Straw in architecture: traditions and future

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Abstract – The study has analyzed the use of natural and eco-friendly material – straw – in construction activities. The history of straw housebuilding, construction methods of straw, advantages and disadvantages of straw houses were considered. Examples of practical application of wood-straw panels, their production technology are given. The were shown mistakes made during the construction of tje straw house (the danger of straw decay, mice, difficulties with hanging heavy furniture elements on the walls, unplanned during the design of the frame, the protection of plastered walls from wetting in the process of use) and the methods of their removal or early prediction and resolution. There was considered the stage construction of a country house with straw for 50 days. The were presented foreign and domestic examples of eco-houses with straw: their constructive and planning solution. And also shown the advantages of straw when comparing the characteristics of straw and bricks in building materials systems.

Key words – eco-friendly material – straw, straw architecture, construction methods, wood-straw panels, ecological architecture.

I. Introduction

Annually in the world a huge amount of straw is produced, most of which remains in the fields or is burned. This raw material can be used in construction, which would solve many social and economic problems in various countries of the world. The practice of building houses of straw is known for a long time and has been used in Ukraine, Canada, Holland, the United States and other countries. For example, in the USA intensive construction of houses from straw began in the 19th century and is connected with the invention of a steam press for laying straw in bales and blocks. In our time, the technology of building straw houses is reviving and intensively spreading. In Western Europe, there is government support and interest in building eco-houses. This program is designed to reduce the overall energy consumption in the manufacture of building materials and the exploitation of low-rise housing. The project of eco-house made of straw can be made using wireframe and frameless technology. In first case, a frame is constructed of wood first (less often – metal). This technology is somewhat more expensive, but the house is more reliable. The latter option involves the erection of housing immediately out of pressed straw blocks. The timing of the building depends on the choice of technology. On average, "turnkey" construction takes from four to eight months. (Pic.1, 2)

At the same time, I would like to note that an ecologically clean house made of straw returns us to old traditions, but at the same time, such housing allows us to feel the full comfort thanks to modern technologies and design solutions.

Pic. 1-2. village Hotyanovka, Kiev region.
The biggest house made of straw in Ukraine

II. History of straw housebuilding

Since ancient times, wooden blocks have been used in construction. The modern construction of thatched buildings began in the late of 19th century in Nebraska, USA. In Nebraska, there are vast steppe spaces, on which a large number of cereals are grown. Settlers faced a shortage of drillwood, so the first straw houses were built without a skeleton.

Hand press for hay was patented in the US in 1850. By 1872, balers were sold on a cart drive. In the middle of the 1880's, steam balers began to be produced serially.

Living houses of about 70 m² were built, as well as shops, schools, and facilities for other purposes.

In the 1980s, there was renewed interest in thatched house construction. In Russia, the first building of straw blocks was built in 1994 in the village of Mayak near Chelyabinsk.

In Europe, the leader in straw building industry is France, which has built more than 1500 buildings. The first European straw building, dating back to 1921, is preserved there. The world leader is the United States, where the straw housebuilding is massive (over 100,000 houses). In the last 25-30 years, the technology of straw production has become widespread in different climatic zones from Norway to Australia.

III. Construction methods

Straw houses are built in two types: frame and without a frame.

In a frameless method, the bearing walls are laid directly from the straw blocks. Blocks are fastened together by vertical stakes or mortar. For strength, metal or plastic rods can be used instead of wooden stakes – the lower end of the rod is attached to the foundation, to the upper end of the rod is fastened the nut for the screed of the straw blocks. Advantages of this method of construction are low cost and simplicity of erection.

In the wireframe method, a wooden supporting frame is built, between which the straw blocks are laid. Blocks are densely packed into the frame, it is also possible to use bonding methods similar to those used for the frameless method. Straw blocks are placed on a small elevation above the floor – to protect against moisture penetration.

The frame is similar to that used in the construction of frame houses. A double frame is also possible (with

two rows of vertical pillars, between which the blocks are stacked).

Over the stacked straw blocks, a metal or polymer mesh is attached and several plaster layers up to 75 mm thick are applied. Plaster protects straw blocks from water, fire, rodents and other pests. (Pic.3)

Straw blocks can be used both in dry form as well as with clay mortar treatment. In the latter case, the block before stowage is dipped for a short time in a thin clay solution. This technology was called "light Saman" (the share of clay is not more than 10%). It gives advantages in accuracy of wall geometry, strength and fire safety, but more time consuming; the walls are harder to dry, they dry long enough and, in wet weather may become moldy while drying, and somewhat worse keep the heat. (Pic.4)

Pic 3. Frameless

Pic. 4. Framework

IV. Characteristics of the building material – straw

For the construction are used blocks from pressed straw. Straw is pressed with balers, or manually on special presses. The compressed block is tied with a metal wire, or a nylon cord. The average block size is 90 cm in length, 45 cm in width and 35 cm in height. The weight of the block is about 23 kg. Either 40cm × 50cm × 50cm (40cm × 50cm × 100cm) at a density of 100 kg / m³. Usually rye, flax or wheat straw is used, but hay can also be used.

The weight of a good block should not be too large (heat-insulating properties worsen and laboriousness of the erection process increases) or too small (especially important for frameless construction). The straw block must be of correct shape and tightly bound. The best type of strapping is a polymer cord. (Pic.5).

Pic. 5. Straw and its collection

V. Advantages and disadvantages of straw. Necessary conditions for construction

Low cost. A straw block costs about 1000 times cheaper than a brick one.

Availability of materials.

Light weight. Due to the light weight of the straw blocks, the building does not require a heavy foundation, no lifting devices are required for the construction.

Low labor costs.

Good heat conductivity. The thermal conductivity of the straw (0.050-0.065) is 4 times lower than that of the tree , and 7 times lower than that of the brick (0.56-0.7), which leads to lower costs for house heating.

Good soundproofing indicators.

VI. Production of wood-straw panels. The essence of technology. Characteristics of the straw panels

The summer of 2013 is marked by interesting events in eco-building. In Ukraine, simultaneously, several construction companies developed and manufactured the first wood-straw panels.

The essence of the technology is as follows:

- According to the prepared draft of the house, separate components of the walls are developed – panels (in the right amount and the right sizes).
- In production, the wooden frame of the future panel is clogged with straw bales with the help of a hydraulic press (as is the case, see the picture below).
- The lateral surface of the panels is tamped, leveled, if necessary – sheared;
- The resulting product is transported to the site.
- Next, the wall panels are mounted on the previously erected foundation.
- The walls are covered with a layer of clay plaster, after which they begin finishing the walls. (Pic.6)

Characteristics of straw panels:

- dimensions of a standard straw panel – height – up to 3 m, width – 1 m, thickness – 0,45 m
- the weight of such a product is from 70 to 250 kg (depending on the density)
- recommended insulation density (straw) – 150 kg / m^3
- the vertical load that each panel can withstand – 7 tons
- plasterd wall of such panels withstands 90-120 minutes. direct exposure to fire (higher fire resistance than most other building materials).

Рис. 6. Wood-straw panel

VII. Errors in the construction of a house with straw

Danger of straw decay with a constant source of moisture. Even if this is a local decay, such a wall should be disassembled and redeployed, it will take 2-3 days without involving hired workers.

Mice. The ignorance of the technology of frame assembly, styling and methodology of plastering will turn out to be unexpected problems in the future. Mice do not eat rye straw, but with strong frosts they will gladly settle in the cracks and voids left in the rush by the builders.

Difficulties with hanging on the walls of heavy elements of furniture, unplanned at the design of the frame. Nevertheless, shelves of moderate weight or decorative embellishments will not be difficult to hang. To do this, use a few 25-30 cm wooden stakes, which are perfectly clogged in straw and hold firmly enough. The plaster adds strength.

Protection of plastered walls from wetting during exploatation. This includes annual maintenance at home, especially plaster inside and outside the house, wherever it is possible to suction moisture. Legislation of a straw house. In the passport, you can not proudly write that your house is built on a new technology of straw bales. It will have to be registered as usual, a frame wooden house, with 40-50 cm of insulation in the walls. In this regard, consult with an architect who is aware of the list of official construction technologies. (Pic. 7, 8).

Pic.7. Restoration of a rain-washed facade.

The effectiveness of the waterproofing properties of clay plaster depends on the oil content and density of the clay itself.

Pic. 8. A low base and a slope from the house can be disastrous when spring flood or abnormal rainfall.

VIII. Straw houses abroad

The eco-building in Southern Finland, "The House for Hobbits", Stunning Modular Framework Houses from ModCell, the Carol Atkinson's straw blocks holiday House, Sustainable and Energy-efficient Houses of Straw Blocks, The First House of Straw Blocks in Rome, Eco House from straw

Pic. 9. Small ecohouse in the south of Finland

Pic. 10. House for Hobbits

Pic.11. Framework houses from ModCell

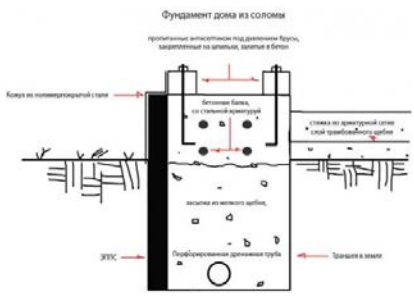
Pic. 12. Rest house from straw blocks by Carol Atkinson

Pic. 13. Stable and energy-efficient homes from straw block

Pic. 14. First straw blocks house in Rome

IX. The technology of building a country house from straw blocks in 50 days (Canada)

The main bearing structure of this house is made of straw according to the old technology "pillars and beams". It differs from the usual framed construction technology of houses, where the bearing support is rarely installed massive columns, connected by beams. It is permissible to use a small surface tape foundation lying on a drained cushion of gravel. (Pic. 15) Outside, the foundation is protected by the EPPS from freezing. This method does not apply to trophies.



Pic. 15. Foundation.

After the foundation is laid, we go to the floor set up on the ground. The interior space is covered with rubble and

trampled. (Pic.16-17) If you plan a set up of warm floors in a house of straw, then it is necessary to put 3-5 cm of the EPPS over the rubble.


Pic. 16-17. Laying the foundation

Such a section of the floor on the slabs makes it possible not to fill the floor instantly, but by stages without fearing that the concrete floor of the house of the straw will crack in unexpected places. In fron of the house the holes are drilled and two supporting piles for the porch pillars are poured. Under the porch, rubble is strewed and a thin (10 cm), divided into two parts, floating reinforced slab is cast. (Pic. 18)

Pic. 18. Floor

On the studs U-shaped steel supports under the beams of the pillars are welded or screwed. Pillars of the future house of the straw are set using a level or a vertical plumb line and are caught by the braces. Wooden beams are mounted over the supporting pillars of the straw house. Installation is carried out with the help of special steel angles. The rafter system is put together based on a ridge beam and not requiring puffs or braces.

On the porch pillars a pre-assembled farm is installed, reinforced with steel straps, stitched with studs and tightened with nuts. The roof of a house made of straw is covered with sheets of profiled galvanized iron. Also on the top of OSB can be used a simple fusible roofing or bitumen soft tile. (Pic. 19-22)




Pic. 19-22. Arrangement of constructive caracas and roof

The basis for laying straw blocks into the wall: a layer of waterproofing is put on the foundation, a sheet of OSB is laid on top, the bar is impregnated to the studs under pressure (the incisions on it are the factory treatment against cracks, which reduces the internal pressure in the bar). The poles are fastened with braces of steel tape crosswise. This tape and the pillars themselves are externally insulated with a waterproof membrane. Blocks of straw are stacked like bricks – with overlapping of vertical seams. Straw blocks are well cut with an ordinary chain saw. (Pic. 23-24).


Pic. 23-24. Arrangement of walls and window openings

We prepare the wall for applying cement (and not clay) plaster. We tighten the windows and doors with a packing tape and carefully glue the tape. Plaster will be applied mechanically using a compressor and a sprayer. Mechanized plastering. A mixture of sand and white cement (from lime stone) is recommended. Outside, the house is plastered with a mixture of sand and white cement – it is much more durable than portland cement and has a beautiful white color. The house does not need to be painted. (Pic. 25-26)


Pic. 25-26. Facing the house

Pic. 27 Hemming of soffits

Pic. 28. Ceilings and a roof in the house of straw are sheathed with lining

Pic. 29. Final look of the house

The plaster is carried out in two layers. The first roughing layer of the plaster during curing will shrink and crack. Drying time is several weeks. After drying out all the cracks and defects of the plaster are sealed. (Pic.27-29)

X. Straw versus brick and concrete (Assessment Methodology, Building Systems, Estimation of Construction Systems, "Solo Straw").

When choosing a building system, it is necessary to take into account many factors and make their integral evaluation. On the one hand, it is important to fully take into account all the significant characteristics, properties and aspects of the construction system. On the other – do not get lost in their diversity and multiplicity. These requirements, in our opinion, are best met by a point weighted criterial evaluation. The multiplicity of criteria helps to make the analysis more complete and comprehensive.

Under the construction system is understood the totality of the basic building materials, together with the ways of their use in the construction of the building. For example, the term "tree mass" means construction systems in which the tree is laid horizontally. This can be planed or rounded logs, glued beams, etc. If the same tree we use in the construction vertically, we get another construction system – wireframe. Besides wireframe it also consists of different wall materials.

To date many materials and building systems are known. Buildings can be made of wood, brick, concrete or combinations of these materials. Houses can be erected on frame, monolithic and other technologies.

It should be noted that the concept of a building system primarily characterizes the bearing walls. The foundation, roof, floors and partitions are to some extent independent of the materials and construction of the main walls.

Brick

Like other ceramic materials, bricks can have an increased specific activity of natural radionuclides in finished products. This is often found in situations where the radiological control of raw components is not performed properly. However for the effect on health it gets positive rating of "+1".

The opinion about the good thermal insulation properties of the brick is erroneous: to get at least a minimum standard heat resistance for Novosibirsk, it would take a wall of 2.8 m thick. The heat resistance of a common wall 1.5 cm thick (38 cm) is 0.7 m2 × oC / W, with the minimum required 3.7. Increasing the thickness of the brick wall for reasons of increasing thermal insulation does not make sense: even a "warm" (with voids) brick is not a heat insulator. Not insulated brick houses require large expenses for heating.

Brick – is not a cheap material. It requires relatively high laying skills of workers, and the construction speed is low. All this leads to a negative sum of points for the main group of criteria. According to the second group of criteria, brick received a rather high positive rating, but the third one again goes into negative. As a result, the overall low score is less than 30. (Pic. 30)

Concrete

An uninsulated concrete wall receives a total minus amount. Concrete due to variability of its composition may represent a greater or lesser danger for health. Studies have shown that the toxicity of concrete depends on the components used in the production. So, sometimes the ash used in its production can have increased radioactivity. Concrete on granite gravel is often with excessive radioactive radiation. (Pic. 31)

Foam Concrete

In general, foam concrete has a greater air permeability than ordinary concrete, and can be considered as neutral in terms of health effects. Having similar assessments for the second and third groups of criteria, foam concrete wins against the brick in the first group due to the best thermal insulation properties, speed, construction cost and current resource availability (availability in the market). This determines its relatively high overall score. (Pic.32)

Woodmass

House of solid wood (beam, log) has a good effect on health, but it is cold (the walls are thin, the insulation is weak). Wooden houses are expensive to operate and fire hazardous, which predetermines a low score for the main group of criteria. Woodmass got little points in other groups as well, which determined its presence in the group of outsiders. Woodmass houses certainly, require warming. But there is a nuance: good heat insulators for wooden walls (straw or reed mats) are not produced now, and the use of artificial insulants largely crosses the ecological advantages of wooden walls. (Pic.33)

Foamed concrete + styrofoam

The system "foam concrete + expanded polystyrene" receives
the sum of points comparable to the "carcass + minvata" system, somewhat winning in the first group of criteria and losing in the third.

Adobe

The house got a good amount of points, much bigger than the "brick" or "woodmass" ones. A significant role in this played the cheapness of construction, the availability of materials and good buffer properties. (Pic. 34)

Geokar

Frame walls with a geocar filler, having few shortcomings and many advantages, got a high score for all criteria groups and as a result a high total amount. (Pic.35)

Straw

The properties of straw as a building material are not widely known to the general public, and therefore it makes sense to dwell on them in more detail. To begin with, straw has high thermal insulation properties. They are 3.5-4 times higher than wooden across the fibers (and 6-7 better than along). This makes it possible to class the pressed straw to good heaters. The cost of operating straw houses due to good thermal insulation is low.

Straw is not only not harmful to health – it has healing properties. This is evidenced both by subjective assessments of living in straw houses, as well as objective evidence (for example, statistical studies of French physicians). Even a tree that has a high rating on this parameter loses to straw. The cost of construction form straw is one of the lowest. The current resource availability for straw blocks is low: the supply market is

not formed due to unfulfilled demand. Building systems from straw bales have a minimum of negative estimates by our method: only for the current resource availability, for building fire safety and resistance to long (more than a few weeks) moistening.

Pic. 30. Brick

Pic. 31. Concrete

Рис. 32. Foamed concrete

Pic. 33. Woodmass

Рис. 34. Adobe

Pic. 35. Geokar

XI. Statistics of houses which were built from straw in Ukraine

Pic. 36. House of straw near Odessa. The owner of the house and the author of the project Anatoly Lukian

Pic. 37. House of strawbales near Kiev. The owner of the house and the author of the project is Artem Domashenko

Pic. 38. A frame house with straw insulation under Poltava. Andrei Konyuk, Radion Khovanets, Oleg Ivanenko worked on project of the house and its construction.

Pic. 39. Straw house in Chernivtsi. The owners of houses and authors of the project are Maria Shutak and Victor Nitsovic.

Pic.40. The Straw House near Kherson.The author of the project and the owner of the house is Yuri Vaysblat

Pic. 41. House of straw in Kiev region. Construction of the house was handled by Valery Gomenyuk and his team

XII. Straw is the future of Ukrainian power engineering

The energy intensity of straw in pyrolysis modes (and now the equipment works exactly in this mode) is quite comparable with coal. According to experts, in average about 1.5 tons of straw per hectare per year are received by farms after harvesting. Of this volume, at best, 5-7 percent is spent on economic needs, forage, litter for livestock.

Technology of use for power engineering. Straw, not used in the farming, is burnt in specially constructed boilers. But the cost price of heat energy produced on straw in the boiler room is almost two times lower than

the boiler house on natural gas: 87.1 UAH / Gcal and 187.1 UAH / Gcal, respectively. The heat generating plant on straw with a capacity of about 0.5 MW consumes an average of 450 tons of straw (equivalent to an energy consumption of 6,800 GJ). Presumably, it will replace the fuel oil boiler with an efficiency of 80%. Incidentally, we note that the investment effect should also take into account 25% of the savings in thermal energy. Such boilers burn bundles (briquettes) of cereal straw, which makes it possible to provide schools, kindergartens, enterprises and other facilities with heating and hot water supply. Energy saving is obvious.

I suggest to consider the following tables:

TABLE 1
WEIGHT OF STRAW BALES DEPENDING ON SIZE. KG

Small square straw bale		15
4 x 4 (square)		150
5 x 4 (square)		240
8 x 3 x 2 (square)		150
8 x 3 x 3 (square)		450
8 x 4 x 3 (square)	2,4m x 1,2m x 0,9m	500-600
8 x 4 x 3 (square, consolidated)	2,4m x 1,2m x 0,9m	700-800
8 x 4 x 4 (square)		625

TABLE2.
PARAMETERS OF STRAW BLOCKS

Length of straw blocks	from 300 mm to 1200 mm
Width of straw blocks	460 mm
Height of straw blocks	360 mm

TABLE3.
ENERGY VALUE OF STRAW OF DIFFERENT CROPS IN HUMIDITY 15% PER TON (ACCORDING TO DATA OF TEAGAS)

Type of straw	Caloric content, MJ/kg	Energy content, kW.year/t	The equivalent of oil burning, l	Ash content, kg/t
Wheat straw	14,4	4,032	396	57
Barley straw	14,7	4,116	406	48
Rape straw	14,3	4,004	393	62
Hay	14,3	4,004	393	71

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