Mechanized installation for molding of wood-concrete panels

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Abstract. The article presents new technical solutions aimed at improving the performance of the installation for the molding of wood-concrete slabs. Calculation and design of rotary wheel racks which provide movement of installation in two mutually perpendicular directions is made; the proportioning bunker; conveyor that distributes and discharges the ready mortar into the formwork with two pneumatic cylinders; frames of plate forming installation. The study of the frames of plate forming installation, proportioning bunker and conveyor. Engineering analysis was carried out in CAE system ANSYS. Engineering analysis included five types of calculations: calculation of stiffness with rigid and elastic grip conditions, modal analysis, dynamic calculation, thermal and thermal-deformation calculations. The obtained results of the engineering analysis allowed us to conclude that the deformation of the frames is insignificant, that is, their rigidity provides the required accuracy of the manufacture of plates and the accuracy of the position of the proportioning bunker relative to the conveyors. The carried out measures on modernization of plate forming installation provided increase in productivity approximately in 2 times.

1. Introduction

Wood-concrete «Arbolitis» is a type of lightweight concrete, which includes wood chips, high-grade cement, chemical additives and water. The need for chemical additives in the composition of wood-concrete is due to the fact that in the organic component it is necessary to neutralize the residual sugar to increase the adhesion of the crusher and cement, and also improve the properties of the final material, such as porosity, hardening acceleration, bactericidal, etc.

The economic efficiency of using this type of waste is proved by the leading enterprises for the production of wood-concrete. An important role in this issue is played by the rational use of wood. The main component for the manufacture of wood-concrete, as mentioned above, are wood waste of joiner’s and furniture production, from which the output is obtained chips of the required size.

One of the most important advantages of wood-concrete is its environmental friendliness. It is a safe building material for human health. Its composition and production are also absolutely safe, including for the environment. And chemical additives have long been used for the benefit of mankind. For example, an additive such as aluminium sulfide is used to effectively purify water in water treatment plants. In comparison with brick and expanded clay concrete blocks, which contain mineral fillers, "Arbolit" has thermal and sound insulation properties and low weight. "Arbolit" is not subject to biological destruction. Low thermal conductivity of the material does not require additional insulation; the material is also refractory. There are no analogues of wood-concrete among other building materi-
als in terms of combination of properties and technical characteristics. It is a building material that combines the best properties of wood and stone [1-3].

An important factor in ensuring the high quality of wood concrete is the production technology. All production of panels includes five stages: production of wood chips; demineralization of raw materials; mixing with cement; molding with pressing; "maturation".

Production of "Arbolit" is impossible without wood chips, which is obtained after crushing the wood in a special machine. In order for wood chips to be suitable for the production of wood-concrete, air exposure is necessary. An open space of up to 6 months is shown to wood chips in order to neutralize the sugars contained in it. To reduce the time of neutralization of sugars, wood chips can be soaked in a special chemical composition for a period of not less than a day. The quality of chemical additives must also be high in order to ultimately obtain a quality material. The sequence of adding components also plays an important role in the creation of high quality wood-concrete. The mixture must be mixed in a forced mixer type.

Pressing is an important process in the production of plates. Usually pressing (compaction) concrete is done by hand – bayonet and tamping (performed by hand tools). The time spent on pressing should be no more than 20 seconds, otherwise the output will be a puff mixture of cement and chips, and not "Arbolit". Therefore, it is necessary to mechanize the process of tamping.

2. Object of research
This paper presents one of the options for the installation of molding plates used in the future for low-rise construction. Development of the installation project was carried out in the CAD-system COMPAS 3D. Installation (figure 1) includes the following components and assemblies: 1 – frames of installation of molding of plates; 2 – drive wheel rack; 3 – driven wheel rack; 4 – bunker-batcher; 5 – conveyor with tilting device; 6 – tamping device; 7 – formwork.

![Figure 1. General view of installation](image)

Frames of installation of molding of plates used as a carrier system for bunker-batcher, conveyor with tilting device and tamping device. To be able to move the installation on the shop floor from one formwork to another, the installation is equipped with two types of wheel racks: drive and driven (figure 2). The corresponding type of wheel struts are arranged diagonally (figure 1). Each of the
leading wheel stands are equipped with individual motor-reducer, which, through flexible coupling transmits motion to the wheel and drives the whole installation of the molding plates. The wheel rack has a rotating part, which provides a fixed rotation of the wheel by 90 degrees and, thus, the movement of the installation in two mutually perpendicular directions. Driven wheel struts do not have a drive.

![Figure 2](image1.png)

**Figure 2.** Frame of installation of molding of plates (a) with the wheel stands (6)

Bunker-batcher, mounted on the installation molding plates, performs the function of accumulation, storage and dosing of ready-made solution for plates (figure 3). The bunker is equipped with an motor with the eccentric mounted on the rear wall of the bunker. In this case, the engine acts as a vibrator. The vibrator is necessary in order that the finished mixture consisting of cement mixed with water and wood chips does not stick to the walls of the bunker, but flows down due to vibration. Bunker-batcher it is attached to the frame by means of brackets welded to it and is attached to the main frame of installation of molding of plates by means of bolts. Two augers are installed in the lower part of the hopper, rotating at a fixed speed and thus push the solution through the outlet to the conveyor, where the mixture is distributed over the entire surface.

![Figure 3](image2.png)

**Figure 3.** Bunker-batcher with frame (a) and augers with drive (6)
Material supply to the formwork is carried out by two conveyors with tilting devices (figure 4). The conveyors are located specularly to each other relative to the middle of installation of molding of plates. The purpose of these conveyors is the distribution, accumulation on the surface of the conveyor of the finished mixture for forming plates and tilting the distributed finished mass into the formwork. The mixture comes from the bunker-batcher by rotating the drive drums and moving the tape. Tipping is carried out by two pneumatic cylinders located on the edges of the conveyor. Overturning of the conveyor is carried out by two pneumatic cylinders. The conveyor drive is made in the form of a motor-drum (figure 4).

![Figure 4. Conveyor (a) with motor-drum (b)](image)

Tamping device (figure 5) used for compaction of concrete mix after feeding it to the installation site to remove air bubbles from it and give it maximum density. Due to the available spring, the tamping device is in a constantly stressed state. The compaction force is transmitted through the pneumatic muscle. When the tamping device is in the starting position, the pins are in the extended position. With a frequency of 2 Hz tamping device tampings the material. After the first blow and return to the initial position, due to the existing pneumatic cylinders, the pins are retracted into the guide. The second blow is made without the participation of pins and the material is even more compacted. After completion work of the first rammer takes its original position, and begins to work the second rammer. Both ramming complete the tamping in the initial position, they move to the desired distance due to the drives and the operations are repeated again.

![Figure 5. Tamping device (a) with rammers (b)](image)
Formwork of molding of plates (figure 6) — design of metal and wood to give the shape and dimensions of viscous mixtures. In this case, a formwork dimensions 3500х1000х400 mm. This construction is assembled from square profiles and wooden sheets. Profiles for formwork welded, wood sheets are fastened with screws. The formwork is in a stationary position, because the installation will move around the shop. Formwork must stand for at least 30 minutes from the time of its full rammer. Further having disassembled it, it is possible to move on shop the created plate. For storage of ready panels it is necessary to sustain them in a cool place beforehand, thus they should not concern each other. In this position, the plates should stand for three days, then they can be folded one on the other.

![Formwork](image)

**Figure 6.** Formwork

### 3. Research result
Since the "weight/stiffness" ratio is very important for the designed structure, an engineering analysis of the load-bearing system of the installation was performed. Engineering analysis of the installation was carried out in the universal CAE system ANSYS. Engineering analysis included the following types of calculations: stiffness with rigid and elastic fixation in the racks; modal analysis, dynamic calculation, as well as thermal and thermodeformational. As a typical finite element, a rod two-node element BEAM188 was used. The results of engineering analysis made it possible to perform multivariate calculations of various design solutions and achieve the optimal ratio of "weight/(static and dynamic) stiffness" of the load-bearing system of the installation.

For figures 7-9 as an example the result of calculation of frames of installation of molding of plates, the bunker-batcher and the conveyor is presented.

![Calculation result of frames](image)

(a) the result of the calculation on the stiffness   (b) the first mode

**Figure 7.** The calculation result the frame of the installation
The static calculation of the load-bearing system of the installation showed that the maximum value of static displacements of the frame of installation of molding of plates with elastic stands was about 0.5 mm, the frame of the bunker-batcher – about 0.8 mm and the frame of the conveyor – about 0.08 mm. This small deformation does not affect the accuracy of the plates and the installation of the dosing bunker-batcher to the conveyors.

Plate forming installation uses a ramming device, which is a source of vibration. Therefore, to make the final design decisions, the designed installation required the determination of natural frequencies and dynamic calculation in a given operating frequency range. To do this, the first modal, and then dynamic calculation was carried out in the CAE system ANSYS [4, 5].

The range from 0 to 300 Hz was considered as the operating frequency range. In this range of frequencies was evident 20 natural frequencies. The minimum value of the natural frequency was 14 Hz, the maximum was 280 Hz. The use of elastic supports provided the oscillation of the load-bearing system in the low frequency region without distortion of the circuit.

As an example, figures 10-12 shows the amplitude-frequency characteristics (AFC) based on the results of the dynamic analysis load-bearing system installation in CAE system Ansys for the directional displacements along X, Y and Z Axes. The X-axis is directed along the conveyor, Y axis is directed across, and the Z axis corresponds to vertical axis.
Analysis of the frequency response shows that along different axes appear different forms of vibration, and the same significant eigenfrequencies correspond to different magnitude of the amplitude.

Figure 10. Frequency response the frame of the installation

Figure 11. Frequency response the frame of the bunker-batcher

Figure 12. Frequency response the frame of the conveyor

4. Conclusions
Thus, the presented approach to the creation of complex mechanical systems, consisting in a combination of automated design systems of different levels of CAD/CAE-systems, makes it possible not only to create a multivariate design using CAD-systems, but also, using the capabilities of the CAE-system, to achieve optimal design solutions for several criteria at the same time, i.e. to solve a multi-criteria problem.
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