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Structural analysis of vibration platform for panel units forming and consideration of its utilizing options

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The review of the utilizing directions of the shakers of various designs for consolidation of concrete mixtures at the production of flat panel elements is executed. The major limitations and advantages of certain designs of shakers are analyzed, the main production technologies of flat reinforced concrete units in which their use is most reasonable. The evaluation of prospects for the equipment of different designs to be quickly adjusted to the production program changes is made. The main idea in the production of flat panel elements on vibrating pads using Industry 4.0 technologies is to use the latest information technology and automation and that business and engineering processes are deeply integrated.

Keywords: readjustment, pallet, vibration platform, technology, volume consolidation.

Аналіз конструкцій віброустановок панельних елементів та напрямків їх використання

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Виконано аналіз напрямків використання різних конструкцій вібромайданчиків для ущільнення бетонних сумішей при виробництві плоских панельних елементів із можливим застосуванням сучасних технологій індустрії 4.0 для підвищення загальної ефективності будівництва. Проаналізовано основні недоліки і переваги тих чи інших конструкцій вібромайданчиків, виявлені основні технології виробництва плоских залізобетонних виробів, у яких їх використання є найбільш доцільним. Виконано оцінку і виявлено можливості обладнання різних конструкцій бути швидко переналагодженими під зміни виробничої програми. Встановлено, що у переважній більшості у технології збірного залізобетону використовують малорухомі бетонні суміші з яких у результаті виробляють потрібні як за конфігурацією так і за належною якістю поверхонь суцільні (одношарові) панельні залізобетонні елементи, які відповідають необхідним вимогам по міцності, водонепроникності, морозостійкості і при цьому з належною якістю поверхонь. Останні десятиліття все більшого використання набувають різного роду багатошарові панельні елементи, які складаються з шарів залізобетону, розділеного різними за складом ізолювальними матеріалами. У обох випадках суміш, яка завантажена у форму, вимагає додаткового ущільнення для зменшення кількості повітря і витіснення зайвої рідини. Найбільш розповсюдженим методом ущільнення є об’ємний метод з використанням вібраційної дії на оброблюване середовище, для чого зазвичай використовують вібраційні майданчики різних конструкцій. Встановлено, що основна ідея при виробництві плоских панельних елементів на вібромайданчиках із застосуванням технологій індустрії 4.0 полягає в тому, щоб використовувати новітні інформаційні технології та автоматизацію, щоб бізнес-процеси та інженерні процеси були глибоко інтегровані. Завдяки цьому виробництво працюватиме гнучким, ефективним та екологічно чистим способом із постійно високою якістю та низькою вартістю.

Ключові слова: переналагодження, палета, віброустановка, технологія, об`ємне ущільнення.

Introduction

Nowadays, the selection and use of equipment that would best meet the technological production scheme of flat reinforced concrete products is an increasingly important task. At the same time, the most responsible process is the consolidation of concrete mixtures on shakers, vibrating tables, which should ensure high productivity and product quality. In addition, such equipment should provide opportunities for rapid readjustment of production lines depending on market needs.

Review of the research sources and publications

In times of increasing use of the monolithic-frame method of building construction, the technology of manufacturing precast reinforced concrete structures seems to have lost its relevance. However, it opens a new milestone in the form of the use of precast units in monolithic technology, various types of floors, cabins, which can accelerate the construction rate by reducing the number of concrete works on the construction site [1]. The costs of materials used in the reinforcement of units in the factory are much lower [2]. Also, this technology does not lose its relevance in the construction of low-rise buildings for both private and non-residential use. The most common method of compacting concrete mix in factory production conditions is the three-dimensional vibration method of forming [3].

Definition of unsolved aspects of the problem

The equipment used in compaction has a wide range of both design and manufacturing technology of products in which it is advisable to use, which causes problems in choosing both equipment [4] and technological parameters of the compaction process [8].

Problem statement

The work aims to review the designs of vibrating equipment for volumetric compaction of concrete mixtures and to analyze the production technologies in which their use is most appropriate.

To achieve this goal it is necessary to solve the following tasks:

– to inspect the most common designs of vibrating equipment for forming and compacting flat reinforced concrete units;

– analyze their advantages and limitations;

– assess the possibilities of different designs of vibration equipment for rapid readjustment, depending on changes in the production program.

Basic material and results

The vast majority of precast reinforced concrete technology uses low-density concrete mixtures, which result in manufacturing the continuous (single layer) reinforced concrete panel units of the required configuration and proper surface which meet the necessary criteria of strength, water- and frost resistance having an independent surface quality

In recent decades, various types of multilayer panel elements, which consist of layers of reinforced concrete separated by insulating materials of different compositions, have become increasingly used.

In both cases, the mixture, which is loaded into the mold, requires additional compaction to reduce the amount of air and displace excess fluid [7]. The most common method of compaction is the three-dimensional method with the use of vibration action on the treated medium, which usually uses vibrating pads of different designs.

In the production of solid reinforced concrete units in the conditions of flow-aggregate and conveyor technology, the most common at present are vibrating stationary platforms of frame or block construction with removable forms (Fig. 1) [2].

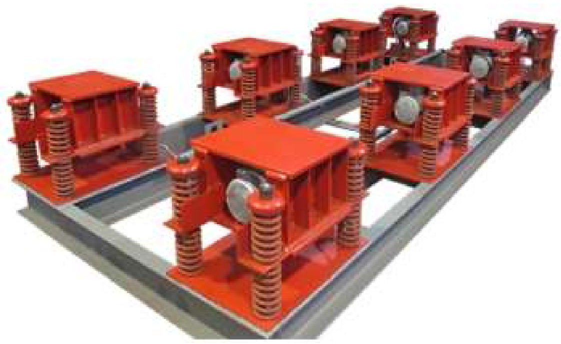

Figure 1 – Vibration platform for compaction of concrete mix in removable forms

The following technological and operational requirements are set for them: achieving the required degree of compaction of the concrete mixture throughout the unit, high productivity, reliability, as well as durability of equipment and compliance with sanitary and hygienic standards, ease of maintenance.

Vibration platforms of the frame type have been used in the twentieth century for a long time. They became most widespread due to developments and research at Poltava Civil Engineering Institute in 1972 and were mostly used for compaction of large concrete products weighing 10-50 tons, with low noise, oscillations mainly in the horizontal plane, and operation at low oscillation frequency 24 Hz.

We will consider designs of frame vibrating platforms in more detail by the example of the VPG 1,5x12 vibrating platform which scheme is shown in fig.2.

Vibrating platform HSV 1.5×12 consists of a movable frame 1, which is welded from channels and steel sheet, in the middle part there is a ledge 2 for rigid mounting unbalanced vibrator excitation of circular action with a vertical shaft (vibrator) 3, the movable frame rests on eight elastic rubber-metal supports mounted on the support frame 5. Rubber-metal supports work on shear and compression, providing horizontal and vertical components of vibration.

The electric motor 6 is mounted on the lower support frame and transmits rotation using a V-belt transmission to the vibrator pulley. The mold with the concrete mixture is fixed on a movable frame between the rigid stops 7.

The simplicity of a design allows to reach low noise level in workplaces, has high reliability and efficiency of compaction.

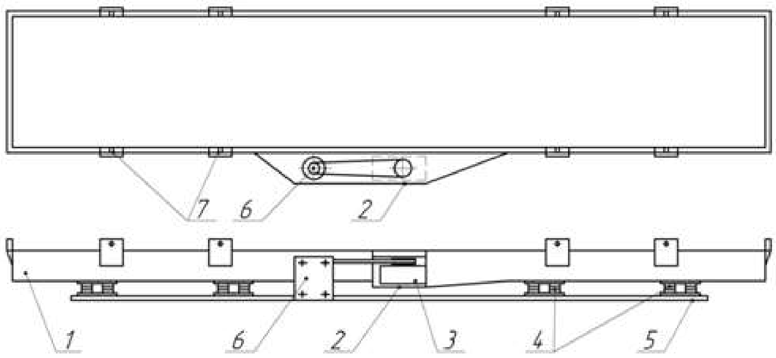

Figure 2 – VPG 1,5×12 vibrating platform scheme

The simplicity of a design allows to reach low noise level in workplaces, has high reliability and efficiency of compaction.

The disadvantage of frame vibrating tables is the high metal capacity of the structure, due to the requirements for rigidity of the structure, which must be kept under high loads, transmit vibrations from one vibrator and distribute them evenly over the whole area of the mixture.

The blocked vibrating tables were another development area for compaction of concrete mixtures with vibration or shock-vibration action on the mix. Serial block vibrating tables such as SMZh-187 and SMZh-200 were proposed in the late 50s of the last century at the VNDI Buddormash. These vibrating tables were generating vertical harmonic frequency oscillations up to 50 Hz. The concrete`s mixture form is mounted on a frame with electromagnetic grips. The scheme of construction of the vibrating table SMZh-187 is presented in Fig.3.

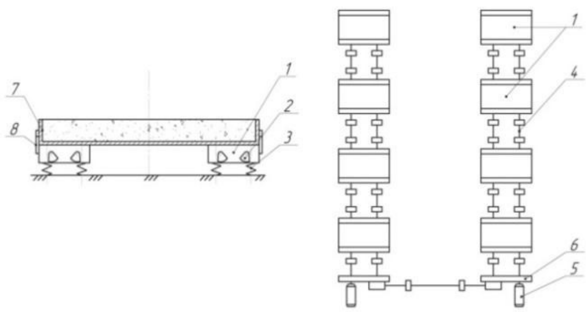

Figure 3 – Scheme of the vibrating table SMZh-187

The SMZh-187 vibrating tables consist of eight vibrating blocks 1 with the vibrators 2 mounted on them, generating vertical fluctuations.

Vibrating blocks rest on the elastic pile 3, which is mounted on the foundation. The vibrators of all four vibrating blocks are interconnected by cardan shafts 4, and they provide synchronous operation. The drive of the vibrating table consists of two motors 5, which are connected to the vibrators by synchronizers 6 and cardan shafts. The form with the concrete mixture 7 is fixed with the help of electromagnetic grips 8.

Low-frequency vibrating tables with vertical oscillations freely mounted on them through elastic gaskets forms have also become quite common in reinforced concrete plants due to high efficiency in the compaction of mixtures. The low-frequency vibrating tables include the shock-vibration platform UVP-10 (Fig. 4), developed based on the design of the vibrating table SMZh-187A.

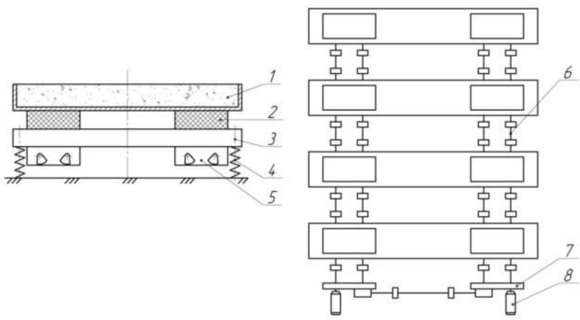

Figure 4 – Scheme of shock-vibration table UVP-10

It consists of four vibrating blocks 3 with vibrators 5 connected to them from below, which create vertical oscillations. The frame of each vibrating block rests on elastic support elements 4 mounted on the foundation. The vibrators of all four vibrating blocks are interconnected by cardan shafts 6 due to their synchronous operation is provided. The drive of the vibrating table consists of two motors 8, of which there are synchronizers-frames 7 and cardan shafts are connected to the vibrating frames.

The main difference is that between the mold with mixture 1 and the vibrating block table 3, elastic rubber elements 2 are established, which allows implementing the shock-vibration mode of the site. The shock-vibration mode of work increases compaction efficiency, and rubber elements reduce the noise load in the workshop.

The block design of vibrating tables, in general, allows adjusting them to a certain type-size of the product, which is planned for production on the production line, by changing the number of vibrating blocks. This, in turn, reduces the company`s costs when changing the production program, changing the size of products, and more.

Among the disadvantages of block vibrating tables there may be noted lower, compared to the frame, reliability due to the high number of components: gearboxes-synchronizers, elastic supports, card shafts, due to which such structures create high noise levels in the workplace.

There are constructions of tables in which the frame with vibration exciters of oscillations is at the same time a pallet (form) for concrete mix (Fig. 5), sometimes they are called stationary vibrating tables.

Figure 5 – The vibrating table with mounted exciters of oscillations

The scheme of this table is presented in Fig.6. It consists of a frame 1, which is mounted on elastic piles 2. The installation is actuated by excited oscillations 3, which are mounted asymmetrically on the structure`s frame [5]. The structure`s frame is directly and is a pallet (form) on which to perform compaction of concrete mixtures 4. The dimensions of the future product are formed due to removable magnetic boards and partitions in the plan. On such vibrating tables, they perform laying of reinforcing structures, concrete mix, sealing, and partial steaming of the product, thanks to the heating registers established under the table. After the product has gained sufficient strength, it is removed from the vibrating table and transported to the steaming rooms for final aging.

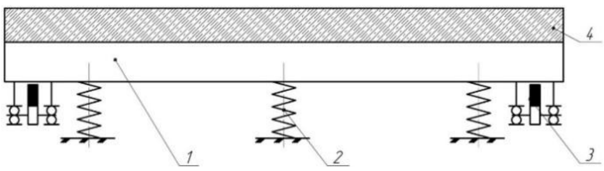

Figure 6 – Scheme of a vibrating table with mounted exciters of oscillations

These vibrating tables have advantages such as reducing the metal content of the structure due to the uniform installation of mounted vibrators along the contour of the frame, which reduces its stiffness and increases the uniformity of oscillation amplitudes over the area of the forming surface and energy transfer. Product`s different sizes compaction is due to the use of the magnetic boards and partitions.

The disadvantage is the lower productivity due to the lack of removable forms, due to such tables being used in the stand technology of small and medium-scale production of flat reinforced concrete products.

Recently, the use of multi-layered elements as prefabricated units, which are several materials connected in one panel, is becoming more and more common.

These include the following types of products (Fig.7-9):

- double wall (Fig. 7, a), consisting of two parallel prefabricated reinforced concrete slabs with a thickness of at least 50 mm, interconnected by lattice trusses at some distance, resulting in an air layer appear, which allows reducing thermal conductivity;
- double wall with additional intermediate insulation with foam (Fig. 7, b), which serves to further reduce the thermal conductivity of the panel for use in cold regions;
- wall sandwich panel (Fig. 8, a), which consists of an outer massive reinforced concrete part and smooth inner slab, the space between which is filled with insulating material;
- facade walls (sandwich panels) (Fig. 8, b), which differ from the previous type of panels in that the outer (front) part is provided with various design solutions, such as washing, grinding, or polishing and the use of matrices and facing materials for decoration;
- walls made of light concrete (Fig. 9), with or without decoration of the front sides.

Figure 7 – Multilayer thin-walled elements:
a – with an air layer;
b – with an air layer and foam

Figure 8 – Sandwich panels with a heat-insulating layer:
a – without external decoration;
b – with external decoration

Figure 9 – Solid slabs of lightweight concrete

Using prefabricated multilayer slabs (panels) enables operating all the advantages of precast concrete technology. It significantly reduces the time of building concrete work on the construction site and reduces their cost, also creating residential and non-residential buildings that will comply with modern technical solutions for energy efficiency.

As you can see from the above elements, the finished panels vary in type, form and size. From this, we can conclude that they require the use of appropriate production technologies and equipment that will allow without significant readjustments of production lines to perform their production.

A large number of companies around the world specialize in the development of such equipment, including Ebawe, Avermann, Weckenmann.

The main requirement for more flexibility and productivity of the technological line is using fully standardized variable forms, the so-called "forming pallets" (Fig. 10).

Figure 10 – Molding pallet for the production of panels

Such pallets pass through all processes at the production of prefabricated elements and are used both at the bench and on aggregate-current technology. The dimensions of the future product in the plan are formed due to removable magnetic boards and partitions.

To complete the compaction of mixtures in pallets, the vibrating units are used (Fig. 11), in which all the elements inherent in conventional vibrating tables are separate nodes. They are connected only by an installed molding pallet.

a) b)

Figure 11 – Vibrating structures for mixtures compaction in molding pallets of different manufacturers:
a) Ebawe; b) Weckenmann

In this case, such structures can perform seals in the vertical or horizontal directions and simultaneously in both directions.

The schematic diagram of this vibrating structure type is shown in Fig.12 and consists of mounted on the foundation of elastic supports 1, vibrating blocks 2, vibroisolating from the foundation by elastic elements 3. The elastic supports and vibrating blocks have locks 4 for fixing the molding pallet 5 with concrete mixture 6 during the sealing process. The lock for the fastening of a pallet can be electromagnetic, pneumatic, or with a mechanical drive.

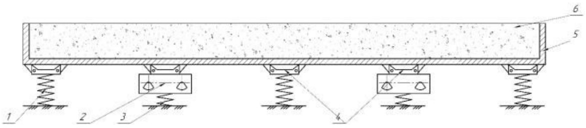

Figure 12 – Schematic diagram of a vibrating structure for vibrating molding pallets

The high reliability of the structure due to the separation of the nodes from each other [6], low noise, high performance, the ability to change the direction of oscillations, and vibration frequency during operation are among the advantages. It makes it possible to perform compaction of elements with different characteristics and enables flexible and logistical efficient organizing the production process and its quick-adjusting when changing the production program, which in today's environment is an important factor.

Among the disadvantages is the inexpediency of their use in small and medium-scale production of prefabricated structures.

Swivel (tipping) vibrating tables or tilters have become widespread (Fig. 13). They are used in the production of flat precast concrete products (single-layer, multilayer). The design of rotary tables is an improved version of the stationary vibrating table, which is additionally equipped with mechanical devices or hydraulic cylinders to move the surface from horizontal to close to vertical (about 80 degrees to horizontal).

Figure 13 –Weckenmann turntable

Moving the molding surface to an almost vertical position enables the safe removal of the element with the least risk of damage.

Therefore, the industry needs a radical change and it is the Industrie 4.0 that addresses this change. The core idea of Industrie 4.0 is to use the emerging information technologies to implement IoT and services so that business processes and engineering processes are deeply integrated making production operate in a flexible, efficient, and greenway with constantly high quality and low cost [10, 11].

Conclusions

As a result of the analysis completed, the main structures of vibrating machines for three-dimensional compaction of concrete mixtures in the production of precast reinforced concrete structures are determined. The production technologies in which they are mostly used were given. Their disadvantages and advantages in terms of logistically efficient organization of production activities are considered. It was found that in the modern realities using flat prefabricated reinforced concrete structures, it is advisable to choose such equipment in their production that will allow you to quickly readjust production depending on changes in the production program without excessive costs.

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