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**Straw bale construction as an
environmentally appropriate building
technique.**

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The .pdf file of this presentation, and the "Straw Bale Building in Siberia" report for Builders Without Borders about the project mentioned later in this paper, can be downloaded from:

<http://www.jakubwihan.com/>

The next important web page is:

<http://www.strawbalefutures.org.uk/>

This is the web page of Amazon Nails. Amazon Nails are a British not-for-profit social enterprise that have built so far over 100 straw bale buildings, mostly in the UK and Ireland,. They are the UK's foremost natural building experts, with 12 years of experience of building out of straw in UK's and Irish rough climate. This makes them one of the most experienced straw bale building professionals in the world.

0.1 Advantages of straw: *It is durable*

The straw bale house was invented in Nebraska, USA, just after the invention of the baling machine that was at that time horsepowered. Later, straw bale buildings were forgotten, thanks to the cement revolution in building industry.

Nobody was interested in houses of straw until the 1970's oil crisis, when they were rediscovered. In the 1980's straw bale building became a widespread alternative all over the USA. In Europe the straw bale revival started in the early 1990's. Amazon Nails introduced their technology in the UK in 1994.

The first great advantage of straw is that it is durable. There are early straw bale houses standing in Nebraska up until now and their straw is in a good condition. However, before drawing any conclusion one has to take into consideration the Nebraskan climate, which is dry.

If the house is properly designed and straw is properly protected, then straw is durable in any climate. The house in Montargis, France, built in 1921 is the proof of that. It's facade is covered in ivy. Unlike Nebraska, in France there is sometimes driving rain and plaster protected by ivy makes a fantastic protection.

With proper design the straw bale building is durable even in Siberia.

0.2 Advantages of straw: *It is superinsulation*



Figure 1: Straw bale house by Igor Ogorodnikov, Academ Gorodok, Novosibirsk

Straw bale buildings are now, being explored with growing interest. It is just on a verge to become mainstream business, but somehow the building industry still resist to really embrace the straw bale technology. Contemporary straw bale world is created by growing number of straw bale building professionals as well as enthusiasts that are experimenting with straw bale building. Igor Ogorodnikov belongs so far to the group of enthusiasts and he is a great pioneer in Siberia. Igor's house (see fig. 1) makes a statement that straw bales can

be used anywhere in the world. He had chosen to build with straw bales for its superinsulating qualities. Superinsulating quality of straw bale is something that will be in Siberia greatly appreciated.

The thermal conductivity varies with density of a bale. Higher the density, higher thermal conductivity.

The sample of panel made out of compressed straw (British technology "Stramit" www.ecopanneaux.com) consists of straw compressed up to 400 kg/m³ and thermal conductivity is equivalent to that of solid soft wood.

Average straw bale has a density of about 90kg/m³. That, as a building block, has a coefficient of thermal conductivity $\lambda_{strawbale} = 0.05$ W/mK, which is the value suitable for insulation of passive houses (houses that don't need any energy to heat).

However, when straw bales are stacked together, the overall U-Value of the wall section is higher than expected. All of the independent studies presented on fig. 2 (Andersen, 2002) show thermal transmittance of the whole wall assembly. The average value is about 0.2 W/m².K. Christian, et al. (Andersen, 2002) made very interesting observation. The tremendous difference makes the degree of how well packed the wall is, so never forget to stuff your wall with straw well.

U-value

Property of wall, depending mainly on thickness and λ .

200 mm mineral wool gives $U \sim 0.18$ W / m²K

Table 2. U-value for stuccoed straw bale walls.

Straw orientation	Thickness of straw	Surfaces	U-value, W/m ² K
Present study¹			
parallel to heat flow	385 mm	34 + 42 mm stucco	0.208
perpendicular to heat flow	365 mm	26 + 26 mm stucco	0.196
Christian et al. (1998)¹			
parallel, with cavities	470 mm	Stucco + 13 mm board	0.365
parallel, without cavities	480 mm	Stucco + 13 mm board	0.210 ³
Watts et al. (1995)², parallel			
	460 mm	Stucco	0.21

1. Guarded hot box test excluding air film resistance. 2. In situ test. 3. Value determined from data in (Oak Ridge National Laboratory, 1998).




Figure 2: $\lambda_{straw bale} 90kg/m^3 = 0.05$ W/mK, from (Andersen, 2002)

For more detail concerning the thermal conductivity, U-Value and possible advice of how to keep it as low a possible open following web page:

http://lithgow-schmidt.dk/isbbc/files/presentations/jma_slides_halmhuse.pdf

0.3 Advantages of straw: *It is fire resistant*

Fire testing on straw bale walls was done in laboratories all over the world. To mention one: Tests done by BRE (Building Research Establishment) in 2004 confirm that unplastered(!) straw bale wall withstands fire for 2hrs 40mins, which is better than most modern materials and fulfills B.regs for commercial buildings.

By the way, the compressed straw panels (www.ecopanneaux.com), were produced decades ago in communist Czechoslovakia and used as a fire resistant sheeting of steel structural members.

0.4 Advantages of Straw: *Is it simple & cheap?*

In ecovillage near Academ Gorodok, Novosibirsk were built two straw bale houses. In addition to timber framed straw bale house of Igor's there is still a straw bale house built by his brother Vladimir Ogorodnikov in the neighbourhood. Vladimir's house uses a steel frame. Both houses use straw bales as an insulating infill.

a) Post and beam technique, straw as an insulating infill

One can assume that the cost of post and beam construction with straw bale infill might be very similar to the cost of any other superinsulated house and it will not be much simpler to do it.

The simplicity of straw bale construction resides mostly in it's potential. Many people who want to build with straw fail to recognize it at first. There is a myth deeply embedded in some of them that makes them believe, you can't make house out of straw. People tend to think that it is impossible. The reason for this assumption might be a fairly tale of three little piggies.

However, good news is that you can forget about the timber frame and build your house almost exclusively out of straw. The way to do it is to use straw bales as bricks and let them to carry the roof.

b) Loadbearing and hybrid techniques, straw as a structural element

Another good news is that the loadbearing method is very simple and if the investor is willing to work by him(her)self, it could be done cheaply as well.

The piece of wood that is placed on top of the walls is called roof plate. It needs to be rigid and connected all the way around a perimeter of building. It ties the walls structurally together and redistributes the load of the roof, or of another story, onto the straw.

In hybrid system, posts by the windows are cut shorter, than the full height of the straw bale wall. The roof plate on top of the straw walls comes down, as

straw bales compress during the construction of roof. The compression stops, when roof plate hits the top of the posts. Any other additional load is carried by the posts then. In hybrid system the window posts need to be designed as load-bearing. This method combines the post and beam structural "safety factor" and allows the bales in a wall to be compressed, which is very important. The compression of bales in a wall contributes to elimination of unwanted cavities. Compressed straw bales not only get close to each other vertically (in courses), they also expand to their sides.

There is very small difference between hybrid and loadbearing systems. Basically, in loadbearing system the wooden posts making the sides of the windows, are allowed to slide into an opening in a roof plate, so that it allows the bales to fully participate on the load. The loadbearing system is the most progressive building technique there is, because it utilizes the full potential of straw bale as a building material. If straw bales are happy to carry the roof, why not to let them do it?

And not only the roof, the straw bales are happy to carry the second story as well. The fig. 3 is the first double story loadbearing house built in Europe. It was built by Amazon Nails in years 2001/2/3



Figure 3: Advantages of Straw. It is simple & cheap. The Spiral House in Ireland, built by Amazon Nails, 2001/2/3

It isn't entirely truth, that it is the straw carrying the roof. It wouldn't be very comforting, if the second floor was supported by wobbly straw bale walls.

The testing on compressive strength of plastered straw bale wall revealed, that once the straw is plastered, the plaster start to carry the weight. Any additional load on a wall causes the straw to compress more. Plastered wall can not compress, because the plaster is rigid and resists compression.

Plastered straw bale wall consists structurally of two elements:

1. The straw that is willing to compress¹ and
2. plaster that is rigid.

The compressive strength of load bearing straw bale wall was measured by several institutions worldwide. A compression test of plastered straw bale walls in University of Colorado at Boulder, 1999 showed that 7 bales high wall plastered on both sides has design capacity over 30kN/m.

The plaster, which can be up to 60mm thick, becomes in fact incredibly strong, because it is reinforced by straw fibre. The load bearing plaster is tightly imbedded in straw bale wall core.

The structural interaction between straw and plaster doesn't happen only in one direction. In fact, the straw bale and the plaster ingrown into it create structurally very rigid modern system — the whole wall assembly starts to behave structurally as a single element — a *light stress-skin panel*. Furthermore the plaster-straw bond has the advantage of being flexible, so that any movement of straw bales is accommodated without transfer of stress to the plaster. This helps to prevent stress related plaster cracking.



Figure 4: Advantage of Straw: It is beautiful

The load bearing system uses straw in its full potential. Straw in loadbearing system is insulation, building block and surface for plaster in one. The loadbearing walls make structurally modern, strong, flexible construction and beautiful buildings (see fig. 4). The structural rigidity is enhanced by curved shapes.

¹It means that it gives up the load which is taken by plaster.

0.5 Advantage of Straw: *It is sound proofing*

The plaster—straw—plaster wall assembly, as you can imagine, gives high sound proofing performance. It competes well with heavy weight construction. It performs even better in high frequencies, which makes a space enclosed by plastered straw bale walls very quiet place. The background, high frequency noises are eliminated.

0.6 Greatest advantage of Straw: *It is sustainable & annually renewable*

We have serious reason to think that man made carbon dioxide emissions released into atmosphere are responsible for global warming. If we fail to reduce the CO₂ emissions, we are going to drastically alternate the worlds climate.

- 15% of all the CO₂ emissions globally produced by industrialized world is due to heating or cooling the houses and about 11% due to producing new construction materials (Wihan, 2007).

By building superinsulated houses out of renewable local materials we are going to bring the CO₂ emissions down by one quarter (26%).

- Cement production is responsible for 7-10% of total CO₂ (greenhouse gas) emissions worldwide (McLeod, 2005).

Do we need to use cement? This is a serious question. In the past, people managed to build fantastic houses, cathedrals and bridges without use of cement for thousands of years. Unfortunately there are not many builders, and almost zero building professionals who are trying to avoid use of cement in their projects. Amazon Nails don't use cement neither for foundations, because straw bale structure is flexible enough to allow for small movements of bearing soil. For that reason, the foundations for straw bale houses can be shallow.

The degree of cement use on the site could be the measure of how serious the builders actually are about the environment.

- Natural organic materials like local wood and straw are potential CO₂ sinks.

Straw in a construction as a CO₂ sink:

Lets estimate the amount of CO₂ emissions that is associated with construction of a straw bale wall. For this, it is necessary to know the energy it takes to produce it, bring it on the site and place it into the wall.

The energy from the extraction of raw materials through manufacture, processing and packaging, transportation at all different stages is called embodied energy and it is measurable quantity.

Production of 1kg of baled straw, plus the local delivery uses approximately 0.24 MJ.

On average, 1 MJ of embodied energy produces 0.098 kg of CO₂ (Balderstone, 2005). This means that 1 kg of baled straw with embodied energy 0.24 MJ/kg produces 0.023 kg of CO₂.

Straw has by weight up to 60% of carbon (Wihan, 2007).

Thus 1 kg of straw contains 0.6 kg of carbon.

1 kg of carbon in presence of oxygen forms approximately 3.7 kg of CO₂ in a process called decay.

Therefore there is about $0.6 * 3.7 = 2.22$ kg of stored CO₂ in 1 kg of straw (see fig. 5).

$$\frac{kg\ CO_2\ (embodied\ energy) - kg\ CO_2\ (stored)}{1\ kg\ baled\ straw} = \frac{kg\ total\ CO_2\ emissions}{1\ kg\ baled\ straw}$$

$$0.023 - 2.22 = -2.197 \frac{kg\ total\ CO_2\ emissions}{1\ kg\ baled\ straw}$$

Overall CO₂ emissions will vary with using different type of baling machinery, with different types of straw, etc.

0.7 Advantages of Straw: *Simple, Cheap, Beautiful, Environmentally Appropriate & Fun*

The excellent guide to straw bale building is downloadable for free from this website:

<http://strawbalefutures.org.uk/>

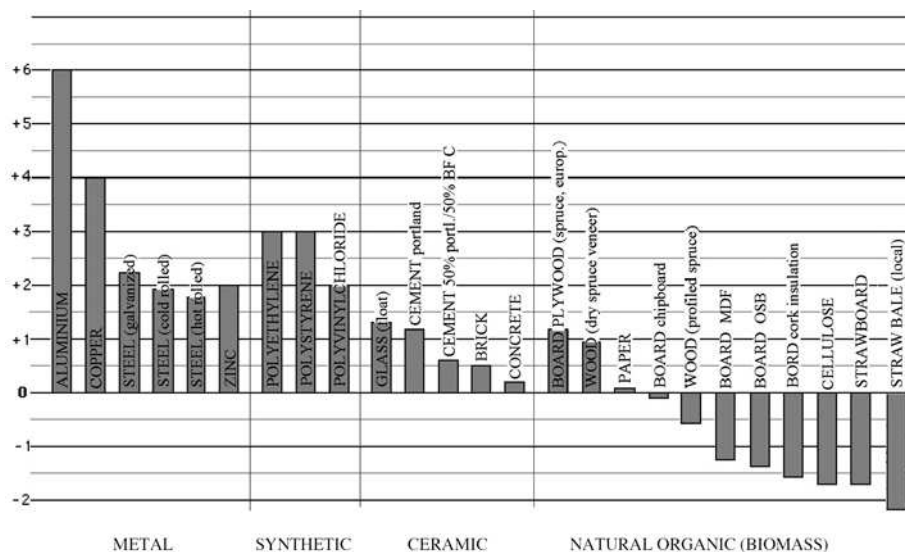


Figure 5: Carbon Dioxide Intensity Ratios (CDIRs) by weight for twenty-four common building materials (MacMath, 2000). The CDIR of local baled straw by weight was calculated by author (see below). A positive CDIR indicates a net CO₂ source and a negative CDIR indicates a net CO₂ sink.

0.8 Straw Bale Building in Mongolia and Northern China; *UNDP, ADRA*

For five years, UNDP- Mongolia has been supporting a new building technology in the social sector which has produced significant savings in terms of central heating costs but has also helped in reducing air pollution. Currently, around 30-45% of the state budget is spent on heating. Based on the successful implementation of the previous straw bale building project in the social sector, the Mongolian Government is now expanding its scope through the construction of straw bale houses for the general public. Between 1997-2002, thanks to a UNDP supported project, 34 public buildings and kindergartens were built using straw bale technology and 16 buildings were retrofitted with straw bale.

From: <http://www.undp.mn/index.php?name=News&file=article&sid=48>

American architect and professional straw bale builder Kelly Lerner was presented the 2005 World Habitat Award at the United Nations/UN-HABITAT "World Habitat Day" celebration in Jakarta Indonesia, for her work on the Chinese Straw-Bale Energy Efficient Housing Project. Working with the Adventist Development and Relief Agency (ADRA), she spearheaded the introduction of straw-bale construction to China and built over 600 straw-bale houses and three straw-bale schools in five northeastern provinces in a project funded by Kadoorie

Foundation of Hong Kong.

Scott Christiansen, ADRA's director in China, says that the homes have several advantages over conventional ones. The new homes are economical, saving owners money, and environmentally friendly, reducing carbon dioxide emissions from interior fireplaces. Straw-bale homes are 20 percent cheaper to build and require 80 percent less coal to heat than traditional homes. A higher moisture retention in straw-bale homes leads to a decrease in respiratory disease for residents.

"We are aiming to put in place the technology and experience to enable the building of potentially thousands of straw-bale houses all over northern China," says Christiansen.

From: <http://www.one-world-design.com/awards.asp>

0.9 Straw Bale Building in Chermal, Altai, Russia; *Builders without Borders, The Fund for the 21st Century Altai*

In summer 2005 Builders without Borders sent american professional straw bale builders to Chermal in Altai mountains. They were invited by local non profit organization The Fund for 21st century Altai, to build on their property small straw bale structure.

The hybrid construction consisted of large load bearing posts cut out of fallen local cedar wood.

Local clay and sand were used to mix plaster. The plaster work was supervised by american professional plasterer Cindy Smith.

At the end the plaster was protected by lime wash. And wide wooden posts will be carved.

In this project and in the straw bale houses near Academ Gorodok built by Igor and Vladimir Ogorodnikovi, there are the first seeds, from which the field in Siberia will sprout eventually. The Barnaul Institute of Architecture and Design at Altai State Technical University actively works in introducing the straw bale technology to their students. They are planning to design and build straw bale retreat center on Katun river in Altai mountains. The professors are working with students on a whole scheme of straw bale building in this environmentally precious region.

The CO₂ reduction need to be addressed by building sector right NOW. Three straw bale houses in Siberia are not enough, but they represent a good example of how to address the issue in this region.

Someone told me that once you set foot in the Altai mountains you are going to be coming back. I'm here for the third time. It was in 1998, when I visited



Figure 6: Straw Bale Building in Northern China, Chermal, Altai, Russia. Built by Builders without Borders, The Fund for the 21st Century Altai, 2005

first and since then I see the country changing. Hopefully, thanks to people like Igor Ogorodnikov, people from The Fund of 21st Century Altai and many others, the magnificence of our planet the way we know it will be preserved. And we don't have to do much, straw bale houses will do the job, we just need to start to build them. They grow in the neighborhood.

References:

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