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To The Question of the Choice of Technological Equipment For Continuous Shell less Forming Reinforced Concrete Products on a Long Stand

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Abstract: The article discusses modern technological lines for continuous formless molding of reinforced concrete products on a long stand, presents materials on the technical and economic efficiency of this molding method, and also gives recommendations on the most appropriate methods for the conditions of Uzbekistan.

Keywords: concrete, reinforced concrete products, formless formation, wire, rope, hollow core slabs, production efficiency analysis, equipment, production line.

The observed growth in the construction of housing from prefabricated reinforced concrete with load-bearing reinforced concrete walls does not allow to fully load the industrial base for the production of prefabricated reinforced concrete, which remained after the collapse of the USSR and today is represented in Uzbekistan by more than 80 enterprises mainly focused on conveyor, aggregate-flow and cassette technologies. Such technologies do not correspond to the modern level for a number of reasons: significant consumption of cement, low productivity, high energy costs per unit of production, the use of a large amount of side equipment, products produced in this way do not have high quality indicators, etc. [1-7].

At present, more advanced modern technologies have been developed, among which continuous formless molding (extrusion, splitformer, vibroforming) occupies a special place. Methods for continuous formless molding of concrete and reinforced concrete products and structures correspond to the state of the art and demonstrate high competitiveness due to a significant degree of automation of technological processes, low metal consumption of production and the possibility of producing a wide range of products. At the same time, this technology has not yet become the leading one in the construction industry, their wide distribution is hindered by a number of reasons, one of which is ignorance about the advantages and disadvantages of these technologies. At present, the key to the success of the enterprise for the production of concrete products is the production of a wide range of products. Consequently, a modern enterprise, plant, combine needs automated production lines, easily reconfigurable equipment, universal machines, and the use of energy-saving and

energy-efficient technologies [8-12]. In the world, a number of companies produce equipment for continuous formless molding of concrete and reinforced concrete products on a long stand. Each of them positions itself in a special way, and it becomes problematic to make the right choice in favor of one manufacturer. We need objective evaluation criteria for the selection of equipment.

In table. 1 provides general information about the enterprises for the production of equipment for the technology of continuous vibroforming of reinforced concrete products. For comparison and selection of a production line, we will consider and compare what types of compaction of concrete mixtures are specifically oriented by equipment manufacturers.

As shown by the analysis of Table. 1 vibroforming is unrivaled in terms of product range. This method can produce any products of constant cross section. The forming equipment is replaced in 20-30 minutes. This is ten times faster than in a splitformer. Extruders do not allow the production of a wide range of products and are focused only on the production of products that occupy the entire width of the molding track. Beams, piles, crossbars, lintels, poles, trays, etc. cannot be produced by extrusion. In terms of the speed of transition from one product to another, vibroforming outperforms layer-by-layer molding many times over. In a vibroforming machine, it takes several minutes to change the forming tooling, and in a splitformer it takes several hours. For molding products by extrusion, high-grade concretes are used; the mixture must be rigid or especially rigid. As a result of strength gain, the products have significant strength, which in the future, when cutting the products to the required length, the cutting disc, screws and other mechanisms fail faster. Also, for the formation with the help of an extruder, washed and dry inert aggregates should be used: sand with a fraction of 2-5 mm and crushed stone with a fraction of 5-10 mm, most often granite. With an increase in the particle size modulus of crushed stone, it is not uncommon for the aggregate to get stuck in the screws, which leads to the shutdown of the extruder or to its repair.

In terms of the quality of raw materials and materials, vibroforming is the most unpretentious technology. In vibroforming machines, the most common and crushed stone of a fraction of 5-20 mm is used. For comparison, on vibroforming lines, it is allowed to use cheap gravel and even lime crushed stone with a fraction of 5-20 mm for the production of high-quality reinforced concrete products [13].

Table 1 Comparative table for assessing the capabilities of equipment manufacturers for the technology of continuous vibroforming of reinforced concrete products

	Manufacturer or trade mark	**The country**	**Product molding method**	**Reinforcement type**	**Reinforcement reliability**	**Availability of warranty service and repair facilities**	**Performing complex installation work "Full construction"**	**Possibility of reinforcement as below, and at the top of the product**	**Possibility of transverse mesh reinforcement**	**Guarantee period for the whole technology**
1	«CT-	Russia	Vibroformi	wire	high	avail	availabl	availa	avail	2

	МАШИН»		ng in one step			able	e	ble	able	years
2	«Technospan»	Spain	Vibroforming in one step	wire	high	available	not available	not available	not available	1 year
	«Prensoland»					not available			not available	
	«Resimart»					not available			not available	
3	Золотой Дракон	PRC	Vibroforming in one step	ropes	high	not available	not available	not available	not available	-
4	«Echo engineering NV»	Belgium	Two- or three-layer vibroforming with simultaneous longitudinal movement of slipformer punches	Ropes, wire	low	not available	not available	not available	not available	1 year
5	«Weiler»	Germany	Extrusion, 2- or 3-layer vibroforming and tamping	Ropes, wire	low	not available	not available	not available	not available	1 year
6	«Weiler-Italia» (WiTech)	Italy	Two- or three-layer vibroforming and tamping	Ropes, wire ropes	low	not available	not available	not available	not available	1 year
	«Nordimpianti»			ropes						
	«Joint Stosk Company» trademark «Plan S.R.L.»		Extrusion	ropes	low	not available	not available	not available	not available	1 year
7	«PCE Engineering»	Finland	Extrusion	ropes	low	not available	not available	not available	not available	1 year
	«Elematic							not available		
	«X-tec»							not available		

	«TNK-System»							not available		
8	"Ultra Span»	Canada	Extrusion	ropes	low	not available	not available	not available	not available	1 year
9	«Spiroll Precast Services ltd»	Great Britain	Extrusion	ropes	low	not available	not available	not available	not available	1 year
10	«Ricon»	Russia,	Extrusion	ropes	low	not available	not available	not available	not available	1 year
11	«Викон»	Russia,	Extrusion	ropes	low	not available	not available	not available	not available	1 year
12	«Spancrete»	США	tamping	ropes	low	not available	not available	not available	not available	1 year

In terms of equipment reliability and ease of maintenance, it should be recognized that extrusion molding is the best technology for the production of plates, except for the wear of screws and the need for frequent replacement. Therefore, vibroforming should be used most preferably from this position. The last place is occupied by the most complex machines - split formers. They are characterized by the complexity of the mechanical system and require highly skilled maintenance.

At the same time, operating costs when using an extruder are the highest. A set of screws has to be replaced after every 5-8 km of plate forming, i.e. at full load of the plant - monthly. Split formers and vibroforming machines are similar in terms of operating costs, but vibroforming is simpler than layer-by-layer molding in terms of the number of working mechanisms. The operating costs of vibroforming machines are lower than when using mechanically complex split formers.

A significant part of the operating costs is the cost of replacing the cutting discs. When cutting a much harder workpiece, the cutting discs wear out faster. In extrusion, B40 concrete is used, and the products are cut at 90% strength. One disc is enough for 700 - 900 cuts of the plate. Split formers occupy an intermediate position here (B40 concrete is used, products are cut at 70 - 80% strength). Vibroforming actually has a big advantage because the products are molded from B30 concrete and cut at 70 percent strength. One new cutting disc is enough for 1300 - 1800 cuts of the hollow core slab.

It can also be noted that extrusion after layer-by-layer molding with splitformers is living its life, objectively yielding to vibroforming both technically and economically.

Another factor affecting the operating costs and the cost of products is the consumption of cement.

In table. 2 show the results taken from the practice of operating vibroforming machines, extruders and split formers.

Table 2 Consumption of cement when forming floor slabs

Way molding	brand concrete kgf/cm²	emptiness (width slabs 1.2 m)	Average consumption cement M500 D0, kg/m3
extruder	550	40 %	380 – 460
	600	40 %	450 – 500
Splitformer	400	39 %	380 – 480
	550	39 %	430 – 500
Vibroforming	400	40 %	350 – 480

Differences between the consumption of cement in the extruder, split former and vibroformer are not statistically significant. Vibroforming uses more cement, but this is offset by the higher operating costs of extruder or split former molding. Saving cement during extrusion is several times less than the cost of periodically replacing screws. In addition, during extrusion, the costs for cutting discs, applying anti-seismic veneers and installing anchors are twice as high.

For further technical and economic calculations, Table 3 shows the approximate prices of well-known manufacturers of molding machines for each method of forming:

Table №3 the cost of molding machines without formwork molding

Shutterless Forming Machines	Country of origin	Molding method	Reinforcement type	Reinforcement reliability	Price, euro (for November 2021)
СТ-МАШИН	Russia-Spain	Vibroforming	Wire	high	450 thousands
Nordimpianti	Italy	Extrusion	strands	low	620 thousands
Spancrete-Mashinery	USA	Layered molding (splitformer)	strands	low	990 thousands

In table. 4 shows the characteristics of machines and mechanisms of the production workshop for formless production using molding machines for vibroforming and extrusion.

Table 4 Characteristics of the production workshop for the production of reinforced concrete products according to the technology of formworkless molding using vibroforming and extrusion units

Manufactured products	Multi-hollow pre reinforced reinforced concrete slab type PB
Production hall dimensions	Length - 150 m Width - 18 m Height under HAK - 5.5 m
Regulations	O'z DSt 2805-2013 GOST 9561-91
Product brand	PB 60.12-8 Vr1400 S9
Working staff	8 people/shift
Performance	80 plates/shift

Temperature regime in the room	not lower than 10 degrees Celsius
Steam power equipment	Hot water boiler – 500 kW/h
Consumed electricity (general power)	180 kW
The main production equipment of the molding workshop	Concrete mixing unit - 1 pc. Forming machine -1 pc. Cleaning machine - 1 pc. Trolley for laying wire - 1 pc. Installation for a tension - 1 piece. Trolley for protective coating - 1 pc. Hydraulic jack for stress relief - 1 pc. Cutting machine - 1 pc. Overhead crane 10 t. - 2 pcs. Export trolley at SGP 20 t. - 1 PC. Matrix of products (shaper) - 1 pc.
Производственное оборудование арматурного цеха	Гибочный станок - 1 шт. Ножницы механические - 1 шт.

In table. Figures 5 and 6 present the results of calculating the payback of the production shop for formless continuous molding of concrete and reinforced concrete structures.

Table 5 Calculation of the payback of the production workshop with formworkless continuous molding of concrete and reinforced concrete structures

Equipment name (vibroforming)	**Price per one., thousand soums**	**Total cost, thousand soums**	**Name of equipment (extruder)**	**Price per one., thousand soums**	**Total cost, thousand soums**
Concrete mixing unit - 1 pc.	1 602 429,0	1 602 429,0	Concrete mixing unit - 1 pc.	1 602 429,0	1 602 429,0
Forming machine for vibropressing - 1 PC.	5 629 914,0	5 629 914,0	1 x extrusion molding machine	7 756 770,4	7 756 770,4
Cleaning machine - 1 pc.	427 314,4	427 314, 4	Cleaning machine - 1 pc.	427 314,4	427 314,4
Trolley for laying wire - 1 pc.	160 242,9	160 242,9	Trolley for laying wire - 1 pc.	160 242,9	160 242,9
Installation for a tension - 1 piece.	106 828,6	106 828,6	Installation for a tension - 1 piece.	106 828,6	106 828,6
Trolley for protective coating - 1 pc.	32 048,58	32 048,58	Trolley for protective coating - 1 pc.	32 048,58	32 048,58
Hydraulic jack for stress relief - 1 pc.	74 780,02	74 780,02	Hydraulic jack for stress relief - 1 pc.	74 780,02	74 780,02
Cutting machine - 1 pc.	747 800,2	747 800,2	Cutting machine - 1 pc.	747 800,2	747 800,2
Overhead crane 10 tons - 2 pcs.	142 550,8	285 101,6	Overhead crane 10 tons - 2 pcs.	142 550,8	285 101,6
Export trolley for SGP 20 tons - 1 pc.	35 000,0	35 000,0	Export trolley for SGP 20 tons - 1 pc.	35 000,0	35 000,0

Matrix of products (shaper) - 1 pc.	128 194,32	128 194, 32			-
Total		9 229 653, 62			11 228 315,7
Auxiliary equipment of the reinforcement shop					
Bending machine - 1 PC.	213 657,2	213 657,2	Bending machine - 1 PC.	213 657,2	213 657,2
Mechanical scissors - 1 pc.	1 527,0	1 527,0	Mechanical scissors - 1 pc.	1 527,0	1 527,0
Total		215 184,2			215 184,2
Total Equipment Cost		**9 444 837,82**			**11 443 499,90**

Table 6 CALCULATION OF PAYBACK in the production of plates PB 62.12-8 (volume V=0.84 m3, m=2100 kg) by vibroforming and extrusion with concrete grade M400

Name of materials	**measure**	**Consumption rate on the stove**	**Unit price, sum**	**total cost**	**Consumption rate on the stove**	**Unit price, sum**	**total cost**
		Vibroforming			**Extrusion**		
Basic materials							
Wire Ø5 Vr I 400	kg	18,50	12 126	224 331	18,5	12 126	224 331
Cement PC M - 500	kg	352,8	580	204 624	330,5	580	191 690
Sand	m3	0,263	70 000	18 410	0,263	70 000	18 410
rubble 5/10	m3	0,202	57040	11 522	0,202	57040	11 522,1
rubble 10/20	m3	0,605	57040	34 509,2	0,615	57040	35 079,6
Water	l	119	4,42	526,0	119	4,42	526,0
Total Basic Materials	**sum**			**493 922,3**			**481 558,7**
Auxiliary materials							
Black paint	kg	0,0100	15 625,0	156,3	0,01	15 625,0	156,3
Solvent	kg	0,0040	13 392,8	53,6	0,004	13 392,8	53,6
Emulsol / waste oil	kg	0,4	701,0	280,4	0,4	701,0	280,4
soda ash	kg	0,01	7 567,0	75,7	0,01	7 567,0	75,7
lumber	m3	0,001	753 400	753,4	0,001	753 400	753,4
Electricity/Gas	kW	54	450	24 300	72	450	32 400
Total materials (auxiliary)	**sum**			**25 619,4**			**33 719,4**
Labor costs, including:	people per day	**10**	**120 000**	**1200 000**	**10**	**120 000**	**1200000**

Overhead, 200% (from ZP)	sum	30 000	40 000
Cost price for products	**sum**	**564 541,7**	**570 278,1**
Profitability, 15%	sum	84 681,3	85 541,7
Price without VAT	sum	649 223,0	655 819,8
Price with VAT, 15%	sum	746 606,4	754 192,77
Profitability per 1 linear meter of the product	sum	14 113,6	14 257,0
Cost of equipment without VAT	sum	9 444 837 820	11 443 499 900
Payback in soum / linear meter	sum	669 201,2	802 658,3
Productivity per year	linear meter	144 000	108 000
Payback in years	**year**	**4,6**	**7,4**

The analysis of the above tables shows that despite the fact that the cost of cement grade M500 with the vibroforming method (by 12934 soums per slab), and, accordingly, with relatively equal costs for the rest of the main raw materials, the cost of production (excluding the cost of equipment depreciation) by this method more profitable, as it is cheaper by 5736.4 soums per slab unit. Moreover, with the cost of the main equipment, the vibroforming machine is 1998.7 million soums cheaper than the extrusion molding machine. Also, the annual productivity of the vibroforming method is more than 36,000 running meters. (or 6000 pieces) per year compared to extrusion machines.

Conclusions:

- Based on the comprehensive analysis carried out, we can conclude:
- lines for continuous formless molding of reinforced concrete on long stands are equipped with one of three types of molding machines: extruders, split formers and vibroformers;
- in the conditions of Uzbekistan, split formers (layer-by-layer molding machines) are inappropriate to use due to the high cost of equipment and the complexity of operating the molding machine;
- Extruders are used only for the production of hollow core slabs. It is impossible to reconfigure the extruder for the production of crossbars, piles, lintels, poles, beams and other products that do not occupy the entire width of the molding track;
- Comparison of practical results reflects the feasibility of using molding machines with vibroforming as the most economical, productive and technologically mobile, allowing to achieve a return on investment almost 2 times faster than using extrusion molding machines.

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