Proizvodnja proizvoljnih cilindričnih i sferičnih omotača od armiranog betona korišćenjem hidrauličke opreme nove generacije

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Za izradu armirano-betonskih omotača, predlaže se upotreba samonosivog skeleta koji se sastoji od prostorno zakrivljenog skeleta i nevaljivih košuljica za oblaganje, napravljenih od polistirena ili mineralne vune, koji služe kao stalna oplata. Prikazani su šematski dijagrami univerzalne pumpe za beton bez klipnog sistema i kamionskog miksera gravitaciono-prinudne akcije sa hidrauličnom kontrolom. Date su tehnološke šeme rada. Dobijene su zavisnosti za određivanje dometa i visine snabdevanja betonskom mešavinom pumpom za beton bez klipnog sistema.

Ključne reči: Armirano betonska oplata, univerzalna pumpa za beton, troosovinska betonska mešalica, kamionska mešalica, mokar mlazni beton, mlaznica za mokar beton

1. UVODNA RAZMATRANJA

Iskustvo u višekratnoj upotrebi pokazalo je na gradilištima različitih namena, da tehnološki setovi malih univerzalnih uređaja, koji uključuju nove mašine koje su patentirane u Ukrajini, rade efikasno. To su, pre svega, pumpe od betona različitih konstrukcionih rešenja, mešalice za beton koje rade u kaskadnom režimu i prstenastim mlaznicama za prskani beton [1, 2].

Značajno je koristiti takve komplete za slobodno betoniranje direktno na gradilištu. Za proizvodnju armirano-betonskih oplata, predlaže se upotreba samonosivog kostura, uključujući prostorno ukršteni skelet i nevaljive košuljice za oblaganje od polistirena ili mineralne vune (unutrašnja neuklonljiva oplata) koja formira unapred određenu geometriju konstrukcije i predstavlja površinu za obostrano mokro prskanje betonske smeše sa sintetičkim vlaknima [3].

Zbog upotrebe prostornog dizajna armaturnog kaveza, koji se sastoji od spoljnih ljsaka i sistema ravnih rebara koji ih povezuju, obezbeđena je potrebna krutost i nosivost okvira za nanošenje premaza mlaznog betona.

Proizvodnja armiranobetonskih oplata (Slika 1) je izvršena u uslovima deponije sa sledećim setom opreme: pokretna kompresorska jedinica → dvoklipna pumpa sa pumpnim ventilima → gravitaciona mešalica za beton → mlaznica sa prstenastim mlaznicama → gumena creva $d_1 = 50$ mm i $d_2 = 32$ mm.

Crevo prečnika 32 mm je korišćeno za dovod dodatnog protoka komprimovanog vazduha u prstenastoj mlaznici pištolja za prskanje.

Oplate se izrađuju sa pokretljivošću mešavine $P = 6 \dots 8$ cm i sledećom potrošnjom sastojaka po 1 m³ betona klase C30 ... C35: cement PC 500 - 300 t, drobljena kamena frakcija 5 ... 10 mm - 250 kg, drobljeni kamen frakcija 2 ... 5 mm - 875 kg, pesak - 875 kg, voda - 150 kg,

dodatak "Adminol-Rapid" - 3 kg, bazaltno vlakno dužine elemenata $l_f = 12$ mm ($F\% - 0,1$).

Betoniranje vlažnim mlaznim betonom izvršeno je sa sledećim tehnološkim parametrima: radni pritisak $p = 0,6$ MPa, potrošnja komprimovanog vazduha za dovod betonske mešavine sa mlaznicom $q_1 = 7$ m³/min, dodatno snabdevanje komprimovanim vazduhom kroz prstenastu mlaznicu $q_2 = 2$ m³/min, brzina prskanja mešavine armiranog betona na površinu ljske $V_{abr} = 55 \dots 60$ m/s.

Naknadni testovi pokazali su da su armirano betonski kućišta lagane konstrukcije čija je težina 40 ... 50% manje u odnosu na čvrste konstrukcije, zahvaljujući upotrebi nevaljivih obloga - šuplji izlazi od polistirena, koji imaju sve neophodne karakteristike čvrstoće i krutosti nosivih elemenata zgrada i konstrukcija od monolitnog armiranog betona. Takvi armiranobetonski omotači otvaraju suštinski nove mogućnosti u gotovoj monolitnoj konstrukciji uz upotrebu nove opreme i manje vibracije zaptivanjem smese metodom vlažnog mlaznog betona [4]. Trenutno, pored dokazane opreme u korištenoj tehnologiji, razvijene su nove mašine koje bi trebale poboljšati efikasnost obavljenog posla. To je univerzalna pumpa za beton bez klipova [5] (Slika 2) i kamionska mešalica sa gravitaciono-prinudnim dejstvom (Slika 3).

Univerzalnost ove betonske pumpe osigurana je mogućnošću rada na crevima $d_h = 32 \dots 75$ mm sa širokim rasponom performansi i glatkim promenama radnih uslova zbog korišćenja hidrauličnog pogona. Tehnološka šema slobodnog betoniranja koja koristi univerzalnu pumpu za beton sa troosovinskom mešalicom za beton prikazana je na slici 4. Dužina isporuke betonske smese pri korišćenju tehnološke sheme sa univerzalnom crevnom pumpom za beton (slika 4) određena je prema zavisnostima:

a)

b)

Slika 1: Proces proizvodnje oplata prskanjem prstenastom mlaznicom (a) i gotova armiranobetonska oplata (b)

Slika 2: Šema bez klipne crevne pumpe za beton novog dizajna i sa hidrauličkim pogonom
1 – postolje; 2 – kućište; 3 – poklopac kućišta; 4 – rotor sa valjcima; 5 – fleksibilno crevo; 6 – hidraulički motor;
7 – spojnica; 8 – hidrocilindar; 9 – konični vrh, 10 – hidraulička razvodna jedinica

Slika 3: Šema kamionske mešalice sa hidrauličkim pogonom

1 – samohodna šasija; 2 – hidromotor-reduktor, pogon bubnja; 3 – bubanj; 4 – hidromotor-reduktor, pogonsko vratilo; 5 – osovina miksera; 6 – dodavač; 7 – odvodna jedinica; 8 – rezervoar za vodu; 9 – dodatna jedinica odvodnog ležišta

Slika 4: Tehnološka šema rada sa mokrim betonom na gradilištu

1 – bunker sa peskom; 2 – bunker sa šljunkom; 3 – bunker sa cementom; 4 – rezervoar sa vodom; 5 – trakasti dodavač; 6 – troosovinski mikser; 7 – mašina za rezanje vlakana; 8 – univerzibilna crevna pumpa; 9 – kompresor; 10 – mlaznica; 11 – oplata; 12 – vozila za transport materijala; A – zona rada; B – jedinica za mešanje betona

– horizontalno

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

$$L = \frac{d_{TP} \cdot \Delta p}{\lambda \left(\frac{\rho_0}{2} \right)}, \quad (1)$$

gde su:

d_{TP} – prečnik cevovoda za transport betonske smeše;

Δp – pad pritiska na krajevima cevovoda;

λ – koeficijent otpora kretanju smeše kroz cevovod;

ρ_0 – prosečna gustina smeše koja se transportuje kroz cevovod;

V_{cp} – prosečna brzina kretanja smeše kroz cevovod;

– vertikalno

$$H = \frac{\Delta p \frac{8 \mu L_{TP}}{\pi R_{TP}^4} \left(\Pi_{tex} + \frac{\pi R_{TP}^2 \tau_0}{3 \mu} \right)}{\rho_0 \cdot g}, \quad (2)$$

gde su:

μ – dinamička viskoznost betonske smeše;

R_{TP} – poluprečnik cevovoda;

Π_{tex} – tehničke performanse betonske pumpe;

τ_0 – krajnji napon smicanja;

g – gravitaciono ubrzanje.

Tabela 1 prikazuje odnos parametara betonske mešavine sa performansama univerzalne pumpe za beton i pada pritiska na krajevima transportnog cevovoda. Tehnološka šema slobodnog betoniranja u gradilištu pomoću auto-betonske pumpe sa manipulatorom je prikazana na slici 5.

Upotreba kamionskog miksera gravitaciono-prinudnog dejstva u tehnološkoj šemi sa univerzalnom crevnom pumpom omogućava korišćenje tehnološkog seta za rad, sa pokretnim i neaktivnim betonskim mešavinama.

Tako, dostupnost novih razvijenih mašina u tehnološkim šemama, proširuje mogućnosti tehnoloških kompleta i, u nekim slučajevima, dozvoljava da se one koriste efikasnije od postojeće opreme. Kao prednost predložene nove konstrukcije univerzalne pumpe za beton, je glatko opterećeno radno crevo, što bi trebalo da obezbedi duži radni vek nove mašine u poređenju sa sadašnjim. To će u skladu s tim pozitivno uticati na rad čitavog seta opreme u celini, što se potvrđuje proračunom radnih ciklusa postojeće i predložene pumpe za beton (Slika 2):

$$Z_{II} = \frac{3600 \cdot T \cdot K_H}{T_1 + T_2}, \quad (3)$$

Tabela 1: Parametri za dovođenje betonske smeše sa univerzalnom crevnom pumpom

L (m)	H (m)	Δp		
		$\Pi_{tex} = 5 \text{ m}^3/\text{h}$	$\Pi_{tex} = 10 \text{ m}^3/\text{h}$	$\Pi_{tex} = 15 \text{ m}^3/\text{h}$
5	2,75	1×10^4	$6,4 \times 10^4$	$7,6 \times 10^4$
10	5,49	$8,764 \times 10^5$	$1,797 \times 10^6$	$2,676 \times 10^6$
15	8,25	$1,165 \times 10^6$	$2,375 \times 10^6$	$3,543 \times 10^6$
20	10,99	$1,31 \times 10^6$	$2,663 \times 10^6$	$3,976 \times 10^6$
25	13,75	$1,396 \times 10^6$	$2,837 \times 10^6$	$4,236 \times 10^6$
30	16,49	$1,454 \times 10^6$	$2,952 \times 10^6$	$4,409 \times 10^6$
35	19,24	$1,495 \times 10^6$	$3,035 \times 10^6$	$4,533 \times 10^6$
40	21,99	$1,526 \times 10^6$	$3,097 \times 10^6$	$4,626 \times 10^6$
45	24,74	$1,547 \times 10^6$	$3,145 \times 10^6$	$4,698 \times 10^6$
50	27,49	$1,57 \times 10^6$	$3,183 \times 10^6$	$4,756 \times 10^6$
55	30,24	$1,585 \times 10^6$	$3,215 \times 10^6$	$4,803 \times 10^6$
60	32,99	$1,599 \times 10^6$	$3,241 \times 10^6$	$4,843 \times 10^6$
65	35,74	$1,61 \times 10^6$	$3,263 \times 10^6$	$4,876 \times 10^6$
70	38,49	$1,619 \times 10^6$	$3,282 \times 10^6$	$4,905 \times 10^6$
75	41,24	$1,627 \times 10^6$	$3,299 \times 10^6$	$4,929 \times 10^6$
80	43,99	$1,635 \times 10^6$	$3,313 \times 10^6$	$4,951 \times 10^6$
85	46,73	$1,641 \times 10^6$	$3,326 \times 10^6$	$4,97 \times 10^6$
90	49,48	$1,647 \times 10^6$	$3,337 \times 10^6$	$4,987 \times 10^6$
95	52,23	$1,652 \times 10^6$	$3,348 \times 10^6$	$5,002 \times 10^6$
100	54,98	$1,656 \times 10^6$	$3,353 \times 10^6$	$5,016 \times 10^6$
110	60,48	–	–	$5,04 \times 10^6$
120	65,98	–	–	$5,059 \times 10^6$

gde su:

T – vreme rada crevne pumpe sa hidrauličkim pogonom;

K_H – faktor pouzdanosti rada crevne pumpe (K_{H1} – ponuđen, K_{H2} – radni).

Radni vek nove pumpe za beton je 25% veći od životnog veka u modernim crevima za beton.

2. ZAKLJUČAK

1. Mogućnost izrade čeličnih betonskih oplata cilindričnog i sfernog oblika prikazana je u uslovima gradilišta uz pomoć opreme po metodi vlažnog mlaznog betona.

2. Prikazane su osnovne šeme predloženih hidrauličnih mašina za upotrebu u tehnološkim setovima: kamion-betonska pumpa bez manipulacije sa manipulatorom i kamion-mikser gravitaciono-prinudne akcije.

3. Prikazane su tehnološke šeme rada sa novim mašinama.

4. Navedene su zavisnosti za određivanje dužina isporuke betonske smese pomoću novih tehnoloških sklopova opreme.

5. Utvrđeno je da zavisnosti određuju broj radnih ciklusa procesne opreme. Radni vek nove pumpe za beton i, shodno tome, celog kompleta, je za 25% viši od onog na mašinama koje rade.

Slika 5: Tehnološka šema izvođenja radova mokrim betonom korišćenjem manipulatora

1 – auto mešalica; 2 – auto pumpa za beton; 3 – univerzalna crevna pumpa; 4 – strela miksera; 5 – mlaznica; 6 – oplata

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Shapeless Manufacture of Reinforced Concrete Cylindrical and Spherical Shells with the Help of New Generation Hydraulic Equipment

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For the manufacture of reinforced concrete shells, it is proposed to use a self-supporting skeleton consisting of spatial curvilinear reinforcement skeleton and non-removable liners of hollow-core, made of polystyrene or mineral wool, which serve as a permanent formwork. Schematic diagrams of a non-piston universal concrete pump and a truck mixer of gravitational-forced action with hydraulic control are presented. Technological schemes of work are given. The obtained dependences for the determination of the range and height of the concrete mixture supply by the hoseless piston-type concrete pumps are provided.

Keywords: Reinforced concrete shell, Universal hose concrete pump, Three-shaft concrete mixer, Truck mixer, Wet shotcrete, Shotcrete nozzle

1. INTRODUCTION

As the experience of reusable use has shown at construction sites of different purposes, technological sets of small-sized universal equipment that include new machines patented in Ukraine operate effectively. These are, first of all, mortar-concrete pumps of various design solutions, concrete mixers operating in a cascade mode and shotcrete nozzles with annular nozzles [1, 2].

It is of interest to use such kits for formless concreting directly on the construction site. For the manufacture of reinforced concrete shells, it is proposed to use a self-supporting skeleton, including a spatial curvilinear reinforcing skeleton and non-extractable liner-void-formers made of polystyrene or mineral wool (inner non-removable formwork) that form the predetermined geometry of the structure and are a screen for spraying on both sides of the wet concrete spraying of concrete mixture with synthetic fibers [3].

Due to the use of the spatial design of the reinforcing cage, consisting of the outer shells and the system of flat ribs connecting them, the necessary stiffness and load-carrying capacity of the frame for applying the shotcrete-concrete coating is provided.

Manufacture of reinforced concrete shells (Figure 1) was performed in the landfill conditions using the following equipment set: mobile compressor unit → two-piston mortar pump with poppet valves → gravity concrete mixer → shot-nozzle with ring nozzle → rubber hoses $d_1 = 50$ mm and $d_2 = 32$ mm.

Hose in diameter 32 mm was used to feed additional compressed air flow in the annular nozzle of gunning nozzle.

Shells are made with the mobility of the mixture $P = 6 \dots 8$ cm and the following consumption of constituents per 1 m³ of concrete of class C30 ... C35: cement PC 500 – 300 t, crushed stone fraction 5 ... 10 mm – 250 kg, crushed stone fraction 2 ... 5 mm – 875 kg, sand – 875 kg, water –

150 kg, supplement "Adminol-Rapid" – 3 kg, basalt fiber with the length of the elements $l_f = 12$ mm ($F\% = 0.1$).

Concreting by the wet shotcrete was carried out with the following technological parameters: working pressure $p = 0,6$ MPa, compressed air consumption for supply of concrete mix with a nozzle $q_1 = 7$ m³/min, additional supply of compressed air through the ring nozzle $q_2 = 2$ m³/min, spraying speed of fiber-reinforced concrete mixture on the shotcrete surface of the shell $V_{abr} = 55 \dots 60$ m/s.

Subsequent tests showed that reinforced concrete casings of lightweight construction, whose weight is 40 ... 50 % less compared to solid structures, due to the use of non-extractable liners – polystyrene concrete hollow-outers, which have all the necessary characteristics of strength and rigidity of load-bearing elements of buildings and structures from monolithic reinforced concrete.

Such reinforced concrete casings open up fundamentally new opportunities in the off-the-shelf monolithic construction with the use of new equipment and vibration less sealing of the mixture by the wet-shotcrete method [4].

Currently, in addition to proven equipment in the technology used, new machines have been developed that should improve the efficiency of the work performed. It is a universal non-piston hose concrete pump [5] (Figure 2) and a truck mixer of gravitational-forced action (Figure 3).

The universality of this concrete pump is ensured by the ability to work on hoses $d_h = 32 \dots 75$ mm with a wide range of performance and smoothly changing operating conditions due to the use of a hydraulic drive. The technological scheme of the formless concreteless using a universal hose concrete pump with a three-shaft concrete mixer is shown in Figure 4.

The delivery distance of the concrete mix when using the technological scheme with a universal hose concrete pump (Figure 4) is determined according to the dependencies:

a)

b)

Figure 1: The process of wet gunned shells with a working nozzle with a ring nozzle (a) and a finished reinforced concrete shell (b)

Figure 2: Scheme of a non-piston universal hose concrete pump of a new design with a hydraulic drive
1 – frame; 2 – pump housing; 3 – the cover of the case; 4 – rotor with rollers; 5 – flexible hose; 6 – the hydraulic motor;
7 – coupling; 8 – the hydrocylinder; 9 – conical tip, 10 – hydraulic distribution unit

Figure 3: Scheme of a truck mixer with hydraulic drive

1 – self-propelled chassis; 2 – hydromotor-reducer, drive of the drum; 3 – the drum; 4 – hydromotor-reducer, shaft drive; 5 – mixing shaft; 6 – feed hopper; 7 – the discharge tray; 8 – a tank with water; 9 – additional section of the discharge tray

Figure 4: Technological scheme of works by the wet shotcrete method directly on the construction site

1 – bunker with sand; 2 – bunker with rubble; 3 – bunker with cement; 4 – water tank; 5 – belt feeder; 6 – three-shaft concrete mixer; 7 – a machine-cutter of a fiber; 8 – universal hose concrete pump; 9 – the compressor; 10 – shotcrete nozzle; 11 – shotcrete shells; 12 – truck for transportation of materials; A – the area of shotcrete works; B – concrete mixing unit

– horizontally

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].

$$L = \frac{d_{TP} \Delta p}{\lambda \left(\rho_0 \frac{V_{CP}^2}{2} \right)}, \quad (1)$$

where are:

d_{TP} – is the diameter of the pipeline through which the concrete mixture is transported;

Δp – pressure drop at the ends of the pipeline;

λ – coefficient of resistance to movement of the concrete mixture through the pipeline;

ρ_0 – the average density of the mixture that is transported through the pipeline;

V_{CP} – average speed of transportation of a concrete mix through the pipeline;

– vertically

$$H = \frac{\Delta p \frac{8\mu L_{TP}}{\pi R_{TP}^4} \left(\Pi_{TEX} + \frac{\pi R_{TP}^3 \tau_0}{3\mu} \right)}{\rho_0 g}, \quad (2)$$

where are:

μ – is the dynamic viscosity of the concrete mixture;

R_{TP} – radius of the pipeline;

Π_{TEX} – technical performance of a concrete pump;

τ_0 – is the ultimate shear stress;

g – acceleration of gravity.

Table 1 shows the relationship of the parameters of the concrete mix with the performance of the universal hose concrete pump and the pressure drop at the ends of the transport pipeline. Technological scheme of the formless concreting in the construction site using an auto concrete pump with a manipulator is shown in Figure 5.

The use of the truck mixer of gravity-forced action in the technological scheme with a universal hose auto concrete pump allows using the technological set for work, both mobile and inactive concrete mixes.

Thus, the availability of newly developed new machines in technological schemes extends the capabilities of technological kits and, in some cases, allows them to be used more efficiently than existing equipment. For the advantageous sides of the proposed new construction of the universal hose concrete pump, the working hose is smoothly loaded, which should ensure a longer working life of the new machine compared to the current ones. This will accordingly positively affect the operation of the entire set of equipment as a whole, which is confirmed by the calculation of the operating cycles of the existing and proposed hose concrete pump (Figure 2):

$$Z_{II} = \frac{3600 \cdot T \cdot K_H}{T_1 + T_2}, \quad (3)$$

Table 1: Parameters for feeding concrete mix with universal hose concrete pump

L (m)	H (m)	Δp		
		$\Pi_{TEX} = 5 \text{ m}^3/\text{h}$	$\Pi_{TEX} = 10 \text{ m}^3/\text{h}$	$\Pi_{TEX} = 15 \text{ m}^3/\text{h}$
5	2,75	1×10^4	$6,4 \times 10^4$	$7,6 \times 10^4$
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40	21,99	$1,526 \times 10^6$	$3,097 \times 10^6$	$4,626 \times 10^6$
45	24,74	$1,547 \times 10^6$	$3,145 \times 10^6$	$4,698 \times 10^6$
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75	41,24	$1,627 \times 10^6$	$3,299 \times 10^6$	$4,929 \times 10^6$
80	43,99	$1,635 \times 10^6$	$3,313 \times 10^6$	$4,951 \times 10^6$
85	46,73	$1,641 \times 10^6$	$3,326 \times 10^6$	$4,97 \times 10^6$
90	49,48	$1,647 \times 10^6$	$3,337 \times 10^6$	$4,987 \times 10^6$
95	52,23	$1,652 \times 10^6$	$3,348 \times 10^6$	$5,002 \times 10^6$
100	54,98	$1,656 \times 10^6$	$3,353 \times 10^6$	$5,016 \times 10^6$
110	60,48	–	–	$5,04 \times 10^6$
120	65,98	–	–	$5,059 \times 10^6$

where are:

T – is the time of non-recyclable work of the hose concrete pump under consideration with hydraulic drive;

K_H – factor of reliability of work of a hose concrete pump (K_{H1} – offered, K_{H2} – operating).

The service life of a new concrete pump is 25% higher than the life of a watch in modern hose concrete pumps.

2. CONCLUSIONS

1. The possibility of manufacturing ferro-concrete shells of cylindrical and spherical shape is shown in the conditions of a construction site with the help of equipment by the wet shotcrete method.

2. The basic schemes of the proposed hydraulic machines for use in technological kits are presented: the truck-concrete pump hose-free with the manipulator and the truck mixer of the gravitational-forced action.

3. Technological schemes of work with new machines are presented.

4. The obtained dependences for the determination of the delivery distance of a concrete mixture with the help of new technological sets of equipment are given.

5. Dependences have been found to determine the number of operating cycles of process equipment. The service life of the new concrete pump, and, consequently, of the whole kit, is 25% higher than that of the operating machines.

Figure 5: Technological scheme of carrying out works by the method of wet shotcrete using a manipulator
 1 – truck mixer; 2 – auto concrete pump; 3 – universal hose concrete pump; 4 – boom of a truck mixer; 5 – shotcrete nozzle; 6 – shotcrete casings

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