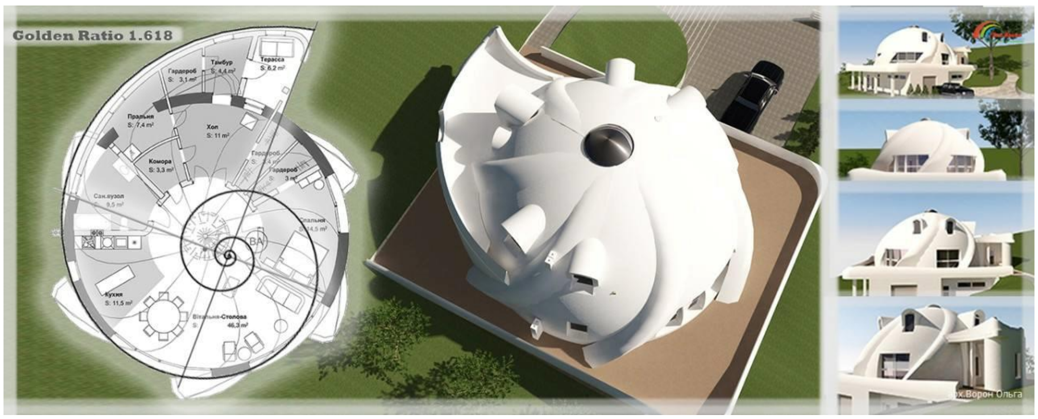

FIGURE 1. Dome house made of polystyrene concrete

The frame of the building is built using a unique formwork made of multilayer fiberglass. The structures can be of three diameters - 4,7 m and 9 m. The finished mixture is transported to the formwork by means of a concrete pumping station. The design of the frame is not used reinforcement. The walls are smooth and do not require additional leveling of the surface after removing the formwork.

DESCRIPTION OF THE SMALL-SIZED EQUIPMENT PACKAGE FOR THE PREPARATION OF BLOCKS OF POLYSTYRENE-CONCRETE MIXTURES

There are designs of the small-sized equipment that works as part of a technological package, with the same production. They are used for preparation of concrete mixes, and then for transportation of mix or carrying out shotcrete works. Such packages are mobile, compact and organized automatic work [13 - 15].

After the analysis of the existing equipment and technological lines of production of products from polystyrene-concrete the technological package of the small-sized equipment (fig. 2) is offered [16]. Thanks to this package it is possible to make high-quality polystyrene-concrete mix with addition of fiber elements. The presence of a cutter for grinding fiber allows you to get a homogeneous mixture and thus increase the strength of the products.

The package of equipment consists of a basic machine - a forced mixer, a cutter for fiber, a belt feeder for feeding the components of the mixture, an auger feeder for transporting the finished mixture. All equipment is mounted on one frame and works at the same pace (depending on the performance of the mixer), which reduces the time to feed the components of the mixture.

The package of equipment works as follows. The components of the mixture are stored in the hopper 5 and then on the tape feeder 4 are transported to the loading hole of the mixer 1. The fibers are cut with a fiber cutter 3 and placed in equal portions on the tape feeder 4 at this time. The finished polystyrene-concrete mixture is unloaded from the mixer 1 to the receiving hopper of the motor 8 and then transported to the place of formation of products.

Analyzing the existing designs of mixers used for the preparation of polystyrene-concrete mixtures, it should be noted:

- the complexity of the design of concrete mixers;

- uncertainty in the possibility of obtaining homogeneous mixtures; - adhesion of the mixture to the surface of the mixer;

- a long time of the process of preparation of the mixture.

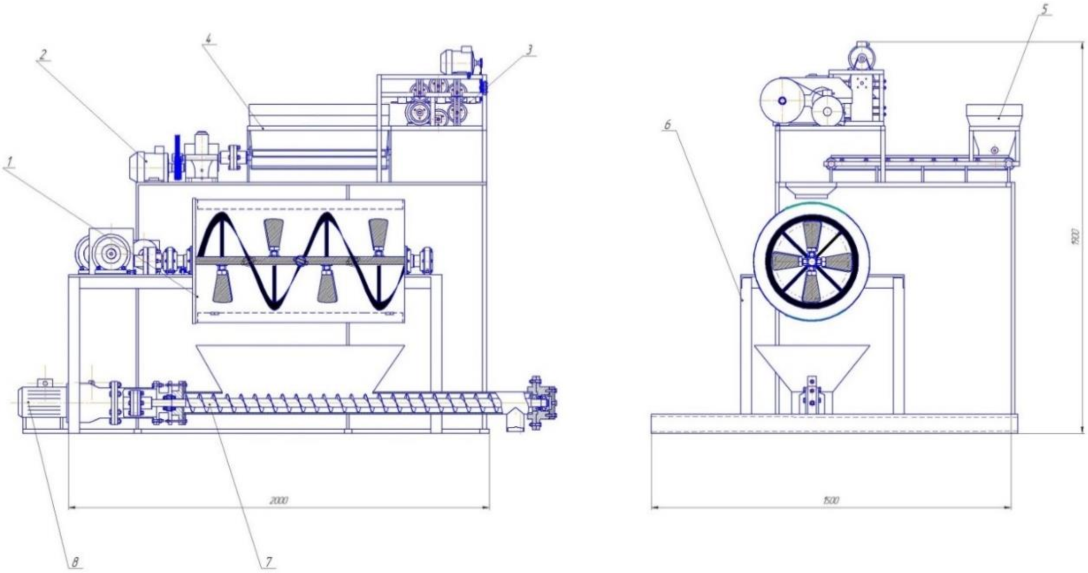

FIGURE 2. A package of equipment for the preparation of polystyrene-concrete mixture 1 - gravity-forced mixer; 2 - motor of the tape feeder; 3 - a cutter for fiber; 4 - tape feeder; 5 - hopper for components; 6 - frame; 7 - auger feeder; 8 - motor of the auger feeder

Given these shortcomings of existing machines, it is proposed to use a gravity-forced concrete mixer (operating in cascade mode) for the preparation of such mixtures.

The known design of the gravity-forced concrete mixer was used for preparation of low workability and low-slump concrete mixes, passed approbation in the conditions of the company.

A new design solution of such a mixer, which in terms of parameters will conform the conditions for the preparation of polystyrene-concrete mixtures with fiber elements is presented in Figure 3.

Gravity-forced mixer consists of a cylindrical shell. A horizontal tape-blade shaft, the blades of which are fixed to it along a helical line, is located in the middle of the shell. The mixer shell and the tape-blade shaft rotate in opposite directions.

The design of the mixer allows to prepare polystyrene-concrete mix by means of rotation of a tape-blade shaft. During the operation of the tape-blade shaft, additional rotation of the mixer shell is created in the opposite direction when using a fine aggregate (sand) for the preparation of polystyrene-concrete mixture. Also, when the volumetric coefficient kf is more than 0.5, it is recommended to use the simultaneous rotation of both the tape-blade shaft and the mixer shell.

The principle of operation of the machine is as follows: from the motor 6 through the connecting box 12 torque is transmitted to the reducer 8. In turn, from the reducer shaft 8 through the connecting box 10 begins to rotate the horizontal shaft 1 with fixed blades 5.

From the motor 7 through the V-belt transmission 13 torque is transmitted to the reducer 9. Next, the torque from the reducer shaft 9 through the connecting box 11 rotates the concrete mixer shell 2 by means of a chain transmission consisting of a sprocket 14 and a chain 15 fixed on the outer surface of the shell 2.

To the shell of the concrete mixer 2 are attached covers 3, which cover the loading and unloading hole of the machine and, if necessary, open or close.

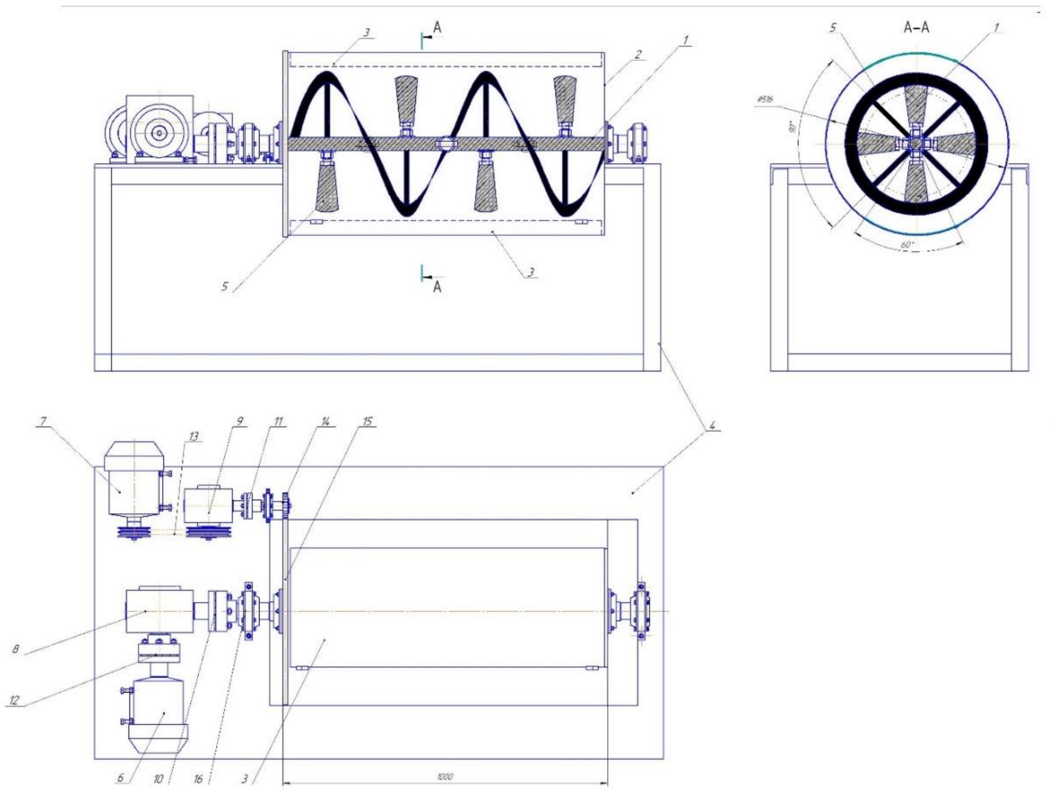

FIGURE 3. Basic diagram of the gravity-forced mixer 1 - auger shaft; 2 - shell; 3 - cover; 4 - frame; 5 - the blade of the shell; 6, 7 - electric motor; 8, 9 - worm reducer; 10,11,12 - connecting box; 13 - V-belt transmission; 14 - sprocket of chain transmission; 15 - chain; 16 - roller carriage

CALCULATION OF BASIC PARAMETERS FOR A PACKAGE OF EQUIPMENT

To determine the main parameters of the equipment, a method of their calculation is proposed. These parameters are the production and power expended on the process of preparation of the polystyrene-concrete mixture.

Determination of technical productivity of the mixer is carried out taking into account design parameters of the machine and features of working process:

$$P_t = V_{tot} \cdot K_f \cdot Z_c \cdot \rho_0, t/hour \quad (1)$$

where V_{tot} – the total volume of the mixture in the mixer shell, m^3; K_f – volumetric coefficient of the mixer; $Z_c = 3600/t_c$ – number of machine cycles by hour; $t_c = t_1 + t_2 + t_3$ – duration of one cycle, which consists of time for loading of components t_1, their mixing t_2 and unloading of the ready mix t_3, s; ρ_0 – is the average density of the mixture, t/m^3.

The total volume of the mixture in the mixer shell, can be determined by the formula:

$$V_{tot} = V_s - V_{sh} - V_b - V_{bl} - V_a - V_r, m^3. \quad (2)$$

Total volume of the shell:

$$V_s = \frac{1}{2} \cdot \pi \cdot R_{s.in}^2 \cdot L_s, m^3,$$

where $R_{s.in}$– internal radius of the shell at the mixer, m; L_s – the length of the shell, m.

The total volume of the shaft, $V_{sh} = \frac{1}{2} \cdot \pi \cdot r_{sh}^2 \cdot L_{sh}, m^3$, where r_{sh} – is the radius of the shaft, m; L_{sh} – shaft length, m.

The total volume bases of blades, $V_b = \frac{1}{2} \cdot \pi \cdot r_{b.in}^2 \cdot z_b \cdot C_b, m^3$, where $r_{b.in}$ – the inner radius of the base, m, m ; z_b – number of bases; C_b– base thickness, m .

Total volume of blades:, $V_{bl} = \frac{1}{2} \cdot z_{bl} \cdot b_{bl} \cdot h_{bl} \cdot C_{bl}, m^3$, where z_{bl} – is the number of blades; b_{bl} – width of a blade, m; h_{bl} – blade height, m; C_{bl} – thickness of a blade, m.

The total volume of the auger: $V_a = \frac{1}{2} \cdot \pi \cdot (L_a - l_a) \cdot (R_a^2 - r_a^2) \cdot C_a, m^3$, where L_a, l_a – the length of the auger in the expanded form of the inner and outer diameters $L_a = \sqrt{S^2 + (\pi + D_a)^2}, l_a = \sqrt{S^2 + (\pi + r_a)^2}, m$; R_a, r_a– external and internal radii of the auger, m; C_a – auger thickness, m.

The total amount of racks for mounting auger as: $V_r = \frac{1}{2} \cdot \pi \cdot R_r^2 \cdot z_r \cdot C_r, m^3$, where R_r – inner radius racks m; z_r, C_r – the number and thickness of the auger rack, m

The power of the mixer expended in the process of preparation of the mixture consists of: power expended to create torque; power expended to overcome the friction forces arising from the interaction of the mass of the concrete mixture with the blade shaft and the auger belt; the power expended to move the mixture in the axial direction; power expended to overcome the friction forces arising from the interaction of the mixture with the auger part of the shaft:

$$N_{p.m} = \begin{pmatrix} \omega_{sh} \cdot M_{bl.sh} + F_{fr} \cdot V_{abs.sh} \cdot z_{bl} + \\ + \frac{c \cdot \rho_0 \cdot s_{mid} \cdot \omega_{sh}^3 \cdot k_f \cdot z_a (D_{a.out}^2 - D_{a.in}^2)}{32 \cdot \pi^2 \cdot k_m} + k_f \cdot \omega_{sh} \cdot M_a \end{pmatrix} \cdot \frac{1}{1000 \cdot \eta_{sh} \cdot \eta_a}, \quad (3)$$

where ω_{sh} – angular speed of rotation of the blade shaft, sec-1; $M_{bl.sh}$– blade shaft torque, $M_{bl.sh} = P_{bl.m} \cdot R_{bl.sh} \cdot z_{bl}$, N·m; $P_{bl.m}$ – the force arising from the action of the mixture on the shaft blade, $P_{bl.m} = q \cdot b_{bl} \cdot h_{bl} \cdot c_{bl} \cdot \cos\beta \cdot R_{bl.sh.mid}$, N; q – the pressure of the mixture on the blade of the shaft, $q = C_0 \cdot \rho_0 \cdot V_{sh}^2$, P; V_{sh} – circular speed of the shaft, $V_{sh} = \omega_{sh} \cdot R_{sh}$, m/sec; where C_0 – the coefficient of resistance of the blade when interacting with the mixture; α_{sh} – the rise angle of the mixture, from which the mixture begins to climb from the shaft blade; $R_{bl.sh.mid}$ – the average radius of the blade shaft, $R_{bl.sh.mid} \frac{R_{bl.sh} + r_{bl.sh}}{2}$, m; F_{fr}– - the force of friction that occurs during the movement of mixture particles on the surface of the blade, $F_{fr} = G_m \cdot \frac{1}{3} \cdot (f_1 \cdot \cos\varphi_{sh} + \sin\varphi_{sh})$, N; G_m– gravity of the mixture, $G_m = V_{tot} \cdot \rho_0 \cdot g$, N; g – acceleration of gravity, m/sec2; f_1 – the friction coefficient of the mixture on the surface of the blade; z_{bl} – the number of blades on the shaft; η_{sh} – the efficiency of the drive shaft; $V_{abs.sh}$ – the absolute velocity of mixture particles on the shaft blades, $V_{abs.sh}, V_{abs.sh} = \omega_{sh} \cdot R_{sh} \cdot \sqrt{1 - \frac{R_{sh.in}}{R_{sh.out}}}$ m/sec; c – the resistance coefficient of the blade in the process of mixing the mixture in the direction of its movement in a circle; $S_{mid.a}$ – the pitch of the auger on its average diameter, $S_{mid.a} = \pi \cdot D_{mid.a} \cdot tg\alpha_{mid.a}$; $D_{mid.a}$ – the average diameter of the auger, $D_{mid.a} = 0.5 \cdot (D_a + d_a)$, m; $\alpha_{mid.a}$ – angle of climb spiral auger in average diameter, $\alpha_{mid.a} \approx arctg \frac{k_1 \cdot s}{D_{a.out}}$; k1 – coefficient equal to k1=0.4…0.45; S – step spiral auger; $S = E \cdot D_a$, m; E – the ratio of the auger pitch to the diameter of the auger; z_a– the number of the auger turns; k_m – the return ratio of the mixture; M_a – the moment of friction forces of the concrete mixture on the surface of the auger is determined by the following dependence, N·m.

$$M_a = \frac{\pi \cdot c \cdot s_{mid} \cdot \omega_{sh}^2 \cdot f_1 \cdot z_a \cdot tg\alpha_{mid.a} \cdot \sin\alpha_{mid.a} (D_{a.out}^5 - D_{a.in}^5)}{80 \cdot k_m}. \quad (4)$$

The design of the mixer offers the use of a rotating shell, which allows you to load a larger volume of components and make low-slump mixtures.

Therefore, the power required to rotate the faucet shell can be defined as:

$$N_s = \frac{0.85 \cdot G_m \cdot h \cdot Z \cdot \omega_s \cdot f_{fr.}}{\eta_s \cdot 1000}, \quad (5)$$

where G_m – the weight of the concrete mixture that rises under the action of friction forces, $G_m = V_{tot} \cdot \rho_0 \cdot g$; h – the coordinate of the vertical displacement (shift) of the mass of the mixture in the shell; Z – the number of circulations of the mixture in the shell of the machine; ω_s – angular speed of rotation of the mixer shell; $f_{fr.}$ – the friction coefficient of the mixture on the surface of the shell; η_s – efficiency of the shell drive.

CONCLUSIONS

- The analysis of the existing equipment and technological packages of the equipment is carried out.
- The technological package of small-sized equipment for preparation of polystyrene-concrete mix with fibers is offered. The design features of the mixer, which works in cascade mode, are revealed.
- Dependences for determination of production and power of components of a technological package of the equipment are resulted.

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