E3S Web of Conferences **709**, 05001 (2026) https://doi.org/10.1051/e3sconf/202670905001
ICERE 2026

Organic Waste Used for Monolithic Wall Construction in Low-Rise Buildings

Vjacheslav Zaprudnov [1*], *Dmitriy* Burmistrov[1], *Galina* Gorbacheva[1], and *Zoltán* Pásztory[2]

[1] Bauman Moscow State Technical University (National Research University) (Mytishchi Branch), 1, 1st Institutskaya Str., Mytishchi, Moscow Region, 141005, Russia
[2] University of Sopron, 4 Bajcsy Zs. str Sopron 9400, Hungary

Abstract. This study presents a production technology for monolithic three-layer walls incorporating thermal insulation based on organic waste materials, such as hemp chaff, to enhance sustainability in low-rise construction. Key materials include Portland cement M400, calcium chloride additives, and organic fillers compliant with GOST 19222, prepared in forced-action mixers for at least 8 minutes. Wall formation utilizes large-panel formwork with hinged sections, enabling horizontal pouring of layers: inner heavy concrete (100 mm for external walls), wood-cement insulation (160 mm for external walls, density up to 500 kg/m³, strength B0.35–B1), and outer protective concrete (40 mm for external walls). Compaction involves vibrators and tampers, with curing under natural conditions at an air temperature of at least 15°C and 60–80% humidity, reaching approximately 50% design strength in three days at 18–25°C.

1 Introduction

The use of raw nature-based materials is essential to modern sustainable construction practices. Nature offers a wealth of yet unutilized renewable materials that present considerable advantages. The construction industry is responsible for a considerable amount of carbon dioxide emission from material production, shipment and building. Therefore, organic waste materials such as bamboo or wood have great advantages of being utilised [1-6]. To even use these materials instead of other inorganic parts is highly beneficial, as it helps reduce the carbon footprint of the building.

Other research findings on this topic have been reported by scientists [7-9], including those based on experience with monolithic low-rise construction using wood-cement materials in the Krasnodar Region (Russia) [1,2]. The studies conducted have led to the conclusion that three-layer walls are the most appropriate option for structures using wood-cement material. Such structures contain an inner load-bearing layer of heavy or light concrete, a thermal insulation layer of wood-cement material, and an outer protective layer of concrete or cement-sand mortar.

* Corresponding author: zaprudnovvi@bmstu.ru

Recent article deals with the usage of wood waste materials in monolith concrete structures focusing to the technology and the local preparation to minimize the transportation load. Besides that, it is important to keep the technology in a low level which can be implemented without high technology and high carbon footprint machines.

2 Materials and Methods

The process of erecting walls in precast and monolithic housing construction involves: preparing a wood-cement mixture at the construction site; delivering mortar and concrete by truck, or preparing them at the construction site; forming wall structures; curing wall structures; and lifting and erecting wall structures.

Materials that meet the requirements of GOST 19222 are used to prepare the wood-cement mixture. These materials include: organic filler – hemp chaff without prior fractionation, dust screening, drying, or soaking in water, crushed to a maximum particle length of no more than 100 mm; Portland cement grade M400 (to reduce wall construction time, quick-hardening cements are recommended); and chemical additive – calcium chloride.

The wood-cement mixture is prepared in forced-action mixers of the SB-138 type. The components of the wood-cement mixture are fed into the mixer in the following order: aggregate, water (taking into account the water content of the wet aggregate), chemical additive solutions, and cement. Mixing time depends on the mixer used, its design, and the intensity of the mixing action. Our research has shown that the mixing time should be at least 8 minutes. The wood-cement mixture can be prepared simultaneously with the placement of the concrete layer of the wall structure.

The wall structures are formed using large-panel formwork developed at the Moscow State University of Forestry. The formwork consists of frame panels. Each panel consists of two parts – a base and a wall. The two parts of the panel are connected via a hinge, allowing the wall section to rotate 90° relative to the fixed base section during construction, assuming a horizontal or vertical position.

The movable wall section bears the bulk of the load during concrete placement and compaction, and when the wall panels are moved from a horizontal to a vertical position. The formwork portion of the wall panel is constructed as a sheathing consisting of longitudinal, transverse, and diagonal purlins. The formwork is designed to withstand a load of P = 10 kN/m², taking into account the overload factor and dynamic loads.

The complete formwork kit consists of 10 formwork panels of four standard sizes, removable sidewalls, trays with jacks, opening formers, ties, and plinth formwork panels. The height of the wall portion of the panel is 3.0 m, and the plinth portion is 0.65 m.

To reduce labour costs during installation and dismantling, the formwork panels are oversized, allowing for the installation of two panels along each wall of the house. The formwork can be installed either as individual panels or as panels across the entire wall. Formwork panels are installed along the perimeter and interior load-bearing wall of the house using a truck crane, ensuring that the wall portion of the panel is strictly horizontal (Fig. 1). Next, plinth formwork panels are installed on the interior side of the wall, secured with tie rods inserted in conical bushings.

Recess formers are attached to the horizontal wall panels, and volumetric side panels are installed, which are secured to the panels with tie bolts. If decorative tiles are planned for the exterior surfaces, the tile carpets are laid on the formwork, followed by the installation of reinforcement cages, various recess formers, ventilation units, and electrical conduits. The reinforcement cages are installed on spacers to ensure that the reinforcement is contained within a protective layer of mortar or concrete.

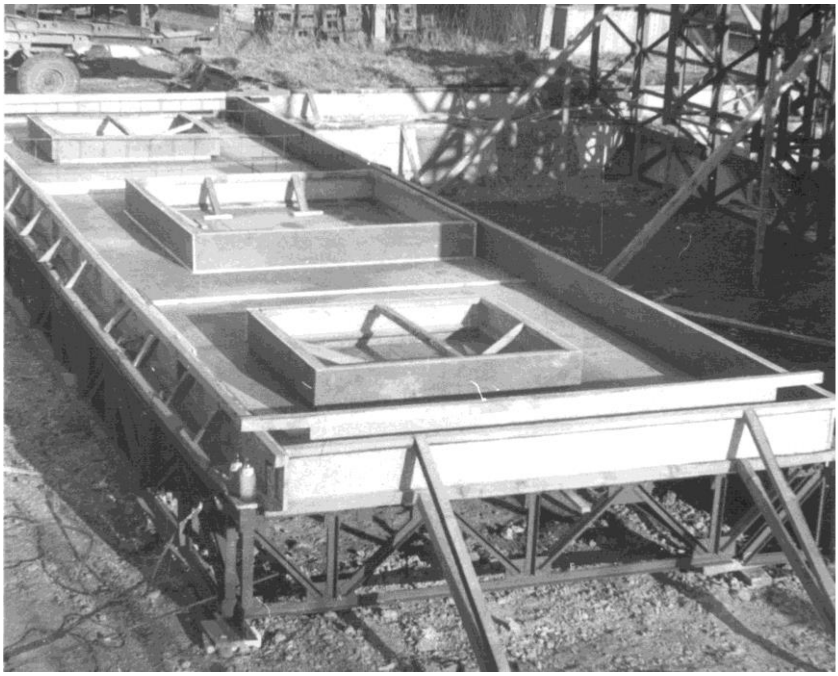

Fig. 1. Wall panel formwork with installed sides and opening formers.

Fig. 2. Wood-cement mixture placed in the formwork.

Filling the formwork with concrete and wood-cement mixture should only begin after thoroughly cleaning the formwork surfaces of cement mortar and construction debris, and checking the proper installation of the reinforcement cage and embedded parts.

To reduce adhesion between the concrete and the formwork and ensure stripping, the formwork is lubricated with special lubricants, such as ESO-GISI-151, before concreting.

Wall concreting begins with placing a lower textured concrete layer of the specified thickness. The concrete mixture is placed using a concrete pump or concrete distributor. The concrete mixture is distributed sequentially at several points uniformly across the entire surface of the wall being concreted. Filling and levelling the concrete layer across the entire surface of the wall formwork should be completed as quickly as possible, but in no more than 30 minutes. Compaction of the concrete layers of three-layer wall structures can be accomplished using surface vibrators or vibrators mounted on the formwork. A concrete mix layer up to a thickness of 50 mm is compacted in a single pass at a rate of 0.4–1 m/min. The recommended surface vibration frequency is 2800–6000 rpm, with an oscillation amplitude of 0.2–0.5 mm.

After the concrete layer is laid, a wood-cement layer is laid (Fig. 2). The wood-cement layer must be laid over the entire formwork area before the cement in the concrete layer begins to set. The laboratory determines the overlap time depending on the type of cement and the ambient temperature. To ensure the required thermal insulation properties of the wood-cement layer, its thickness must be maintained with an accuracy of ± 10 mm.

Rigid wood-cement mix is compacted by manual or mechanical tamping. Manual and pneumatic tampers are advisable for lightly reinforced structures.

Porized wood-cement mixtures with a minimum flow rate of 2 cm can be compacted using internal vibrators with a flexible shaft and a vibrating tip no larger than 50 mm. The thickness of the compacted layer should be no more than 1.25 times the working area of the vibrating tip. The vibrator's increment should not exceed 1.5 times its radius of action. For approximate calculations, the average radius of action of vibrators is 25–30 cm. When vibrating, do not rest the vibrator on the reinforcement, especially at the joints between the rods. The stiffer the mixture, the longer the vibrating time. Excessive vibration leads to stratification of the mixture. The compaction time for wood-cement mixtures is 20–50 seconds. The degree of vibrating compaction is determined visually. Compaction is considered sufficient when the mixture stops settling, laitance appears, and air bubbles cease to form. The vibrator's zones of action should overlap.

Particular attention should be paid to compacting the wood-cement mixture at the formwork edges, near the openings, and so on to prevent the possibility of cement paste leaking from the top layer of concrete and the formation of thermal bridges.

Next, the concrete is placed using a concrete pump. The top layer of concrete is placed until the surface of the wood-cement mixture dehydrates due to evaporation and moisture absorption by the aggregate. A type SO-132A vibrating screed is used to compact, level, and smooth the top layer of concrete. The completed wall structure is shown in Fig. 3.

During the initial curing period of the poured concrete mix, it is necessary to maintain favourable temperature and humidity conditions to prevent significant thermal and shrinkage deformations of the wood-cement mixture.

Early dehydration of the wood-cement mixture due to evaporation can slow or stop the curing process and lead to a loss of strength, as well as significant shrinkage and cracking.

Contact of the wood-cement mixture with moisture causes swelling of the wood filler. Curing of three-layer structures with wood-cement thermal insulation material should occur under natural conditions at an air temperature of at least 15°C and a relative humidity of 60–80%.

After the wall structures have been formed, they should be protected from atmospheric influences (with polyethylene film, thermoelectric mats, etc.). Maintenance methods for monolithic three-layer structures depend on the type of structure, the type of cement, and local climatic conditions. Walking on concrete structures, as well as finishing and repairing defects, is permitted no earlier than after the concrete has cured.

When curing structures with a wood-cement composite insulation layer made with grade 400 Portland cement and more, under natural conditions at 18-25°C and a relative humidity of 60-80%, the wood-cement composite material reaches 50% of its design compressive strength in approximately three days.

Fig. 3. Curing the structure until the concrete reaches its installation strength.

Fig. 4. Lifting a three-layer wall structure using a truck crane.

Once the wood-cement composite material has reached 50% of its design compressive strength, the three-layer wall structures can be installed in their designed positions.

The walls are vertically positioned by rotating them around a fixed hinge together with the formwork panel. Lifting is performed using a 10-ton truck crane with a boom length of 14 m (Fig. 4). Before installing the panels in a vertical position, the basement is waterproofed and a 2-3 cm thick levelling layer of cement-sand mortar is laid over the waterproofing on the building's basement. To prevent panel displacement along the formwork plane during installation, it is secured to the formwork structure using rebar extensions. The installed wall structures are temporarily braced with metal braces and screw jacks. The wall structures are fastened together by welding Class A-I rebar extensions with a diameter of 12 mm, located at the ends of the panels on two levels. After the wall panels are permanently secured, the formwork panels are lowered, and the formwork is dismantled. Corner and end joints in the panels are sealed with lightweight concrete after the air barrier layer is applied and the sealing gaskets are installed.

3 Results

1. The results of this study show that the monolithic connection of layers in three-layer structures is achieved by laying them sequentially during manufacturing in a single technological cycle. The absence of additional discrete connections eliminates the formation of heat-conducting defects, similar to other types of three-layer structures, and maximizes the thermal resistance of the panels.

2. The engineering of three-layer structures with monolithic bonding between layers should be carried out in accordance with the economically viable thermal resistance of structures to heat transfer, determined by thermal engineering calculations for wall enclosures. The layer of heat-insulating wood-cement material in the external walls (Fig. 2) is 160 mm thick and is protected on both sides by layers of heavy concrete. On the side facing the interior of the room, the thickness of the concrete layer is 100 mm, and on the outside, the wall structure is protected from atmospheric moisture by a 40 mm thick layer of concrete. The internal load-bearing wall consists of a layer of wood-cement material protected on both sides by layers of heavy concrete 50 mm thick. The total thickness of the internal wall is 200 mm (Fig. 3).

3. The thermal insulation layer of wood-cement material in wall structures is made with an average density of up to 500 kg/m^3 and a strength class of B0.35 – B1. The inner load-bearing layer is made of B15 concrete with a density of 2400 kg/m^3, and the outer protective layer is made of B15 concrete with a density of 3400 kg/m^3, and frost resistance of M_{rz}50.

4. Studies on the performance of the thermal insulation and structural layer made of wood-cement material and concrete in three-layer wall structures have shown that the actual load-bearing capacity of such compressed structures is 2.5–3 times higher than the theoretical capacity calculated using the equations in regulatory documents. In bendable structures with monolithic bonding of layers, wood-cement material in the tension zone participates in the absorption of tensile stresses together with reinforcement under short-term and long-term loads.

5. In developing structural reinforcement for the walls of a residential building, in accordance with the requirements of regulatory documents on design and in view of the use of three-layer structures with monolithic bonding of layers, it is customary to reinforce walls with spatial frames consisting of longitudinal flat frames and separate rods, which are welded at the points of intersection using spot welding.

6. Rebar cages and fasteners must be manufactured in accordance with the requirements of GOST 10922 ‘Welded reinforcing products and inserts, welded, lap and mechanical joints for reinforced concrete structures. General specifications’ and GOST 14098 ‘Welded joints

of reinforcement and inserts for reinforced concrete structures. Types, constructions and dimensions. Flat frames are joined together in space directly in the formwork at the construction site by knotting the rebar crossings with binding wire. Rebar for wall structures is made of steel grades A-I, A-II, and Bp-I.

7. The proposed technology for the construction of residential buildings with prefabricated monolithic walls of a three-layer structure involves the manufacturing of large wall panels in a site setting and their installation in project position, with mandatory fastening between them using welded metal elements.

8. To assemble a two-apartment, three-room residential building with dimensions of 11.4 x 8.8 m using the proposed technology, it is necessary to manufacture 10 wall panels with the following dimensions: 7500 x 2800 x 300 mm – 2 pcs.; 2600 x 900 x 200 mm – 1 piece; 4400 x 2800 x 300 mm – 4 pieces; 3900 x 2800 x 300 mm – 2 pieces; 3900 x 2600 x 200 mm – 1 piece.

4 Conclusion

As a result of the research, a technology was developed for the manufacturing and erection of walls from three-layer structures with monolithic connections between layers for prefabricated-monolithic low-rise housing construction. The technology makes it possible to increase the efficiency and load-bearing capacity of existing structural designs, compressed and bent structures based on wood-cement materials.

It is recommended that three-layer structures be constructed with a middle layer of wood-cement material for thermal insulation and structural support, and protective load-bearing outer layers of heavy concrete, which significantly improves their strength, deformation and thermal insulation properties.

Three-layer structures made of different types of concrete with a monolithic connection of layers across the entire contact surface should be made load-bearing, self-supporting and reinforced with a frame, with working reinforcement placed in the load-bearing concrete layers.

Along with the general requirements for three-layer walls with monolithic layer connections established by building codes, the developed structural solutions provide, during the manufacturing period (before the wood-cement material reaches its full strength), part of the vertical and horizontal loads from the structure's own weight, technological feasibility of construction, characterized by minimal labor costs, and the creation of a distinctive architectural appearance for the building.

Three-layer structures can be used as wall panels, block lintels for block cutting of walls, and lintels above openings in large wall panels with openings. The most characteristic forces are loads from floors, wind and snow loads, as well as their own weight.

Studies on the performance of wood-cement materials in structures made of various types of concrete with monolithic layer bonding confirm that under short-term and long-term loads, the wood-cement material of the middle layer participates in the absorption of compressive and tensile forces together with the outer concrete layers and reinforcement.

The integrated building systems like this organic filled monolithic wall can reduce the cost and the time of building, that is why further development can be done for optimizing the building efficiency and improve the thermodynamical properties. Despite of this is a promising technical solution still has the potential for perfection and make it more competitive in the market.

References

1. A.S. Shcherbakov, V.I. Zaprudnov, V.I. Kucheryavyy, E.F. Miroshnikova, *Development of wall panels from arbolite and their implementation in production*, in Nauchnyye trudy / Moskovskiy gosudarstvennyy universitet lesa [in Scientific Proceedings / Moscow State Forest University], **293**, 5–13 (1997) (in Russian)
2. V.I. Zaprudnov, Trekhsloynyye konstruktsii s drevesno-tsementnymi teploizolyatsionnymi sloyami [Three-layer structures with wood-cement thermal insulation layers], 2nd ed. (MSFU Publ., Moscow, 2006) (in Russian)
3. V. Zaprudnov, V. Sanaev, S. Karpachev, D. Levushkin, G. Gorbacheva, Mater. Sci. Forum, **972**, 69–76 (2019)
4. F.Z. Gigar, A. Khennane, J.-L. Liow, B.H. Tekle, E. Katoozi, Constr. Build. Mater., **400**, 132793 (2023)
5. D. Maier, D.L. Manea, D.-R. Tămaș-Gavrea, A. Țiriac, P. Costin, J. Compos. Sci., **8**(11), 474 (2024)
6. J. Zhao, M. Sufian, M.A. Abuhussain, F. Althoey, A.F. Deifalla, Reviews Adv. Mater. Sci., **63**(1), 20230181 (2024)
7. E.F. Valuyeva, Stenovyye konstruktsii iz arbolita na osnove kostry konopli [Wall constructions from hemp hurd arbolite], Extended Abstract of Cand. Sci. (Eng.) Dissertation, Moscow, 1998, 20 p. (in Russian)
8. V.V. Stoychev, Tekhnologiya vozvedeniya mnogosloynykh monolitnykh konstruktsiy v skol'zyashchey opalubke [Technology of erecting multilayer monolithic structures in sliding formwork]. Extended Abstract of Cand. Sci. (Eng.) Dissertation, Moscow, 1980, 25 p. (in Russian)
9. O.M. Schmit, Opalubka dlya monolitnogo betona [Formwork for monolithic concrete] (Stroyizdat Publ., Moscow, 1987) (in Russian)