RENEWABLE BUILDING MATERIALS FOR HIGH ENERGY EFFICIENCY CONSTRUCTION ERA

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Summary: *This article provides information about the possibilities and technologies [2] available for the building industry in the Republic of Serbia, and concerns the trends - which expansion is expected in Europe and worldwide - the of use of renewable sources of building materials. Exploitation of sand and gravel from rivers and dry mines in many EU countries is prohibited. Excavation of clay from clay deposits and blasting the rock mass are considered as a violation of the natural environment and resulting with scars on our planet Earth.Renewable sources of construction materials are considered materials which each year can be renewed and which are the most common by-product of agricultural production.Materials obtained by recycling existing materials already used in construction, as well as by-products of industrial production are also considered sustainable materials.Renewable materials are supporting the new, worldwide trend in building industry, called "Green Building" with the aim of reducing harmful CO_2 emissions.This paper will discuss renewable materials obtained as a by-product of agricultural production such as grain straw (wheat, barley, rye and oats), cane and hemp shiv obtained by mechanical breakingof hemp stems.These materials are cheap because they are by-products and they are energy efficient, which is particularly important nowadays.The construction of buildings with the above mentioned materials should be well planned to ensure the durability, fire resistance and particularly the pleasant and comfortable stay for the people.The walls made of this material must be solved, and ensured to avoid occurrence of rodents and other pests that may be carriers of dangerous and contagious diseases.*

Keywords: *Materials, renewable, ecology, energy, efficiency*

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1. INTRODUCTION

Serbia is an agricultural country where significant grain cultivation. Straw can be a good raw material and source of renewable material for the construction of buildings.The straw-bale construction can be carried outwith bales bound to standard dimensions during mowing or later.During the construction of walls, the surface of thecompressed straw-bales should be treated in a thin layer with a roller or immersed in a liquid mixture of chemicals for impregnation and binder that will increase the strength.Impregnation is necessary for several reasons. The impregnating material should be hygroscopic to extract moisture from the interior of the straw wall. Another way of using straw is to cut to length aprox. 5 cm to 10 cm and then treat it in a mixer with an impregnation agentand cure after placing.

Figure 1.Students of Faculty of Civil Engineering in Subotica, on the subject Traditional materials processing wheat straw by treating in a mixer with impregnating materials to achieve strength after the compressing phase (straw, cement, lime, pucolic powder, water, chemical impregnation agents)

The strawprocessed that way could be compress into special masonry blocks. The result would be a masonry element, made of lightweight concrete with a lightweight aggregate - straw.These blocks would not be load-bearing but simply serve as a good thermal insulation and sound insulation.

Cane as building material has been used for hundreds and thousands of years. Nowadays cane is used in the form of square panels of thickness 5 cm and 10 cm.The cane has long been used as a plastering base in the form of thin trunks of thickness of the individual cane.Such mats are fixed with special "v" nails on a slippery substrate on ceilings or walls, and then plastering is finished on such prepared substrate. The cane can also be ground in mills and as an aggregate it can be used to produce lightweight mortar and concrete with the role of a thermal insulation and fiber reinforcement.

Shiv is obtained by mechanical breaking of hemp stems. Hemp is an industrial plant that is sowed in the fields and after mowed and can be processed into dozens of products from which we highlighttwo basic products. Hemp fibers are used in the textile and

automotive industries and the seed is used in the food industry for the production of edible oil. The hemp stem, as a by-product, can be grinded, and in this way, a shiv is obtained, an excellent lightweight aggregate for the production of lightweight concrete and mortar. It is possible to use a combination of shiv and milled straw in a way thatthe larger aggregates up to 15 mm are shiv and the smaller aggregatesare made of straws up to 5 mm long.

Figure 2. Industrial hempcan be applied in several different industries: textile, food, pharmaceutical, automotive and even in the construction industry (www.udruzenjekonoplja.net)

The treatment and impregnation of these materials, straw, cane and shiv is neededin order to protect these materials, enabling a good contact and bonding of materials and also enabling full - hydration and curing process of a binder.

2. AGRICULTURAL BY-PRODUCTS AS A SOURCE OF RENEWABLE CONSTRUCTION MATERIALS WITH GOOD ENERGY EFFICIENCY

If we want to design and build a reinforced concrete floor slabs of larger span andwith increased safety in case of an earthquake(seismic action), then we need usewaffle-slabs.

2.1 STRAW AS A RENEWABLE BUILDING MATERIAL

Straw can be a good source of building material for family houses, but not just by stacking into walls without processing and treating such straw. Straw must be treated

before mounting or immediately after. Treatment of straw by impregnation is mandatory for several reasons:
- Fire protection,
- To extract the moisture from the central part of the wall,
- To prevent appearance of rodents and insects in the straw-bale walls,
- As a substrate for application of fire protection mortar.

Plastering of straw-bale walls represents their fire protection in the same hand. Plastering with fire protection mortar must be from the both sides of these walls. Keeping moisture in the walls would be very harmful as it would reduce the thermal insulation characteristics λ (W / mK). The high humidity level of the straw walls would also favor the development of microorganisms (fungi) and the occurrence of mildew and rotting of the walls. Rodents and insects may be a major problem for such walls and special measures must be taken to avoid such walls to becametheir habitat. Prior to plastering with treated straw-bale walls, a coating layer or galvanized steel mesh with smaller openings must be placed through which small rodents cannot pass.

Figure 3. Surface treatment and impregnation of straw-bale, performed by students of the Faculty of Civil Engineering in Subotica on the subject Traditional Materials

Elements made of straw built up into the walls would not have a load-bearing role, but they should be treated that they in order to avoid subsiding under their own weight. Thermal conductivity measurements were performed and these pressed straw elements have a value of0,1163 = W / mK with density of γ_m = 655kg / m^3at humidity Ha = 2,5%.

Figure 4. . Pre-treatment and impregnation of straw as a fibrous aggregate in the mixers and afterwards, pressing into the masonry elements were made by students of the Faculty of Civil Engineering in Subotica on Traditional Materials

2.2 CANE AS A RENEWABLE BUILDING MATERIAL

Cane as a material for construction in terms of quality, resistance and insulation characteristics is in the ranking of the best materials.One of the oldest materials is still today among the best thermal insulation materials. In the past, cane was not used as thermal insulation material, although the thermal conductivity properties are just slightly behind conventional thermal insulation materials: mineral wool or expanded polystyrene. The cane has a thermal conductivity value λ = 0.046 W / mK.
The structure of cane is made of tubes, which allows the layer of cane in the wall to vent and release excess water vapor if such ventilation is enabled.

Figure 5. Wall panels made of cane

Cane as a material is very sharp which is not suitablefor rodents to live in these walls. Cane can also be used to cover the roofs of buildings and thus provide decorative roofs with extremely good thermal insulation. Impregnation of cane is necessary if mortar is applied on it. Materials for impregnation and hardening are the same as those used for straw and shiv. The disadvantageof the cane, which reflects to walls and roofs made with it also, is very poor fire resistance. Therefore, these building elements have to be plastered with fire protection mortars. On the roof it is necessary to pour a layer of lightweight concreteagainst fire, as a prevention if during winter the heating is based on solid fuel.

2.3 SHIV – HEMP STEM CHIPS AS RENEWABLE BUILDING MATERIALS

One of the most important plants is industrial hemp, from which various products can be made in textile, food, pharmaceutical, automotive and even in the construction industry. Industrial hemp is planted in fields and can be even harvested two times over a year. Hemp can grow up to 3.5 meters high, Figure 6.

Figure 6.Mowing of industrial hemp is the first stage of processing(www.agrosmart.net)

Hemp stem have a thickness up to 15 mm and it is ground after the removal of hemp fibers. The granulate obtained after grinding of the stem is called shiv. One hectare of land can provide shiv enough to make the walls of a house of 200 m^2. The shivhavegranule size mostly from 5 mm to 30 mm.

Figure 7.Shiv granulate obtained by grinding hemp stems

The shiv is treated in mixers with bonding and curing material, which is usually cement. Materials for impregnation must be applied, which are represented by lime and certain chemicals. With these materials, the pucolic powder and sand can be added into the mixer. Samples of hemp-crete [1], which were made at the Faculty of Civil Engineering in Subotica twenty years ago and were exposed to atmospheric conditions for at least 12 years, are now tested with the following results:

$\gamma_m = 830$ kg/m^3 - density

$\sigma = 2{,}67$ MPa- compressive strength

$\lambda = 0{,}152$ W/mK - heat conductivity

Figure 8.Measuring of the heat conductivity on the hemp-crete

Hemp - concrete after mixing in the mixer should have a consistency class ≤ F4. Liquid consistency is not suitable for this type of concrete because the shiv is lighter than water and it would be separated from the pasteon the surface along with water. Hemp-concrete can be placed in the same way as ordinary concrete. Especially interesting would be the pressing intobuilding blocks. Hemp-concrete was treated as lightweight thermal insulating and sound insulating concrete in 1997 on GFS. In 1998, a patent was filed in which the claim No. 10 describes a new impregnation technology and a mixture of hemp-concrete. This patent was published in 2000 by the world organization WIPO, [2].

Figure 9.Hemp-creteelements ready to be used for separating walls and for lightweight and warmscreeds

3. CONCLUSIONS

The paper highlights the facts and gives clear evidence that the construction industry of the Republic of Serbia has patented technologies for the use of renewable sources of building materials based on agricultural by-products [2]. Renewable sources of construction materials will increasingly become a trend in building industry in Europe and worldwide. "Green buildings" are promoted in order to protect ecology and to reduce harmful CO_2 emissions. The use of renewable building materials which are sowed and harvestedon fields and wetlands (grain, industrial hemp, cane) is contributing to ecology and reducing harmful CO_2 emissions. Fields of industrial hemps are large in green mass, because industrial cannabis are densely planted and stems grow up to 3.5 m, which leads to a significant binding of CO_2 from the atmosphere and to the creation of a significant amount of O_2- oxygen. By using ground straw, cane and stems of hemp-shiv, good construction products can be obtained for building walls and slabs with high energy efficiency and acceptable cost. These products must be impregnated in order to

protect the walls and products from moisture, rodents and other pests. These products can be treated in the mixer as well as all other aggregates for mortars and concrete. Beside cement, lime and puccolanic materials in powder form, the impregnating materials are also added in the mixer. With such prepared aggregates, lightweight concretes, mortars and panel elements for separating walls can be made.Masonry blocks or stay-in-place formwork elements for intermediate floors could also be made from these agricultural by-productsaggregates.

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ОБНОВЉИВИ ИЗВОРИ ГРАЂЕВИНСКИХ МАТЕРИЈАЛА ЗА НОВО ВРЕМЕ ГРАЂЕЊА ОБЈЕКАТА ВИСОКЕ ЕНЕРГЕТСКЕ ЕФИКАСНОСТИ

Резиме:*Овај рад даје информације о могућностима и технологијама [2] којима располаже градитељство Р.Србије а тиче се трендова који ће се морати све више користити у Европи и свету а то је коришћење обновљивих извора грађевинских материјала. Ископавање песка и шљунка из река и сувих копова у многим земљама ЕУ је забрањено. Копање глине на глиништима и минирање стенског масива се сматра као нарушавање природног амбијента јер на тај начин настају ожиљци на нашој планети Земљи. Обновљиви извори грађевинских материјала се сматрају материјали који се сваке године могу обнављати и који представљају нузпродукте најчешће пољопривредне производње. Материјали који се добију рециклажом постојећих материјала већ коришћених у грађевинарству као и материјали који су нузпродукти индустријске производње се такође сматрају обновљивим материјалима. Обновљиви материјали подржавају нови тренд градње у свету који се зове „Зелена градња“са циљем смањења штетне*

емисије CO_2. Овај рад ће разматрати обновљиве материјале добијене као нузпродукте пољопривредне производње а то су слама од житараица (пшеница, јечам, раж и зоб), трска и поздер који се добије млевењем стабљике индустријске конопље. Ови материјали су јефтини јер су нузпродукти и они су енергетски ефикасни што је од нарочите важности у овом времену подизања енегетске ефикасности грађевинских објеката. Градња објеката са наведеним материјалима треба бити добро планирана у смислу осигурања трајности, отпорности на пожар а посебно да такве куће представљају угодан и удобан боравак за људе. Зидови са овим материјалима морају бити тако решени и обзбеђени да не могу постати станишта за глодаре и друге штеточине које могу бити и преносници опасних и заразних болести.

Кључне речи: *Материјали, обновљиви, екологија, енергетска, ефикасност*