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# ENVIRONMENTAL AND ECONOMIC EFFICIENCY OF USING INSULATED WOOD CONCRETE IN BUILDING BASED ON AGRICULTURAL AND INDUSTRIAL WASTES

***The article discusses the issues of using insulated wood concrete as a building material and provides an economic reasoning of its efficiency. Advantages of this material industrial application expansion are demonstrated.***

***Keywords:*** *wood concrete, efficiency, resources conservation, building materials, intensification.*

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# ЕКОЛОГІЧНА ТА ЕКОНОМІЧНА ЕФЕКТИВНІСТЬ ВИКОРИСТАННЯ НА БУДІВНИЦТВІ ТЕРМОІЗОЛЮЮЧОГО АРБОЛІТУ, ВИРОБЛЕНОГО З СІЛЬСЬКОГОСПОДАРСЬКИХ ТА ПРОМИСЛОВИХ ВІДХОДІВ

***У статті описано використання термоізолюючого арболіту як будівельного матеріалу та дано економічне обґрунтування його ефективності, аргументовано розширення використання даного матеріалу у виробництві.***

***Ключові слова:*** *арболіт, ефективність, економія ресурсів, будівельні матеріали, інтенсифікація.*

***Табл. 2. Рис. 1. Форм. 1. Літ. 10.***

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# ЭКОЛОГИЧЕСКАЯ И ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ИСПОЛЬЗОВАНИЯ В СТРОИТЕЛЬСТВЕ ТЕРМОИЗОЛИРУЮЩЕГО АРБОЛИТА, ПРОИЗВЕДЁННОГО ИЗ СЕЛЬСКОХОЗЯЙСТВЕННЫХ И ПРОМЫШЛЕННЫХ ОТХОДОВ

***В статье описано использование термоизолирующего арболита в качестве строительного материала и дано экономическое обоснование его эффективности, аргументировано расширение использование данного материала в производстве.***

***Ключевые слова:*** *арболит, эффективность, экономия ресурсов, строительные материалы, интенсификация.*

**Problem setting.** Insufficient elaboration of the issues of effective use of industrial and agricultural wastes, and namely, the application of insulated wood concrete as a building material has formed a background for the given research. As it is widely known, wood concrete has low strength properties. In this regard, new ways for improving mechanical properties of this material are developed. The Kyzylorda region is a major rice-growing region in Kazakhstan. Annually up to 40 ths tons of rice husk and straw are released during raw rice processing. Rice husks prove to be suitable by their technical characteristics for making wood concrete. This widens the area of application of the proposed material in the construction sector of the Republic of Kazakhstan.

**Latest research and publications analysis.** In the national (Kazakhstani) academic literature the issues of wood concrete production and application haven't been

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carefully explored and discussed. However, the process parameters of wood concrete production and its feasibility have been developed by some authors. The works by Russian and foreign scientists I.H. Nanazashvili (2003) and M.I. Klimenko (1982) should be mentioned here.

**Unresolved issues.** At present there is a need to investigate the wood concrete application depending on the climatic zones within the Republic of Kazakhstan. Also there are unsolved challenges related to the optimization of process parameters and the efficiency of production technologies, in particular, the replacement of expensive equipment by technical achievements of local scientists in the field of building materials' science, namely, the cost-effective equipment.

**The research oblective.** Is to determine the economic efficiency of production and usage of wood concrete in contemporary construction.

**Key research findings.** Currently a significant reserve for increasing the building efficiency is the potential decrease of material input and the application of recycled resources in the production of building materials and structures. Both issues are possible to achieve through a wide application of advanced science and technology achievements, resource- and energy-conservation methods, by means of reducing the volumes of material and labor resources per unit of output. Therefore, it is advisable to increase the use of industrial and agricultural wastes for resource conservation. This would significantly improve the expanding range of building composites on cement binder (DCC) such as wood concrete and fibrolite produced by new technical means. In this context manufacturing of wood concrete products for rural construction works seems effective.

Wood concrete production is well arranged in Russia and in some other countries (Nanazashvili, 2000; Vassilkov, 2000). In Europe wood concrete is known as "dyurizol" (Holland, Austria, Switzerland) or "pilinobeton" (Czech Republic). As it is known, wood concrete is a form of a lightweight concrete manufactured from the mixture of cement, organic fillers, chemical additives and water. Organic fillers may be of different origin and with different shapes of particles (crushed waste of trees, chopped cane, fire hemp or flax, rice husk and straw, sunflower husks etc.). But generally, manufacturing technology of wood concrete products is close to the technology of conventional concrete production.

Production of wood concrete is interesting, especially since it is really a unique material.

It is possible to use rice straw and husks or cotton stalks as fillers in the southern districts of the Kyzylorda area. Usually, 20% of all raw materials in rice production are husk (shucks) with the annual volume of rice husk of over 40 ths tons as a replacement of Portland cement by HPC ash. Rice husk as a filler meets the requirements of TC 822-11-78 by its technical characteristics and is suitable for manufacturing wood concrete products.

Nowadays when choosing building materials, especially for masonry, little attention is paid to thermophysical characteristics; the emphasis is rather on its strength.

Wood concrete has the following advantages in this relation:

– self-extinguishing, desiccant and cold-resistant, fire-proof and durable;

– resistant to vibration by damping it (it is possible to build production facilities);

– it is technological – possible to drive nails into it;

– has good diffusion properties.

The advantages of such constructions are:

– the load on foundation is 2,5–3,5 times less than for the same amount of brick masonry;

– the speed of blocks construction increases in 4–6 times as compared to brick masonry;

– the volume of masonry mortar used significantly reduces.

If we compare technical and economic performances of wood concrete designs per 1 m$^2$ of hollow outer walls with light concrete structures, especially made of claydite lightweight concrete, aerated concrete of sandwich panel with mineral wool semi-rigid plates, then the cost of production is lower by 14–38% (Klimenko, 1982).

Advanced technology in manufacturing of wood concrete products is a compactable method of molding wood concrete mixtures followed by a package formed on the vertical conveyor of molding post (Akchabayev et al., 1974).

The advantage of this molding post (Figure 1), compared with the former known one is a small metal capacitance, a replacement of hydraulic press by electric winches, a possibility of forming a number of items into the package, a high capacity of lines. To create an effective technology it is necessary to develop a technology based on the method of pressing with modernization of technological conversion and use of local raw materials and industrial wastes.

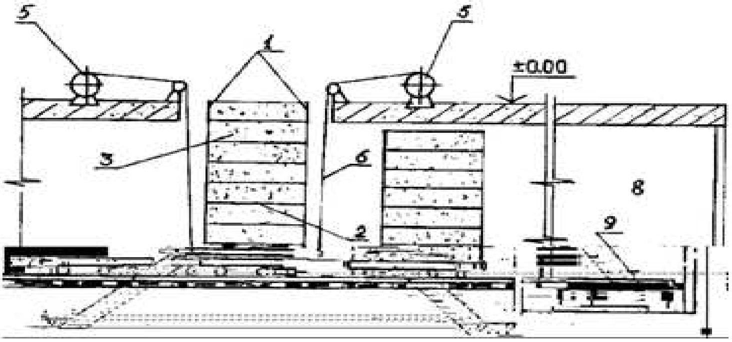


*Figure 1.* **Molding post** *(Akchabaev, 1987)* **of technology for vertical package forming of compact wood concrete products: 1 – stationary board equipping; 2 – sliding trays; 3 – arbolit mixture; 4 – up-and-drain platform; 5 – electric winch; 6 – flexible cable; 7 – forming-drying trolley; 8 – hardening zone (tunnel dryer); 9 – transfer car**

In this context, a fundamental principle was the intensification of the entire factory line and the product quality increase. Improving the wood concrete quality is achieved by the following technology solutions: qualification method of filler fitness for the use in wood concrete, "cellulozation" of filler in the process of its gentrification in an alkaline medium (Bissenov et al., 2004; Bissenov, Uderbayev, 2004), biogentrification of filler on the stage of soaking; introduction of complex mineral supplements for strengthening the framework of wood concrete structure; control ways of changes in the density of molded products during the pressing; repeated pressing; the use of electro-mechano-chemical way of activation for binding properties of ash and slag mixture.

The finely ground sand dunes and limestone rubble were used together with sodium liquid glass for reinforcing the frame of wood concrete structure. The taken measures allowed to improve the filler surface, thus forming a mineral film. In the process of wood concrete curing with complex mineral additives and sodium liquid glass, a solid substance reinforcing its structure is formed. It is assumed that the process goes under the following chemical reaction:

$$Na_2O * nSiO_2 + CaCO_3 = 2NaCO_3(n-1)SiO_2 + CaSiO_3.$$

The introduction of complex additive forms a calcium silicate by reacting of a natrium water glass and dispersed particles of limestone speeding up a crystal formation of hardening bind substance. At the same time, the particulate phase of limestone, expanded clay and sodium silicate forming a mineral layer on the surface of the filler, reduces the possibility of readily diffusing sugars from the filler in a cement-ash paste. Improved traction in the "rice husk – cement stone" system occurs also due to a larger number of mortars and the increase of the contact area between individual structural elements.

Subsequently various binding compositions of wood concrete and binding mixtures, devices and method for activating ash-filled binders, the ways of wood concrete mixture preparation were under development. Thus, their technical novelty is confirmed by their preliminary patents of the RK. The taken measures improve the conditions of adhesion with contact surface, thus increasing the prerequisites for strengthening the wood concrete durability. It should be noted that the energy of adhesion processes is determined by the following factors: kinetics of penetration of a glued substances in the liquid state in the capillary pores of the other porous solid state, structure of material and its surface energy and surface tension of the adhesive substance in the liquid state, and the phenomenon of wetting characterized by contact angle, liquid and solid.

The implementation of modern technology for wood concrete production promotes not only the development of industry for building materials and products, but also addresses a solution of the issue of large waste utilization.

Calculation of the wood concrete cost effectiveness is performed according to the "Instruction on determining cost effectiveness of use of new technology, inventions and innovations in construction. CN 509-78". Determining the economic efficiency of the introduction of the MEP activation of binder in the production of wood concrete blocks is calculated by comparing the cost of production per unit of output by the known technology and the proposed project. Wood concrete blocks as a new material made by the proposed technology of filler preparation by the size of 0.2 x 0,2 x 0,4 m, the base material – wood concrete blocks of 0.2 x 0,2 x 0,4 m manufactured according to the national standard №19222-84 "Wood concrete and its products. General technical requirements". The annual economic impact is defined by the formula:

$$Э = \left[ (З_1 - З_2) - E_н \frac{K_з}{A} \right] x A, \quad (1)$$

where $З_1$ and $З_2$ – the given costs of production on base and new material respectively, tenge; $E_н$ – the normative coefficient equal to 0.15; $K_з$ – capital costs of implementing the measures, tenge; A – the annual production volume, $m^3$.

At a plant power in 2,000 $m^3$ of wood concrete products per a year, the given costs per 1 $m^3$ of wood concrete on the existing technology of production compiled $ 254.90 and on the proposed project – $ 216. In this case, the expected annual savings will be:

$$Э = \left[ (254.90 - 216) - 0.15 \cdot \frac{1340}{2000} \right] \times 2000 = 77599\, \$ / year$$

or $ 38.9 of savings from each $m^3$ of wood concrete products. Additional savings are provided by the increased strength of wood concrete blocks and eco-friendly technology made on rice husk and reduce the number of defects by 15% in the costs of a product unit (Table 1).

*Table 1.* **Comparative estimations of manufacturing costs of 1 $m^3$ of wood concrete**

| № | Costs | Measured unit | Amount of material per 1 $m^3$ of wood concrete | | Unit price ($) | Amount per 1 $m^3$ of wood concrete ($) | |
|---|---|---|---|---|---|---|---|
| | | | By the existing technology | Proposed project | | By the existing technology | Proposed project |
| 1. | Portlant cement | kg | 360 | 216 | 0,17 | 61 | 36,72 |
| | Fly ash | kg | - | 144 | 0,2 | - | 28,8 |
| | Barium chloride | kg | - | 18 | 2 | - | 36 |
| | Sodium silicate | kg | 19,8 | - | 2,7 | 53,46 | - |
| | Rice husk | kg | 240 | 240 | 0,13 | 31,2 | 31,2 |
| | Calcium chloride | kg | 8 | 4,8 | 2,4 | 19,2 | 11,52 |
| | Water | $m^3$ | 0,66 | 0,70 | 0,66 | 0,4356 | 0,462 |
| | Total | | | | | 165,50 | 145 |
| 2. | Basic salary of workers | tg | - (6 peop.) | - (7 peop.) | 340 | 70 | 55 |
| 3. | Electricity | kWt | 6,2 | 12,2 | | | |
| 4. | Additional depreciation and other changing resources | tg | | | 0,9 | 1,4 | 0,9 |
| 5. | Total depart-ental expenses | tg | | | | 6 | 5 |
| | Total | | | | | 254,90 | 216 |

Note - calculations are made by the authors.

$$Э_1 = (38,9 \cdot 0,15) \times 2000 = 11670\, \$$$

Wood concrete products are used in construction in the form of panels and blocks, cover plates for combined roof and floor slabs, reinforced by concrete bars or supporting framework, partition plates, monoliths etc. Wood concrete proved itself as a great wall material in construction. Due to its macroporous structure, this type of concrete has valuable features, especially for agricultural buildings, such as high thermal insulation, the ability to maintain drying conditions in the premises because the surface does not condense moisture and does not increase the moisture content in walls. Constructed with such wood concrete garages, livestock buildings and administrative buildings studied by the authors were built on the basis of wood concrete blocks during 11 September – 23 November, 2008. The walls were built of blocks of 200x200x400 mm with the density of 850 kg/$m^3$. Wood concrete plates of the size 600x400x250 mm with the density of 650 kg/$m^3$ were used as insulation in coating. Wood concrete products were produced on the basis of complex preparation of raw materials in the production building of JSC "Kurylys".

Production and use of wood concrete has several advantages as compared to traditional building materials:

– reducing building mass (weight per unit of 200 x 200 x 400 is 7–7.5 kg.);

– decreasing a complexity of building construction;

– reducing up to 40% of costs for construction of 1 $m^2$ of wall surfaces without compromising on strength characteristics;

– higher resistance to thermal and sound insulation of wall structures.

Wood concrete having a macroporous structure provides good ventilation in premises and high thermal performance allowing reduce energy consumption for heating and ventilation of buildings. No need for additional external heat /sound insulation. In today's mass housing of apartment buildings with using monolithic frame-bearing elements, especially important is the use of small sized blocks made of wood concrete. At the optimal thickness of envelope, self-supporting wall of 390 mm (for climatic zone in Almaty – 200 mm) is the equivalent to the one meter of brickwork, wood concrete considerably saves construction materials and therefore total material costs.

In individual construction the most obvious effect is in the construction of self-supporting walls of wood concrete blocks: at the wall thickness of 200 mm an average saving is around 40–60% of wall materials; the cost of heating (cooling) of premises in adverse climatic season is reduced by 2.5 times.

Wood concrete walls are well in dressing like by both traditional decoration, and a vast range of modern materials. The walls of houses built of wood concrete units with the unit weight of no more than 700 kg/$m^3$ become easy which is good for earthquake resistance. Wood concrete has better thermal insulation and sound quality as compared to lightweight concrete on mineral fillers; has good construction quality, easily sawed, fastened by nails, screws holding. Buildings constructed of wood concrete create high environmental comfort for people, and the sanitary indicators are identical to those of wooden house.

All this clearly shows the high efficiency of wood concrete blocks which need to be more widely used in the construction sector.

*Table 2.* **Cost effectiveness of wood concrete block application (as compared to traditional bricks) per 1 $m^2$ of wall**

| Cost | Wood concrete (400-200-200). Wall thickness for Almaty – 200 mm | Brick (Wall thickness for Almaty – 510 mm - 2 bricks) | Foam block (500-300-200) Wall thickness for Almaty – 300 mm. |
|---|---|---|---|
| Consumption of materials | 1 $m^2$/(0,4 x 0,2) = 12 pc. | 1 $m^2$(0.12 x 0,065) x 2 = 200 pc. | 1 $m^2$/(0,5 x 0,2) x 1 = 10 pc. |
| Cost of materials | 12 x 3$ = 36* $. | 200 x 0,3 $ = 60 $ | 10 x 4,4 $ = 44 $ |
| Cost of work | 12 x 1$ = 12 $ | 200 x 0,1$ = 20 $ | 10 x 1,7 $ = 17 $ |
| Amount of costs | 48 $ | 80 $ | 61 $ |

Note: * - at prices of 2004.
The calculations were made by the authors.

Application of wood concrete blocks is primarily spread among private developers for the construction of houses up to 2—3 floors and having high requirements for performance characteristics of a building (environmental safety materials, comfortable living created by a view of construction materials, low cost of building heating without reducing its carrying capacity and strength). Applying this new material houses as individual buildings, repair and mechanical workshops and agricultural buildings were built.

Total cost difference for a wood concrete wall compared with the most common building materials — ordinary brick and concrete block for the wall area of 1 $m^2$ is (Table 2):

— under the brick wall thickness of 510 mm (in 2 bricks): 80 - 48 = 32 $/$m^2$;

— under the brick wall thickness of 380 mm (in 1.5 bricks): 58 - 48 = 10 $/$m^2$ (not including the difference in quantity and therefore in the costs of the solution);

— under the foam block wall thickness of 300 mm: 61 - 48 = 13 $/$m^2$ (despite the need for laying special adhesive for foam blocks, 25 kg./$m^2$ = 17 $).

Note that the thickness of the brick wall in 1.5 bricks is insufficient for regulatory insulation, and it is likely to have additional heat insulation.

When comparing the wood concrete block with a foam block the former reveals a number of advantages:

— bulk density of wood concrete is less than that of foam concrete by 15—20% on average, therefore, for achieving the same thermal conductivity a foam concrete wall should be 10—15 cm thicker than a wood concrete wall;

— due to the presence of vertical cavities 90x90 mm by 2 pcs. in each block it is possible to pass the vertical concrete "cores" in masonry reinforcement and device to strengthen the building frame and therefore enhance the earthquake resistance.

Unlike the foam concrete block, a wood concrete block perfectly "holds" screws and nails, and this feature greatly facilitates further construction and finishing works (device partitions, windows and doors, plumbing and electrical linkage equipment, fixing a variety of household appliances etc.)

**Conclusions.**

1. Wood concrete products are used in the construction in the form of panels and blocks, cover plates for combined roof and floor slabs reinforced by concrete bars or supporting framework, partition plates, monoliths etc.
2. An effective technology based on the method of pressing with modernization of technological conversion and the use of local raw materials and industrial wastes is developed.
3. Rice husk wood concrete has better thermal insulation and sound quality as compared to lightweight concrete on mineral fillers; it also possesses good building properties. Buildings constructed of wood concrete, create more environmental comfort for their residents and they are identical to a wooden house by their sanitary indicators.
4. High efficiency of wood concrete units is grounded by its practical application in the construction of various buildings and structures. At a power plant of 2,000 $m^3$ of wood concrete products per year, the given cost for 1 $m^3$ of wood concrete

by the existing technology of production made up $ 254.90, and in the proposed project it equals to $ 216. In this case, the expected annual savings will be $ 77,599 per annum.

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