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REUSE OF OLD CORRUGATED CARDBOARD IN CONSTRUCTIONAL AND THERMAL INSULATING BOARDS

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ABSTRACT

Due to the absence of larger company which treats the waste paper from corrugated fiberboard and old corrugated cardboards in Slovakia today, the large amount of this waste paper grade has not been utilized. One of the possibilities is to produce structural or thermal and insulation boards from this waste material. In this paper the production methods of various board grades depending on method of their use are introduced. Their properties of the utility are rated. Structural boards can be used in furniture industry, in production of thermal and insulation boards suitable for thermal insulation of buildings or as building blocks, e.g. in partition walls.

KEYWORDS: Old corrugated cardboard (OCC), construction core board, thermal insulating board, flexural strength, composition optimalization.

INTRODUCTION

Two ways how to utilize old corrugated cardboards are discussed. OCC core board is produced as a semi finished product of paper production with its additional use as a core filling into a wide range of wood products for furniture industry (Fig. 1). The cardboard's core is made of thin strips butt joined into an infinite length. After thickness equalization a layer from recycled paper is added from both sides (test liner). Covering by large surface materials (MDF, HDF....) and an additional final surface treatment (with paints, veneering, or foiling) enables a creation of construction boards for dry environment with significantly higher thickness, which is typical for the current design of furniture (Kollmann et al. 1975). Typical properties of the newly development product is: Density about 200 $kg.m^{-3}$, thickness from 30 to 100 mm and width 600 mm, infinite length. Recycled paper of about 150 $g.m^{-2}$ is used as a surface covering material.

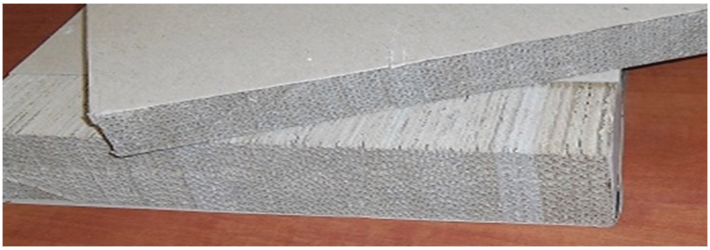

Fig. 1: Core board from OCC.

Insulating panels for exterior and interior thermal and acoustic insulation are the second way how to use environmentally friendly material. Their heat transition properties need to be determined carefully (Hrčka and Babiak 2012). Insulations based on paper have an advantage over wood-based insulations in lower density (Kawasaki and Kawai 2006). Glue is applied at the outer surface of corrugated cardboard and two or three-layer corrugated boards are connected so as to obtain a compact self-supporting, dimensionally stable insulation board of the required thickness. The flexural strength has a parameter of usability which must be determined precisely due to fragile structure of the material (Niemz 1993). A gluing of individual layers of corrugated carton and theirs layering is the base of production such boards. In order to produce boards it is possible to use OCC or primary carton as well. Corrugated carton's structure consists of enclosed channels which provide its insulating properties.

In this project insulation boards have been prepared by four ways from OCC in lab scale:

1. by sticking of layered corrugated cardboard from primary and/or secondary fiber,
2. by sticking of a layered corrugated paperboard prepared from a mixture of primary and/ or secondary fibers and/or inorganic fibers,
3. by sticking of a corrugated paperboard prepared from inorganic fibers,
4. by their mutual combination.

Fig. 2: Thermal insulation boards based on an old corrugated carton.

Air humidity penetrates into wood and paper base materials with influence on interior environment. The penetration can be controlled in layered material (Wood et al. 2006). Moist materials have a greater thermal permeability. Longitudinal channels influence water vapor penetration (Deemter et al. 1956). Diffusion resistance of wood-fibrous board μ is in range 1-5 (while diffusion resistance of polystyrene reaches μ at 224). Diffusion resistance of a brick is at level 5-10. In general it is known that in our climatic conditions it is important for vertical circumference construction to be optimally penetrable for moisture and thus would create conditions for natural climate in interiors.

MATERIAL AND METHODS

Core boards from OCC were produced in laboratory conditions. OCC was manually cut into wide strips. Total thickness of the board was 50 mm. An adhesive solution was sprayed on the strips on both sides. Strips were put into a form with limited width using butt joints. A machine facing was used to modify the upper and lower surface of the board. Test liner was used for the covering.

Thermal insulation panels were made in the laboratory by hand sticking of two, three and five layered corrugated carton. Symmetry from the center of the board toward its surface was maintained. The number of layers was selected to always achieve the desired thickness of the board.

Thermal-insulating properties are evaluated based on a coefficient of thermal conductivity λ. There are few methods of measurement of thermal conductivity for products consisting of separated components. An equipment which works with quasi- steady state method was used (Babiak 1976, Požgaj et al. 1997). Insulating material based on layered corrugated material was prepared using double layered, triple layered and five-layer corrugated board with various combinations.

Glue was selected on results of optimalization of OCC insulating boards' preparation. The use of glue Duvilax BD– 20 and glue UHU turned out to be the best choice. Properties of the prepared boards were evaluated in bending tests.

Optimalization of the boards' composition was provided as well. The basic product of layered corrugated board is double layer carton. Triple layer carton and five layer carton was used for comparison as an alternative solution in case of better thermal-insulating properties. For the construction it is important for surfaces on both sides to be the same. In order to achieve this state it is necessary for the triple and five layer carton to be covered with a smooth paper layer on both sides. The middle layer would then be glued on both sides in such a way that the surface layer would be from this smooth paper layer. Such a board is possible to prepare in two alternatives. In the first case, the boards were produced with the bending part of carton perpendicular to each other. In the second case these cartons were aligned in parallel. Both alternatives were prepared from double layer carton with the use of middle triple layer carton. Both alternatives were tested for thermal-insulating properties and strength in bending (Tab. 1). Strength in bending takes place perpendicularly on the bending part of the upper layer of the sample. In case when the test takes place perpendicular to the bending part of the upper part of sample the values are much lower.

Tab. 1: Properties of insulating boards from old corrugated carton depending on the direction of individual layer.

Sample	Nr. 1/1	Nr. 1/2	Nr. 1/3	Nr. 2/1	Nr. 2/2	Nr. 2/3
Flexural strength (MPa)	0.770	0.815	0.755	1.423	1.389	1.405
λ ($W.m^{-1}.K^{-1}$)	0.045	0.045	0.045	0.045	0.045	0.045

Optimizing of glue amount application on selected sample (individual layers are parallel with bent part of the carton in the whole board) was carried out. The boards were prepared with covering of 55, 80, 100, 122 and 144 g per m². These boards were tested on flexural strength and coefficient of thermal conductivity (Tab. 2).

Tab. 2: Properties of insulating boards from old corrugated carton depending on the applied adhesive amount for individual layers of board.

Sample	Volumetric weight (kg.m^{-3})	Board thickness (mm)	Flexural strength (MPa)	Coefficient of thermal conductivity (W.m^{-1}.K^{-1})	Adhesive amount per 1 m^2 (g)	Used OCC
0	98.3	18.30	0.00	0.045	0	double layer
18	101.2	18.10	1.20	0.045	55	double layer
19	104.1	18.47	1.41	0.045	80	double layer
20	105.0	17.45	1.42	0.045	100	double layer
21	106.9	17.96	1.46	0.046	122	double layer
22	110.5	18.38	1.46	0.047	144	double layer
24	163.5	18.20	2.51	0.052	100	triple layer
25	109.7	18.71	1.67	0.049	100	five layer
26	119.9	19.20	1.73	0.050	100	mixed 5-2-3-2-5

RESULTS AND DISCUSSION

In preparation of insulating boards from corrugated carton the properties depend on the board composition. It is not the same how the individual layers of corrugated carton will be vectored. This depends whether the composition consists of double, triple or five layer carton. Direction of double layer cartons is important as well. The composition must be the same on both sides from the middle layer.

The coefficient of thermal conductivity achieved value of 0.045 W.m^{-1}.K^{-1} in both cases; the composition where individual layers are mutually orthogonal with bent part of carton and the composition where individual layers are mutually parallel with bent part of carton in the whole board (Tab. 1). However, the flexural strength was different. The values in samples with parallel structure of bent part are significantly higher and they reached average values of 1.4 MPa. The flexural strength in case of layers mutually orthogonal was only 0.78 MPa. A coefficient of thermal conductivity of the insulating materials based on wood, synthetic polymers and inorganic materials is ranging between λ 0.032 and 0.049 W.m^{-1}.K^{-1}. Extruded polystyren has a λ of 0.033 to 0.037 W.m^{-1}.K^{-1}, basalt and glass fiber wool has a λ of 0.032 to 0.039 W.m^{-1}.K^{-1} and for wood-fiber boards λ ranges from 0.039 to 0.049 W.m^{-1}.K^{-1} in dependence on the board density.

Optimizing of the glue type and glue coating was performed as well. Wood-fibrous boards have to fulfil all criteria of ecological building materials. It means that no synthetic glues are added. Insulating boards are completely able to recycling. They can be burned or safely composted also. The Duvilax BD – 20 and glue UHU (UHU Holzleim Express Für D2) appear as most suitable glues for the purpose. For comparison, boards prepared by using of the glue Duvilax

BD – 20 had flexural strength value 1.422 MPa and in case of glue UHU 1.385 MPa. Boards prepared during the optimization of glue coating were tested for strength properties (flexural strength) and for thermal insulation properties (coefficient of thermal conductivity). Results show the flexural strength dependence on glue coating (Tab. 2). The strength was improved from the value 1.2 MPa to the value 1.46 MPa by the increasing of a coating. Flexural strength at the value of 1.46 MPa is determined by the strength of bent layer of carton used. That is a reason why the increasing of glue coating over 122 $g.m^{-2}$ does not furthermore shown by strength increase.

Volumetric weight of boards prepared from double layer carton increased with glue coating increase (Tab. 2, samples 18-22), which has unfavorable impact on coefficient of thermal conductivity. It increased from the value 0.045 to value 0.047 $W.m^{-1}.K^{-1}$. The coefficient of thermal conductivity with glue coating up to 100 $kg.m^{-2}$ is on the level of value for sample prepared without the glue (sample 0).

It can be concluded that the optimum coating of Duvilax BD-20 glue, with sufficient guarantee of flexural strength, with coefficient of thermal conductivity λ = 0.045 $W.m^{-1}.K^{-1}$ is 100 g per m^2.

At the utilization of triple layer carton with glue coating of 100 $g.m^{-2}$ the flexural strength was improved to value 2.51 MPa with deterioration of coefficient of thermal conductivity to value 0.052 $W.m^{-1}.K^{-1}$. At the utilization of five layer carton with glue coating 100 $g.m^{-2}$ the flexural strength was 1.67 MPa and coefficient of thermal conductivity was 0.049 $W.m^{-1}.K^{-1}$. Mixed boards composed of five, double and triple layers with composition of 5-2-3-2-5 layer carton had coefficient of thermal conductivity 0.050 $W.m^{-1}.K^{-1}$.

The most suitable composition of insulation boards from OCC is the composition of double layer carton as regards of values of coefficient of thermal conductivity (Tab. 2).

CONCLUSIONS

There are many others ways how to reuse OCC (Boháček at al. 2013). The research has shown the two non chemical methods. Preliminary results have been obtained as shown:

1. Flexural strength of insulation boards from corrugated carton depends on vectoring of the individual layers. It is higher if bent parts of carton are mutually parallel in the whole board. The coefficient of thermal conductivity does not depend on vectoring of the individual layers of board.
2. It is required to use the glue Duvilax BD-20 or UHU for these purposes.
3. The coefficient of thermal conductivity of a board from double layer carton deteriorates from the value 0.045 to the value 0.047 $W.m^{-1}.K^{-1}$ at glue coating of 144 $g.m^{-2}$ if the glue coating on individual layers further increases.
4. The flexural strength of a board from double layer carton improves from the value 1.2 MPa to the value 1.46 MPa if glue coating increases. The glue coating over 122 $g.m^{-2}$ does not increase the board strength.
5. Optimum coating of the Duvilax BD-20 with sufficient characteristics (1.42 MPa and λ = 0.045 $W.m^{-1}.K^{-1}$) is 100 g per 1 m^2 for individual layers.
6. The coefficient of thermal conductivity of a board prepared from double, triple and five layer cartons is the best for the double layer carton with value 0.045 $W.m^{-1}.K^{-1}$.
7. The board with volumetric weight of 105 $kg.m^{-3}$, the coefficient of thermal conductivity λ = 0.045 $W.m^{-1}.K^{-1}$, at the glue coating of 100 g per 1 m^2 achieves the flexural strength of 1.42 MPa which is sufficient guarantee of strength at expected handling this material.

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REFERENCES

1. Babiak, M., 1976: Some thermal properties of spruce wood and its wood based materials. Drevarska fakulta VŠLD Zvolen, 114 pp.
2. Boháček, S., Letko, M., Pažitný, A., Fišerová, M., Gigac, J., 2013: Production of second generation bioethanol based on cellulose, Workshop: Enviral, a.s. Leopoldov, Slovenske liehovary a likerky, a.s. Leopoldov.
3. Deemter, J.J., Zuiderweg, F.J., Klinkenberg, A., 1956: Longitudinal diffusion and resistance to mass transfer as causes of nonideality in chromatography. Chemical Engineering Science 5(6): 271–289.
4. Hrčka, R., Babiak, M., 2012: Some non- traditional factors influencing thermal properties of wood. Wood Research 57(3): 367-374.
5. Kawasaki, T., Kawai, S., 2006: Thermal insulation properties of wood-based sandwich panel for use as structural insulated walls and flors. J. Wood Sci. 52(1): 75- 83.
6. Kollmann, F.P., Kuenczi, E.W., Stamm, A.J., 1975: Principles of Wood Science and Technology II. Wood based Materials, Springer- Verlag Berlin, Heidelberg, New York, 703 pp.
7. Niemz, P., 1993: Physik des Holzes und der Holzwerkstoffe. DRW- Verlag, 243 pp.
8. Požgaj, A., Chovanec, D., Kurjatko, S., Babiak, M., 1997: Wood structure and properties. Bratislava, Priroda, 486 pp (in Slovak).
9. Wood, K.C., Chuang, H.F., Batten, R.D., Lynn, D.M., Hammond, P.T., 2006: Controlling interlayer diffusion to achieve sustained, multiagent delivery from layer-by-layer thin films. The National Academy of Sciences of the USA.

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