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REVIEW OF DESIGNS OF MACHINES FOR SURFACE COMPACTION OF PRODUCTS MADE OF CONSTRUCTION MIXTURES

Concrete works are the most important in construction by scope and cost. Concrete as a building material serves as the basis for creating load-bearing structures of buildings and constructions. This is justified by its high mechanical characteristics and processability. Almost any construction elements of structures of any configuration and purpose can be made of concrete. This research conducted a comprehensive analysis of surface-acting molding equipment of construction industry plants – vibrating and non-vibrating.

The surface-acting molding equipment using vibratory action on the mixture to be compacted is considered. Examples of such installations are locally developed and self-propelled plates of foreign companies Dynapas and Amman. The use of pendulum vibration exciters in autonomous vibrating compactors makes it possible to obtain directional vibrations. The versatility of Amman vibrating plates is ensured by changing the direction of the vibration speed, used for trenches and large areas, and has a working width adjustment. ZENIT-TECHNO is also engaged in the production of equipment for the concrete industry, which presents a wide range of equipment for the production of concrete mixtures – lines for the production of concrete products by vibration under pressure, molds for any products, installations for processing concrete products, equipment and tools for laying paving stones, slabs, curbs, and various clamps.

Despite the continuous improvement of vibratory concrete forming units, it is still impossible to get rid of the increased noise and vibration levels at workplaces, which creates harmful working conditions. Non-vibration forming methods not only eliminate the disadvantages of vibration technology, but also open up new opportunities to *increase labor productivity and reduce the metal consumption of equipment. One of the methods of non-vibration molding is roller pressing, which is characterized by the fact that new portions of the mixture are repeatedly pressed into the freshly laid layer under the roller, which reciprocates across the mold. Extrusion pressing involves pushing the raw material mass through a hole in the die with a screw.*

The analysis of existing technical and economical information, experience of industrial and laboratory researches suggests that the calculation, design and creation of new concrete forming units are relevant and promising at the present stage of their use.

Keywords: machine, unit, aggregate, compaction, forming, vibration, construction mix, concrete, rolling, pressure, product.

Problem statement. Concrete works are the main ones in construction by their scope and cost [1, 2]. Concrete as a building material serves as the basis for creating load-bearing structures of buildings and constructions. This is justified by its high mechanical characteristics and processability. Almost any structural elements of constructions of any configuration and purpose can be made of concrete [1, 2].

In recent decades, along with the development of monolithic concrete structures, precast concrete [1-8], manufactured by construction companies, has become increasingly important in construction. The structure of its production is such that the molding of products, as well as the maintenance and repair of equipment, accounts for about 50% of labor intensity [1, 2]. In the precast and monolithic reinforced concrete industry, the process of equipment aging is taking place, which is explained by the absence of a system for implementing theoretical developments implemented in engineering solutions.

An objective of this research is a comprehensive analysis of surface-action molding equipment of construction industry plants.

Analysis of recent researches and publications. There are two common methods of compaction of construction mixtures: vibration and non-vibration.

Vibration effects on concrete mixtures are of great practical importance and underlie all modern compaction technology [1-11]. The essence of the vibration effect is that when vibrating, the concrete mixture acquires fluidity properties due to the disruption of the bonds between the particles. The particles that gain increased mobility are repositioned and, under the influence of gravity, tend to take a more stable position. At the same time, the air between the particles is forced upward and the mixture is eventually significantly compacted.

The process of vibro-compaction of a concrete mixture is complex and takes place in several stages: repacking of components with intensive air displacement, particle convergence and final air displacement, as well as possible additional compaction due to some additional, for example, static pressure [1, 2]. This stage is called compression compaction and can be carried out both during the vibration of the mixture and after the vibration process is completed. In the first case, a positive effect of increasing the density and strength of concrete is achieved by applying a small static pressure for several minutes. In the second case, the same effect can be obtained only by applying a significant specific pressure of several megapascals. In both cases, the effect is achieved due to partial compression and more even distribution of water in the pores, as well as the sealing of contacts between aggregate grains.

Since the process of vibration action is alternating, the deformation that leads to compaction of the mixture layers can also be reversed, which contributes to the delamination and disruption of the compacted structure [1-8]. Therefore, the compaction process is also influenced by the type of the load applied by the working body of the machine.

Vibrating machines are a source of vibrations due to their functional characteristics. These vibrations can be transmitted to the foundation, the supporting construction, and to the person working with the vibration machine. The latter creates uncomfortable conditions at workplaces, increases noise levels and involves the bearing metal structures of machines, constructions, etc. in vibrations [1-8]. Sanitary and hygienic standards provide for and regulate cases of vibration transmission to the hands of an employee and to his or her workplace [1-4, 9-11].

The non-vibration method of compaction of mixtures is based on the application of pressure to the mixture in a mold or in a special molding cavity [1-4, 12-17]. The fundamental difference between the non-vibration method of compaction of mixtures and the vibration method is that the movement of material particles occurs mainly in the direction of the applied pressure. In this case, the transverse macro-movement of particles in the mold is virtually non-existent. This method is used for the production of certain construction products and materials (slabs, panels, reinforced concrete pipes, concrete hollow blocks, cinder blocks, bricks, etc.) [1-4].

Non-vibration compaction methods are divided into static and dynamic. The static ones include pressing, rolling, extrusion, vacuuming, and the dynamic ones include: pneumatic and mechanical spraying [1-4]. This division is to some extent conditional, as it all depends on the speed of force application and the physical and mechanical properties of the material to be compacted [1-4, 12].

Main part. In modern construction conditions, one of the most pressing problems is the introduction of machinery and equipment that meet the criteria of efficiency and reliability with the provision of process parameters and mobility set by technology [1]. Modern factories and landfills for the production of reinforced concrete products are complex mechanized enterprises, the technological equipment and sizes of individual machines of which are determined by the design of the manufactured products and the adopted production method.

The precast concrete industry traditionally uses mainly heavy concrete mixtures of varying degrees of stiffness, the vibration compaction modes of which have been sufficiently studied. At the same time, mixtures with plasticized additives are increasingly used, the properties and behavior of which under long-term operating conditions have not yet been sufficiently studied. Over the past four decades, the production of reinforced concrete structures with plasticized admixtures has tripled, and their use will continue to grow. The same trend is observed in the USA, England, Japan and other countries. Moreover, plasticizers are used to reduce water consumption and to liquefy the mixture in the manufacture of densely reinforced and thin-walled constructions, to fill hard-to-reach mold cavities, etc. In addition, their use helps to reduce cement consumption and improve the quality of products if there are recommendations on the modes of their placement [1]. At the same time, plasticized concrete mixtures require increased time for heat treatment and, accordingly, the overall productivity of the process decreases.

Compared to using plasticizers, an alternative is to use ultra-hard mixtures, including fine-grained concrete, in the production of precast concrete. This is especially true for those regions that do not have coarse aggregates, and their delivery is economically unprofitable. For the placement and compaction of ultra-hard mixtures, intense vibration effects are required, but they are not effective for some mixtures.

Comparison of specific energy consumption in the forming of reinforced concrete products by local units of various types [1, 10] shows that vibratory broaching units and cassette installations are the most economical in this regard. However, the cassette technology requires the use of a significant amount of plasticizers, which leads to cement overruns and also requires the revision of the front surface after the product curing process is completed.

Sliding vibratory compactors can be used as lightweight stand-alone mechanisms (vibratory beams, vibratory plates) as well as part of the working bodies of concrete molding units. Lightweight self-contained vibratory compactors are used for the construction of small-scope and small-area pavements of insignificant thickness (up to 0,1...0,15 m), such as interior workshop coatings, roadway expansion and repair, etc. They are equipped with an autonomous electric motor or internal combustion engine. Examples of such mechanisms are local developments and self-propelled slabs from foreign companies such as Dynapac, Amman, and others (Fig. 1).

a b

Fig. 1. Designs of lightweight autonomous sliding vibrating compactors:
a – Amman 3020 vibrating plate; b – Dynapac VT90 sectional vibrating rail

The use of a pendulum vibration exciter in autonomous vibrating compactors makes it possible to obtain directional vibrations [10]. The versatility of the Amman 3020 vibrating plate (Fig. 1, a) is ensured by changing the direction of speed. It is used for trenches and large areas. The working width can be adjusted using the included plates.

A vibrating rail (Fig. 1, b) consists of one or two parallel vibrating beams rigidly connected to each other. The beams are made of channels, pipes, bars (metal, welded from sheet and profile steel, or wooden). The working surface of the vibratory rails is usually unprofiled. The vibrating beams are equipped with one to three unbalanced vibrating exciters with circular oscillations without synchronization of their rotation. When the vibratory rails operate, a roller of concrete mixture (0,4...0,5 layer thickness) appears in front of them, which contributes to better filling of the mold. Vibratory screeds weighing more than 35...40 kg are mounted on self-propelled trolleys for which guide tracks are laid. To reduce the effect of vibrations on the guideway, the vibrating rails are mounted on elastic supports.

During operation, the vibrating rails can rest on the concrete mix or on the sides of the mold. The second option is undesirable, as the impact interaction between the vibrating rail and the mold leads to their destruction and an increase in noise at the workplace. Several passes are required to complete the final compaction of products made of plastic mixtures, even of small thickness, otherwise there may be gaps, under-compaction zones, etc. Such devices are used for small-scale work in the formation of secondary structures [1, 10].

The Dynapac VT90 sectional vibrating rail (Fig. 1, b) can be easily assembled from individual sections. The drive is connected to these sections. The width of concrete paving can reach 25 m. It is used for leveling and compacting concrete mix in the construction of bridges, highways, industrial floors, etc.

A special group of sliding vibration compactors are hinged mechanisms that are an integral part of complex working bodies. These mechanisms have a more complex design due to their functional purpose. This complication is due to the fact that the working bodies have a hopper with a distribution device or a mechanism for inducing the mixture to flow in front of the sliding vibrating compactor; behind the sliding compactor are mechanisms for finishing the surface layer. Some elements of the mechanisms of the working body may be common. In this regard, there is a need to take into account and revise the methods of such features of the calculation of the main parameters of sliding vibrating dies and determine the modes in order to coordinate the work.

In the technological cycle of production, surface vibratory stamps, like any machine, must provide optimal modes in various molding conditions. Unfortunately, existing calculation methods do not always provide parametric coordination of the work of the component mechanisms with each other. At the same time, the efficient operation of the molding machine as a whole is possible only with such coordination and with proper consideration of the physical and mechanical properties of the processed medium and the conditions of its interaction with the working body. In addition, to ensure the conditions of full mechanization and automation of the concrete forming unit, it is necessary to accurately dose the material to be supplied and the speed of supplying the required dose, which coincide with the performance of all mechanisms of the working body.

ZENIT-TECHNO also manufactures equipment for the concrete industry, representing a number of world-renowned companies in Ukraine [19]. Equipment for the production of concrete mix, lines for the production of concrete products by vibration under pressure, molds for any product, installations for processing concrete products, equipment and tools for laying paving stones, slabs, curbs, various clamps, spare parts and components [19].

The ZENITH 913 mobile concrete block machine for the production of high-rise construction and design elements is shown in Fig. 2 [19]. With the Model 913, high-quality hollow blocks, formwork and wall stones, floor elements, monolithic stones, landscape design elements and much more can be mass-produced. Available as a semi-automatic or full automatic machine, the ZENITH 913 operates with the highest efficiency, both in the workshop and in the open air. The products are placed in rows on a concrete platform, which is protected from damage by running wheels. In the fully automated version, there is electromechanical lane correction or, alternatively, the machine runs on rails. The quick change from a filled production lane to a free lane is accomplished by means of a hydraulic swivel mechanism that is integrated into the frame of the vibratory press. The ZENITH 913 mobile machine is designed for forming products up to 1240 mm wide and 175-330 mm high.

Fig. 2. Mobile block making machine ZENITH 913

The high-performance stationary concrete molding machine ZENITH 1500-2 (Fig. 3) is a modern and efficient concrete product manufacturing unit [19]. The ZENITH 1500-2 concrete molding machine is designed for the production of standard products such as paving slabs, curbs and wall blocks, as well as products for the garden and park landscape. In addition to high quality and productivity, the designers placed special emphasis on low maintenance and trouble-free operation. The use of bolted connections makes it possible to replace all wearing parts easily and in the shortest possible time. An automatic quick-change mold changer, ColorMix module, stamp cleaning unit and other special equipment complete the ZENITH supply program. All controlled axes are monitored by absolute motion sensors. The ZENITH 1500-2 automatic vibrating press is designed for molding products with a height of 40 to 500 mm and a size of 1320×1050 mm.

In our country and abroad, roller molding is used to produce cylindrical and flat products [1, 12]. This non-vibration method of forming particularly rigid concrete mixtures also belongs to the methods of continuous molding.

Fig. 3. Automatic palletizing vibrating press ZENITH 1500-2

The introduction of non-vibration roller machines in the production of reinforced concrete products is caused by the need to increase the efficiency of molding equipment. Despite the constant improvement of vibratory concrete forming units, it is still impossible to get rid of the increased noise and vibration levels at workplaces, which creates harmful working conditions. Non-vibration molding methods not only eliminate the disadvantages of vibration technology, but also open up new opportunities to increase labor productivity and reduce the metal consumption of equipment. The method has been successfully tested in the production of products from ultra-hard fine-grained (sandy) and medium-grained concrete, fiber concrete, and expanded clay concrete. Roller forming is achieved by repeatedly pressing new portions of the mixture (additive) into the freshly laid layer with a roller working body that makes rotational or reciprocating movements across the mold. Based on this, a functional diagram of roller forming machines is compiled.

Roller forming is ensured by repeatedly pressing new portions of the mixture (additive) into the freshly laid layer by a roller working body that performs rotational or reciprocating movements across the mold [1, 12-17]. Based on this, a functional diagram of roller forming machines is compiled.

Based on the experience of non-vibration radial forming, the technology and equipment for roller forming of flat reinforced concrete structures have been developed (Fig. 4). The molding rollers are placed in these machines between the sleeves of the distribution hopper, forming a molding trolley. During reciprocating movements, the rollers grab the mixture and press it into the freshly placed layer in the mold.

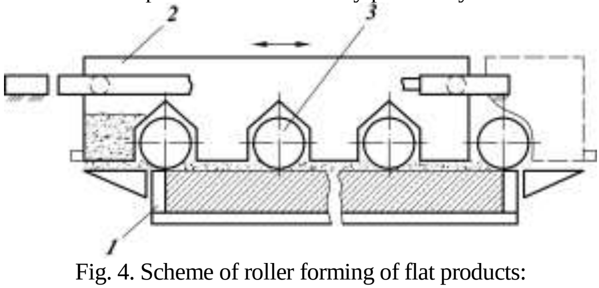

Fig. 4. Scheme of roller forming of flat products:
1 – mold; 2 – supply hopper; 3 – roller trolley

The installation for the non-vibration roller forming of reinforced concrete products (Fig. 5) consists of a portal 1, stationary on the forming post 3, with guides 2, which are fixed on the portal. The working body, made in the form of a dispensing hopper 5 and sealing rollers 4 placed between its sleeves, rolls along the guides. The reciprocating movement of the body is provided by a hydraulic cylinder 7, which is powered by a power hydraulic station 6. The concrete mixture is supplied into the distribution hopper from the main hopper 9. The mold-pallet 8 is installed in such a way that the front edge of the rollers is in line with the inner surface of the front end board. After that, the working body begins to move and the flap of the dispensing hopper opens. The mixture fills the mold cavity to the bottom of the forming rollers and they begin to press new arrivals of mixture into the freshly placed layer - the compaction process begins. After reaching a certain density, the mixture begins to be pressed into the free cavity of the mold, forming a so-called “tongue”. When the growth of the tongue stabilizes (the compaction process is completed at the initial stage), the mold starts moving, and the entire product is sequentially compacted. The speed of movement of the mold and the working body are coordinated to ensure high-quality compaction of products of a given thickness.

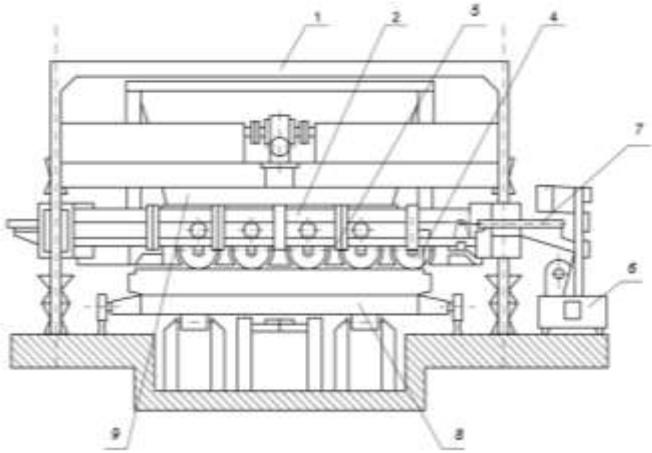

Fig. 5. Schematic diagram of a non-vibration roller forming machine

Further development of the non-vibration manufacturing method is found in design and technological schemes that combine roller forming and extrusion (roller-extrusion forming) to form panels with voids [1]. A schematic diagram of roller-extrusion molding is shown in Fig. 6. A cylindrical rigid (or combined) roller 2 performs reciprocating movements at the height of the product 5 at a speed V_p. Screw extruder 1 pumps the concrete mixture into the mold cavity. This preliminarily forms the shape of the hole, which is subsequently calibrated by the hollowing machine 3. The entire unit moves in the opposite direction with the formation speed $V_ф$ due to the driving forces of the reaction. A stabilizing plate 4 is provided in the design of the unit to eliminate the bulge of the mixture from under the rollers.

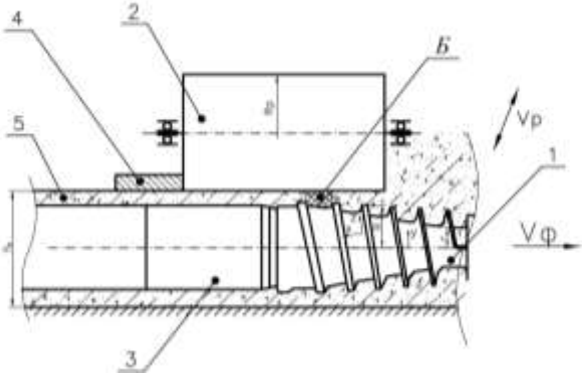

Fig. 6. Schematic diagram of roller-extrusion molding

The specifics of concrete forming units are such that all operations of the technological processing of the product formation process (delivery and placement of the mixture into the mold, its distribution, preliminary and final compaction, shaping, smoothing of the front surface by concrete forming units) are performed by continuous sequential movement of the machine with the executive working bodies relative to the fixed base on which the molds or molded product of the required cross-section are located.

A working body is a set of executive mechanisms arranged in a functionally defined sequence to perform the required operations. The location of the executive mechanisms and their configuration are determined by the surface of the product or structure to be molded. Depending on the technological load (product height, mixture stiffness, specified process performance, product requirements, etc.), the working body of the concrete forming unit may have mechanisms for its uniform distribution, one-, two- or three-stage compaction, as well as mechanisms for preliminary calibration of the layer and for smoothing (finishing) the front surface. To a large extent, the technological sequence of operations and the design features of the working bodies determine the forming properties of concrete mixtures.

Depending on these properties, existing molding processes can be divided into two groups:

- processes of forming slumped concrete mixtures;
- processes of forming rigid concrete mixtures.

In units for the manufacture of products from sedentary concrete mixtures, static pressure in the local volume is created by gravity, which is located above the mass of the mixture. Formation of a given cross-section of the product and compaction in the local volume is realized due to pressure and thixotropic liquefaction of the mixture by means of internal or surfaceI vibration.

In the manufacture of products from rigid concrete mixtures, continuous molding units can be classified according to the following features:

1. by the nature of the impact on the mixture in the local volume during molding:

– static pressure is generated by gravity above the mass of the mixture, combined with internal and surface vibration;

– pressure created by special mechanisms in combination with internal and surface vibration, or in combination with pulsating surface pressure, for example, by means of rollers;

– pulsating or sign-changing dynamic pressure, which is created by special mechanisms;

2. according to the method of laying and compacting the mixture by the height of the product:

– single-layer formation (at the same time, the entire product in height);

– layer-by-layer formation (two-layer, three-layer);

3. according to the method of moving the aggregate during forming:

– forced drive relative to the movement of the unit or form;

– reactive movement of the molding unit from the injection force relative to the stationary base.

Working bodies, as a rule, are mounted on a mobile or stationary portal. Auxiliary movements are provided by gantry (or mold) movement drives, lifting-lowering mechanisms, adjusting mechanisms, etc. Thus, in the general case, the composition of the concrete forming unit includes laying, distribution mechanisms, one-, two- or three-stage compactors and mechanisms for auxiliary operations.

Conclusions. The analysis of the current state of the equipment shows that the factors that allow to significantly increase its efficiency are largely exhausted, and the industry needs further intensification of production. In view of this situation, the methods of production of reinforced concrete products by continuous formation by concrete forming units, whose work is based on the principles of surface action, are worthy of attention.

The experience of forming on long stands has spread abroad. Work on the creation of local units for the continuous formation of precast concrete by vibrating and non-vibrating (roller) methods is being conducted at the Kyiv National University of Construction and Architecture.

The analysis of existing technical and economic information, the experience of industrial and laboratory research allows us to state that the calculation, design and creation of new concrete forming units are relevant and promising at the current stage of their use. Depending on the combination of properties of the mixture, the use of certain auxiliary mechanisms, the method of forming, various layout schemes of concrete forming units and their working bodies are used in the industry.

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Костянтин ПОЧКА, Стефан ЗАЙЧЕНКО, Вадим ШАЛЕНКО, Андрій МАСЛЮК, Максим БАРИЛЮК, Сергій БАРИЛЮК

Огляд конструкцій машин поверхневого ущільнення виробів з будівельних сумішей

Бетонні роботи за своїм об'ємом та вартістю є основними в будівництві. Бетон як будівельний матеріал слугує основою для створення несучих конструкцій будівель і споруд. Це обґрунтовується його високими механічними характеристиками і технологічністю обробки. З бетону можливо виконати практично будь-які конструктивні елементи споруд, будь-якої конфігурації і призначення. В даному дослідженні проведено всебічний аналіз формувального обладнання поверхневої дії заводів будівельної індустрії – вібраційного та безвібраційного.

Розглянуто формувальне обладнання поверхневої дії з використанням вібраційної дії на суміш, що ущільнюється. Прикладом таких устоновок є вітчизняні розробки і саморухомі плити закордонних фірм Dynapac, Amman. Застосування маятникових вібр972збудників у автономних віброущільнювачах дає змогу одержати направлені коливання. Універсальність віброплит виробництва Amman забезпечується зміною напряму швидкості вібраційної дії, використовується для траншей і на великих площах, має регулювання робочої ширини. Виробництвом обладнання для бетонної індустрії займається також компанія «ЗЕНІТ-ТЕХНО», яка представляє широкий спектр обладнання для виробництва бетонної суміші – лінії для виробництва виробів з бетону методом вібрації під тиском, прес-форми для будь-яких виробів, установки для обробки бетонних виробів, обладнання та інструмент для вкладання бруківки, плит, бордюрів, різноманітні захвати.

Незважаючи на постійне удосконалення бетоноформувальних агрегатів вібраційної дії, досі неможливо позбавитися підвищеного рівня шуму та вібрації на робочих місцях, що створює шкідливі умови праці. Безвібраційні методи формування не тільки усувають недоліки вібраційної технології, але й відкривають нові можливості підвищення продуктивності праці, зниження металомісткості обладнання. Одним з методів безвібраційного формування є роликове пресування, яке характерне тим, що відбувається багаторазове вдавлювання в свіжоукладений шар нових порцій суміші-підсипки під роликом, який здійснює зворотно-поступальні рухи поперек форми. Екструзійне пресування полягає у продавлюванні сировинної маси через отвір у матриці шнеком.

Аналіз існуючої технічної та економічної інформації, досвід промислових та лабораторних досліджень дозволяє стверджувати, що розрахунок, проектування та створення нових бетоноформувальних агрегатів є актуальними та перспективними на сучасному етапі їх використання.

Ключові слова: машина, установка, агрегат, ущільнення, формування, вібрація, будівельна суміш, бетон, укочування, тиск, виріб.