Analysis of properties of boards for concrete formwork

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ABSTRACT: The paper summarizes results of the analysis of properties of large-area materials usable for the manufacture of concrete formwork and available on our market. The materials were compared from the viewpoint of physical and mechanical properties including economic evaluations. Materials were assessed manufactured by DOKA company dealing with the production of shuttering systems, viz. Doka 3-SO, Dokadur and Dokaplex. The materials were compared with following boards available on our market: bioboard Agrop, water-resistant (exterior) surface-treated plywood and oriented strandboard (OSB). Results of the paper consist in the comparison of cost/physical-mechanical properties.

Keywords: formwork; large-area materials; three-layer massive board; OSB; construction plywood; bending strength; modulus of elasticity in bending; shear strength; swelling

Concrete formwork is a temporary construction serving as a form for a future concrete construction. It usually consists of a supporting construction and a construction making the form of an element. Building industry is the largest consumer of wood and wood-based products. Companies manufacturing construction plywoods and large-area materials permanently try to develop new suitable materials for the production of concrete formwork according to requirements of project engineers. At present, plywood sheets, three-layer massive boards, blockboards and battenboards are most often used. Specific requirements are put on physical and mechanical properties of the materials. Production technologies of the boards are very demanding and expensive which results in the second requirement, viz. guaranteeing the multiple use. Thus, materials used for the manufacture of formwork should guarantee multifold use. The manufacture of concrete structures is a so-called wet process when the formwork is subject to the aggressive environment of cement from concrete mixtures and also to weather effects. In order their degradation not to occur certain principles have to be observed. Unfortunately, these principles are very often neglected during building.

Large-area materials for formwork are coated with a foil or a paint protecting them from moisture. Also edges of the shuttering used to be coated with a paint functioning in the same way. If it is necessary to shorten the materials during the formwork assembly, the unprotected formwork edge has to be coated with a paint preventing moisture penetration. Prior to the concreting proper it is necessary to coat the formwork surface with a protective means protecting the boards from moisture and supporting the removal of shuttering. If the paint fails there is a danger of flaking the protective coat and thus its debasement (Dvořák et al. 1996) when the board is torn off from the concrete structure.

MATERIAL AND METHODS

The aim of the paper was to analyse large-area materials ordinarily available on the market for the production of concrete formwork. The materials were compared from the viewpoint of physical and mechanical properties including economic evaluation.

Materials manufactured by DOKA company dealing with the production of shuttering systems were evaluated, viz.:

- Doka 3-SO – three-layer panel according to ÖNORM B 3023 standard
- Dokadur – three-layer panel according to ÖNORM B 3023 standard
- Dokaplex – combined plywood sheets Dokaplex and PlomaFoil.

The materials were compared with the following materials available on our market:

- Biopanel Agrop
- Surface-treated exterior plywood sheet
- Oriented strandboard (OSB) Eurostrand.

On the basis of economic evaluations, materials with the optimum relation of cost/ physical-mechanical properties are recommended.

Characteristics of tested materials

Form panel Doka 3-SO 21 mm

The panel is supplied by DOKA company as a special board for the manufacture of concrete formwork. The

Table 1. Density and moisture of Dokadur boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	*w* (mm)	*t* (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	*H* (%)
1	50.65	49.84	20.61	25.671	23.861	493.409	7.6
2	50.12	50.45	20.57	28.023	26.086	538.776	7.4
3	50.19	50.26	20.55	26.960	25.106	520.078	7.4
4	50.57	50.29	20.46	25.422	23.671	488.573	7.4
5	50.16	50.40	20.54	23.768	22.039	457.724	7.8
6	50.59	49.81	20.40	28.490	26.482	554.219	7.6
7	50.12	50.47	20.61	26.889	25.016	515.766	7.5
8	50.45	50.22	20.43	22.597	21.063	436.561	7.3

For Table 1–6: *l* – length, *w* – width, *t* – thickness

Table 2. Density and moisture of Doka 3-SO boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	*w* (mm)	*t* (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	*H* (%)
1	50.29	50.59	20.50	23.513	21.951	450.825	7.1
2	50.51	50.20	20.71	23.841	22.222	454.008	7.3
3	49.97	50.72	20.83	22.995	21.433	435.568	7.3
4	50.72	50.25	20.73	24.448	22.875	462.731	6.9
5	50.53	50.44	20.63	23.265	21.701	442.466	7.2
6	50.59	49.99	20.72	24.584	22.923	469.154	7.2
7	50.67	50.45	20.65	23.271	21.741	440.842	7.0
8	50.62	50.29	20.79	24.448	22.875	461.939	6.9

Table 3. Density and moisture of Agrop boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	*w* (mm)	*t* (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	*H* (%)
1	50.06	49.88	18.95	21.477	20.022	453.886	7.3
2	49.85	50.13	18.94	19.579	18.291	413.664	7.0
3	50.15	50.16	18.95	19.881	18.565	417.062	7.1
4	49.11	49.73	18.90	20.673	19.275	447.871	7.3
5	49.97	50.14	18.96	22.733	21.305	478.547	6.7
6	49.85	50.01	18.90	19.591	18.297	415.789	7.1
7	49.70	50.16	18.91	20.923	19.537	443.832	7.1
8	50.11	49.83	18.92	21.323	19.937	451.348	7.0

manufacturer recommends the panel for the production of atypical formwork and dimension stock. It is manufactured both with smooth surface (GL) and structured surface (STR) which moulds quality concrete with board structure. The panel is manufactured according to ÖNORM B 3023 standard from mountain spruce being resistant to boil and weather effects and coated with artificial resin pressed under high pressure. It is supplied in a broad range of formats from 1,000/500 to 6,000/1,000 mm and thickness 18, 21 and 27 mm.

Form panel Dokadur

The panel serves for the manufacture of ceiling formwork. It represents a new standard of ceiling shuttering. The combination of a special plastic frame of polyurethane (PU) with the two-layer closure of the panel surface protects the panel reliably in the course of an everyday operation of a building site. Thus, the frequency of using the panels and the quality of concrete surfaces hugely increases. Harmonised combination of the two-layer paint of PU and melamine resin considerably increases moisture resistance. Adding corundum the surface becomes slip-resistant so that walk on it is safe. Dokadur form panels are available in thicknesses 21 and 27 mm. They are supplied in three formats, viz. 1,500/500, 2,000/500 and 2,500/500 mm.

The following panels were tested:

a) Form panel Doka 3-SO 21 mm thick supplied by DOKA company as a special board of concrete formwork.
b) Form panel Dokadur serving for the manufacture of ceiling formwork.

Biopanel Agrop

Three-layer massive panel produced of spruce sawn timber. Upper layers are made of lamellas 95–134 mm wide glued along edges. The panel shows the core of blockboard/battenboard being glued using water-resistant AW 100. Its density is about 500 kg/m³.

Plywood sheets

Plywoods are produced by surface gluing of rotary-cut or sliced veneers up to 4 mm thick, viz. always in an odd number (min. 3 plies). Particular plies are each other turned by 90° (cross effect). The odd number of particu-

Table 4. Density and moisture of Dokaplex boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	w (mm)	t (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	H (%)
1	50.42	50.28	20.17	34.740	32.760	679.400	6.0
2	50.21	50.59	20.19	34.386	32.381	670.487	6.2
3	50.79	50.01	20.15	36.099	34.005	705.318	6.2
4	50.15	50.65	20.17	35.311	33.301	689.213	6.0
5	50.77	50.13	20.16	35.833	33.774	698.374	6.1
6	50.11	50.59	20.18	35.547	33.447	694.853	6.3
7	50.62	50.38	20.19	34.992	32.985	679.598	6.1
8	50.55	50.35	20.17	35.744	33.712	696.268	6.0

Table 5. Density and moisture of PlomaFoil boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	w (mm)	t (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	H (%)
1	50.21	49.79	18.2	30.367	28.661	667.418	6.0
2	50.01	49.89	18.2	29.180	27.460	642.604	6.3
3	50.28	49.72	18.2	29.898	28.214	657.120	6.0
4	50.30	49.71	18.2	30.381	28.664	667.604	6.0
5	49.59	49.71	18.2	29.356	27.629	654.316	6.3
6	49.82	49.38	18.2	28.294	26.643	631.929	6.2
7	49.51	49.69	18.2	28.094	26.430	627.452	6.3
8	49.77	49.97	18.2	29.685	27.912	655.826	6.4

Table 6. Density and moisture of OSB 3 boards

Sample No.	Dimensions			Weight		Density	Absolute moisture
	l (mm)	w (mm)	t (mm)	m_1 (g)	M_0 (g)	ρ_w (kg/m³)	H (%)
1	50.1	50.0	18.7	31.070	29.614	663.272	4.9
2	50.1	50.1	18.2	28.874	27.645	632.063	4.4
3	50.0	50.0	18.3	28.578	27.131	624.656	5.3
4	50.1	50.0	18.5	28.227	27.011	609.095	4.5
5	49.9	50.4	17.8	27.207	26.016	607.756	4.6
6	50.1	50.7	18.5	33.326	31.956	709.195	4.3
7	50.2	49.6	17.5	26.985	25.639	619.297	5.2
8	48.9	50.0	18.3	27.126	25.978	606.256	4.4

Table 7. Statistical evaluation of the tested board moisture

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
	H (%)					
$\bar{x}$	7.5	7.1	7.1	6.1	6.2	4.7
n	8	8	8	8	8	8
S^2	0.030	0.029	0.032	0.008	0.026	0.159
S	0.173	0.171	0.178	0.088	0.162	0.399
S%	2.3	2.4	2.5	1.4	2.6	8.5
$L^q_{5\%}$	7.3	6.9	6.7	6.0	6.0	4.3
$U^q_{5\%}$	7.8	7.3	7.3	6.3	6.4	5.3

Table 8. Statistical evaluation of the tested board density

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
	ρ (kg/m³)					
$\bar{x}$	500.638	452.191	440.250	689.189	650.534	633.949
n	8	8	8	8	8	8
S^2	1,582.489	142.678	527.081	137.752	229.139	1,271.018
S	39.781	11.945	22.958	11.737	15.137	35.651
S%	7.9	2.6	5.2	1.7	2.3	5.6
$L^q_{5\%}$	436.561	435.568	413.664	670.487	627.452	606.256
$U^q_{5\%}$	554.219	469.154	478.547	705.318	667.604	709.195

Table 9. Swelling of Dokadur and Doka 3-SO boards after water storage for 24 h

	Dokadur			Doka 3-SO		
Serial No.	t_1 (mm)	t_2 (mm)	G_t (%)	t_1 (mm)	t_2 (mm)	G_t (%)
1	20.58	21.46	4.3	20.68	21.58	4.4
2	20.46	21.50	5.1	20.57	21.76	5.8
3	20.20	21.38	5.8	20.65	21.68	5.0
4	20.57	21.41	4.1	20.68	21.91	5.9
5	20.68	21.53	4.1	20.62	21.65	5.0
6	20.48	21.52	5.1	20.67	21.67	4.8
7	20.33	21.25	4.5	20.66	21.71	5.1
8	20.65	21.28	3.1	20.68	21.80	5.4

lar plies arranged in perpendicular direction guarantees stability in form and decreases differences in mechanical properties both in longitudinal and cross direction. With the increasing number of veneers differences decrease. One ply can also consist of more veneers the fibres of which are parallel each other. Also veneers in the plywood sheet do not need to be from a veneer of the same thickness and tree species. In these cases, however, it is necessary to observe the species and thickness symmetry to the central veneer (core). For constructional plywoods serving for wooden structures rotary-cut veneers are used obtained by peeling veneer logs. By the described arrangement of veneers possibilities of veneer deformation (cross direction) in the course of wood shrinkage and swelling are markedly reduced and thus, dimensional stability of plywoods is achieved. For gluing constructional plywoods, phenolformaldehyde resin adhesives are most used guaranteeing high resistance to external effects. Exterior plywoods are provided with a protective paint or phenolic foil preventing from moisture penetration. Also edges are usually treated with a protective paint serving for the same purpose (MAHÚT, RÉH 1996).

Table 10. Swelling values of Agrop bioboards after water storage for 24 h

Serial No.	t_1 (mm)	t_2 (mm)	G_t (%)
1	18.88	20.06	6.3
2	18.91	19.79	4.7
3	18.92	20.09	6.2
4	18.91	20.03	5.9
5	18.91	19.90	5.2
6	18.91	19.96	5.6
7	18.89	19.99	5.8
8	18.92	19.92	5.3

The following panels were tested:

a) Form panel Dokaplex 18 mm thick, i.e. combined plywood sheet provided with a protective coat resistant to boil and weather effects according to ČSN EN 314-2 standard. It is suitable as formwork with the high frequency of use for the manufacture of smooth shuttering. Dokaplex form panels are available in two thicknesses 18 and 21 mm. They are supplied in three formats, viz. 1,250/250, 1,500/150 and 3,000/1,500 mm.

b) Form panel PlomaFOIL, i.e. exterior plywood produced of broadleaved and coniferous species surface-treated with phenolic foil according to PN 003-49-01.

Table. 11. Swelling values of Dokaplex and PlomaFoil boards after water storage for 24 h

	Dokaplex			PlomaFoil		
Serial No.	t_1 (mm)	t_2 (mm)	G_t (%)	t_1 (mm)	t_2 (mm)	G_t (%)
1	20.11	21.29	5.9	18.18	19.16	5.4
2	20.13	21.25	5.6	18.10	19.00	5.0
3	20.07	21.21	5.7	18.05	18.97	5.1
4	20.07	21.26	5.9	18.15	19.42	7.0
5	20.17	21.30	5.6	18.19	19.12	5.1
6	20.13	21.30	5.8	18.18	19.16	5.4
7	20.11	21.25	5.7	18.07	19.02	5.3
8	20.11	21.27	5.8	18.15	19.09	5.2

Oriented strandboards (OSB)

Oriented strandboards are a relatively new material in our country. With respect to their internal structure and mechanical-physical properties, OSB panels have been above all developed for building structures as a full-value substitute of construction plywoods. The broad range of use of OSB as a large-area board material on the basis of wood is successfully used as formwork for concrete monolithic constructions also in our country. Boards or dimension stock from basic formats have to be used with "sharply" sawn peripheral edges or treated in the form of "tongue – two-sided groove" (2PD) on longitudinal edges of boards or "tongue – four-sided groove" (4PD) where interconnection of particular boards is marked particularly in large-area formwork for "fair-face" concrete in horizontal or vertical constructions. For good formwork stripping and its possible turnover, however, it is always necessary to use suitable form removal means such as Separen or Separen special before concreting.

Oriented strandboards Eurostrand were tested. They are supplied in formats 2,500 × 1,250 mm (2,440 × 1,220 mm) and thicknesses 18, 22 and 25 mm (unsanded), quality class OSB 3 (according to ČSN EN 300 standard – bearing board for use in the moist environment), viz. both square-edged and with treated edges in the form of 2PD or 4PD, all in board thicknesses 18–25 mm.

Particular physical and mechanical properties of analysed boards were determined according to the following standards:

Table 12. Values of swelling of OSB 3 boards after water storage for 24 h

Serial No.	t_1 (mm)	t_2 (mm)	G_t (%)
1	18.56	20.27	9.2
2	18.53	19.91	7.4
3	18.23	19.44	6.6
4	18.32	19.76	7.9
5	18.69	20.20	8.1
6	18.45	19.85	7.6
7	18.41	19.71	7.1
8	18.50	19.75	6.8

ČSN EN 310 Determination of modulus of elasticity in bending and bending strength
ČSN EN 317 Determination of swelling after water storage
ČSN EN 322 Wooden boards – Determination of moisture
ČSN EN 323 Wooden boards – Determination of density
ČSN EN 325 Determination of dimensions of test specimens
ČSN-EN 326-1 Wooden boards. Sampling, cutting and check. Part 1: Sampling, cutting of test specimens and expression of test results
ČSN EN 314-1 Plywood sheets. Gluing quality. Part 1: Methods of testing
ČSN EN 314-2 Plywood sheets. Gluing quality. Part 2: Requirements
ČSN 490136 Janka hardness.

Table 13. Statistical evaluation of swelling of particular analysed boards after water storage for 24 h

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
	G_t (%)					
$\bar{x}$	4.5	5.2	5.6	5.7	5.4	7.6
n	8	8	8	8	8	8
S^2	0.707	0.271	0.292	0.017	0.425	0.693
S	0.841	0.520	0.541	0.129	0.652	0.832
S%	18.7	10.1	9.6	2.3	12.0	11.0
$L^q_{5\%}$	3.1	4.4	4.7	5.6	5.0	6.6
$U^q_{5\%}$	5.8	5.9	6.1	5.91	7.0	9.2

Load trial tests were carried out using a computer-controlled machine of Zwick company (Z 050 according to the standards mentioned above). The measured values were statistically processed (arithmetic mean, standard deviation, variance, lower and upper 5% quantile). In quantities with probably closer dependence of measured values, i.e. dependences of some strength on density which was not evidently too affected by the construction of boards, calculations of correlation were carried out. In the calculation of correlation, materials were divided into three constructional groups, viz. three-layer boards of massive construction, plywoods and OSB. All statistical calculations were carried out using the Statistics 6.0 program.

RESULTS AND DISCUSSION

Moisture and density

In Tables 1–6, values of density and moisture are given of particular materials under analysis. Tables 7–8 give statistical evaluation of tests of the determination of density and moisture.

Average moisture of analysed boards ranges between 4.7 and 7.5%. These differences in moisture cannot markedly affect measured values of physical and mechanical properties of examined boards. Density is lowest in three-layer massive boards (452.191 kg/m^3) and highest in plywoods (689.189 kg/m^3) and OSB (633.949 kg/m^3). A respective diagram shows that boards of a similar construction are also of the same density. The low density of three-layer massive boards (440.250 kg/m^3) is caused by the selection of softwood species for the construction and by two glue joints only so that the glue density does not significantly affect total density. In plywoods, the situation is another. For their construction, veneers of hardwood species are mainly used and glue joints show a marked proportion which results in about 30% higher density. In oriented strandboards, the proportion of a glue is highest. In spite of using softwood species the density of OSB is similar to that of plywood sheets.

Table 14. Values of bending strength and MOE in bending of Doka 3-SO boards

Sample No.	Doka 3-SO 21 mm (longitudinal direction)				l (mm) = 400	
	h (mm)	b (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm^2)	E_m (N/mm^2)
1	20.44	50.61	8.26	1,528	43.35	15,128.99
2	20.69	50.54	11.78	1,870	51.85	15,362.98
3	20.71	50.44	10.78	1,885	52.27	16,468.30
4	20.73	50.61	12.59	2,071	57.14	16,094.31
5	20.71	50.54	12.49	1,635	45.26	11,464.16
6	20.76	50.55	9.18	1,712	47.15	15,820.51
7	20.80	50.50	9.43	1,426	39.16	12,069.99
8	20.75	50.50	7.93	1,627	44.90	18,600.26
	Doka 3-SO 21 mm (cross direction)				l (mm) = 400	
1	20.36	50.44	18.86	354.76	10.18	1,824.10
2	20.66	50.87	22.54	627.59	17.34	2,845.92
3	20.43	50.44	21.26	671.40	19.13	2,578.24
4	20.48	50.44	23.89	596.11	16.91	2,799.64
5	20.48	50.29	14.75	451.57	12.85	2,092.98
6	20.48	50.25	15.81	443.52	12.63	1,984.07
7	20.68	50.52	16.61	394.81	10.96	1,664.17
8	20.55	50.52	14.43	586.23	16.49	2,895.35

Table 15. Values of bending strength and MOE in bending of Dokadur boards

Sample No.	Dokadur (longitudinal direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm²)	E_m (N/mm²)
1	20.6	50.75	8.05	1,905	53.06	18,662
2	20.55	50.50	8.95	2,424	68.21	23,715
3	20.72	50.50	12.14	2,798	77.43	22,439
4	21.00	50.55	9.77	2,507	67.48	21,121
5	20.40	50.55	11.37	2,667	76.06	23,719
6	20.65	50.50	13.78	2,385	66.46	15,484
7	21.00	50.45	11.83	2,814	75.89	23,154
8	20.65	50.40	11.2	2,208	61.63	15,600
9	20.50	50.30	9.46	2,402	68.18	21,687
10	20.67	50.25	9.19	1,925	53.79	16,894
11	20.85	50.55	11.79	2,510	68.53	19,102
12	20.50	50.40	11.8	2,551	72.26	23,289
13	20.60	50.50	9.21	2,139	59.88	20,254
14	20.73	49.42	12.57	2,590	73.17	19,595
15	20.67	50.05	12.7	2,322	65.15	18,085
	Dokadur (cross direction)				l (mm) = 400	
1	20.95	50.45	28.26	551	14.93	2,365
2	20.70	50.60	10.63	344	9.53	2,646
3	20.62	50.50	24.92	493	13.78	2,207
4	20.70	50.50	17.15	504	13.97	2,612
5	20.63	50.70	12.52	309	8.58	1,849
6	20.60	50.50	19.12	362	10.13	2,446
7	20.73	50.50	11.03	364	10.07	2,181
8	20.57	50.47	9.03	298	8.38	2,100
9	20.48	50.43	14.45	501	14.20	2,582
10	20.45	50.43	14.47	437	12.43	2,287
11	20.42	50.28	18.36	492	14.07	2,248
12	20.38	50.38	19.63	379	10.87	1,186
13	20.36	50.26	14.24	419	12.08	2,386
14	20.53	50.40	13.79	355	10.03	2,164
15	20.35	50.50	9.24	338	9.70	2,487
16	20.27	50.50	14.72	559	16.15	2,936

Swelling after water storage for 24 hours

Tables 9–12 give swelling values for particular analysed materials after water storage for 24 hours, Table 13 gives statistical evaluation of swelling determination tests after water storage for 24 hours.

Tables 9–13 show that in the majority of boards swelling is even. Oriented strandboards (OSB) represent an exception. In OSB, swelling is higher by about 25–30% as compared with boards of other constructions.

In the course of swelling, relatively considerable pressures occur. The pressure can cause problems concerning the subsequent removal of shuttering. Under conditions of uneven swelling in fresh concrete, however, failures in the future construction could occur due to the uneven pressure. Therefore, boards with minimum swelling in thickness are more suitable.

Bending strength and modulus of elasticity (MOE) in bending

Tables 14–19 give values of bending strength and MOE in bending of particular analysed materials. Tables 20–21 give statistical evaluation of tests of the determination of bending strength and MOE in bending. Table 22 give values of correlations of density and bending strength or MOE in bending of particular analysed boards.

As for three-layer boards, Dokadur boards (Tables 20 and 21) demonstrated the best properties in longitudinal direction. Differences between Dokadur and Bioboard are, however, minimal. Properties of Doka 3-SO boards are about 30% lower than those in the best board of the given construction Dokadur. Dokaplex plywood sheets show almost the same strength values as Dokadur boards.

Table 16. Values of bending strength and MOE in bending of Agrop bioboards

Sample No.	Bioboard Agrop (longitudinal direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm^2)	E_m (N/mm^2)
1	19.03	49.89	11.18	1,852	61.52	19,210
2	18.95	49.69	10.95	1,772	59.57	18,464
3	19.03	49.91	11.01	1,771	58.80	16,816
4	19.03	49.93	7.39	1,332	44.21	17,091
5	19.02	49.64	9.80	1,653	55.23	18,257
6	19.08	49.20	10.78	1,727	57.86	17,078
7	19.02	49.90	10.95	1,826	60.68	18,960
8	19.05	49.75	10.46	1,810	60.15	19,831
9	19.06	50.56	9.63	1,799	58.77	19,882
10	19.00	49.58	11.55	2,038	68.32	19,852
11	19.00	49.81	9.25	1,511	50.43	17,203
12	19.10	49.46	9.30	1,695	56.37	18,989
13	19.05	49.93	7.69	1,503	49.78	19,900
14	18.99	50.10	8.86	1,728	57.40	20,552
	Bioboard Agrop (cross direction)				l (mm) = 400	
1	18.96	49.89	22.69	388	12.97	1,787
2	18.96	50.15	20.47	404	13.43	1,709
3	18.94	49.98	16.37	336	11.23	1,707
4	18.94	49.90	20.15	485	16.24	2,291
5	19.05	50.02	17.66	286	9.45	1,330
6	18.97	50.02	22.24	472	15.73	1,989
7	18.94	49.80	18.14	506	16.99	2,469
8	18.93	50.00	14.87	322	10.79	1,980
9	18.94	49.90	20.15	485	16.24	2,291
10	19.01	49.50	16.31	213	7.16	1,447
11	18.95	49.99	24.19	487	16.26	2,013
12	19.16	49.81	23.58	413	13.56	1,646
13	18.96	50.03	8.28	182	6.06	1,486
14	18.96	49.84	23.80	477	15.99	1,939

Table 17. Values of bending strength and MOE in bending of Dokaplex boards

Sample No.	Dokaplex 21 mm (longitudinal direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm^2)	E_m (N/mm^2)
1	20.17	50.11	20.35	2,226.51	65.53	14,440.29
2	20.00	49.83	12.42	2,176.85	65.53	15,760.19
3	20.10	50.15	11.93	2,128.93	63.04	16,781.28
4	20.10	49.82	13.46	2,138.55	63.75	14,386.98
5	20.10	50.00	14.48	2,363.80	70.21	15,729.71
6	20.10	50.00	12.57	2,227.13	66.15	15,559.06
7	20.10	49.89	11.34	2,140.12	63.71	16,375.92
8	20.10	50.00	15.06	2,323.05	69.00	14,847.18
9	20.10	50.00	12.00	2,207.54	65.57	16,486.00
10	20.10	50.00	14.59	2,430.41	72.19	16,230.78

Table 18. Values of bending strength and MOE in bending of PlomaFoil boards

Sample No.	PlomaFoil (longitudinal direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm²)	E_m (N/mm²)
1	18.00	49.80	16.92	1,726	64.20	13,867
2	18.05	49.70	24.07	1,934	71.67	13,673
3	18.00	50.00	22.18	1,920	71.13	13,999
4	18.20	49.75	21.56	1,957	71.24	14,957
5	18.00	49.80	21.85	1,904	70.81	14,965
6	18.00	49.70	23.06	1,996	74.37	14,849
7	18.00	49.80	18.93	1,957	72.77	14,963
8	18.05	49.05	22.93	2,112	79.31	15,432
9	18.00	49.65	19.34	1,883	70.23	13,877
10	17.90	49.65	22.10	1,933	72.92	14,534
11	17.90	49.75	19.60	1,872	70.45	15,098
12	17.90	49.55	19.66	1,845	69.72	15,145
	PlomaFoil (cross direction)				l (mm) = 400	
1	18.00	50.05	17.21	2,103	77.80	16,262
2	18.00	50.05	18.73	2,446	90.51	20,115
3	18.00	49.90	21.02	2,499	92.75	20,391
4	18.00	49.90	13.93	2,209	81.99	19,955
5	18.20	50.00	14.72	2,000	72.45	17,693
6	18.10	50.00	12.08	1,971	72.20	19,269
7	18.00	50.00	19.78	2,082	77.09	14,875
8	18.05	50.05	19.78	2,345	86.29	17,676
9	18.00	50.05	16.38	2,059	76.20	16,796
10	18.20	50.05	15.75	2,312	83.68	18,866
11	18.15	49.80	21.76	2,414	88.29	19,537
12	18.05	49.95	16.42	2,271	83.72	18,989

Table 19. Values of bending strength and MOE in bending of OSB 3 boards

Sample No.	OSB (longitudinal direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm²)	E_m (N/mm²)
1	18.00	50.00	9.38	924	34.23	12,962
2	18.34	50.00	8.21	1,023	36.48	13,992
3	17.80	50.20	8.44	810	30.56	11,834
4	17.85	50.75	8.48	970	35.99	13,691
5	18.20	50.10	7.96	987	35.69	14,335
6	18.30	49.86	8.14	909	32.68	12,546
7	18.70	49.95	7.63	1,098	37.70	15,223
8	18.40	48.70	8.88	952	34.66	12,767
9	18.48	50.05	6.50	770	27.02	12,527
10	18.55	50.50	7.14	919	31.72	13,219
11	17.82	50.05	10.89	1,051	39.68	13,940
12	18.35	49.85	10.13	1,173	41.94	13,728
13	18.60	49.85	7.63	979	34.04	13,627
14	19.00	50.10	7.87	1,003	33.27	12,899
15	18.72	50.12	9.41	1,206	41.18	14,009
16	18.40	50.00	9.37	1,086	38.51	13,740
17	18.05	50.22	8.87	1,059	38.83	13,928
18	18.07	49.67	6.15	594	21.97	10,757

Table 19 to be continued

Sample No.	OSB (cross direction)				l (mm) = 400	
	h (mm)	*b* (mm)	deflection (mm)	F_{max} (N)	f_m (N/mm²)	E_m (N/mm²)
1	18.00	50.09	9.94	420	15.54	4,876
2	18.16	50.15	12.47	557	20.21	5,399
3	18.15	50.08	10.41	392	14.25	4,402
4	18.70	50.10	11.15	630	21.57	5,999
5	18.60	49.85	8.57	382	13.27	4,493
6	18.42	50.08	11.45	507	17.90	4,910
7	18.23	50.00	8.86	361	13.05	4,429
8	17.94	50.00	8.52	384	14.32	5,058
9	18.77	50.00	7.64	389	13.24	4,840
10	18.48	50.00	11.23	497	17.48	5,482
11	18.48	50.25	12.12	544	19.01	5,522
12	18.06	50.00	12.00	563	20.71	5,840
13	18.00	50.10	9.81	441	16.31	5,160
14	18.25	50.00	9.03	413	14.88	4,855
15	18.48	50.05	10.37	530	18.60	5,482
16	18.64	50.00	9.45	570	19.70	6,123
17	17.95	50.10	12.34	490	18.20	5,175
18	18.45	50.18	11.78	505	17.74	4,886

Table 20. Statistical evaluation of bending strength (N/mm²) of analysed boards

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
Longitudinal direction						
$\bar{x}$	67.1	47.6	57.1	66.5	81.9	34.8
n	15.0	8.0	14.0	10.0	12.0	18.0
S^2	56.6	33.3	34.5	9. 2	46.7	24.7
S	7.50	5.8	5.9	3.0	6.8	5.0
S%	11.2	12.1	10.3	4.6	8.3	14.3
$L^q_{5\%}$	53.1	39.2	44.2	63.0	72.2	22.0
$U^q_{5\%}$	77.4	57.1	68.3	72.2	92.7	41.9
Cross direction						
$\bar{x}$	11.8	14.6	13.0		71.6	17.0
n	16.0	8.0	14.0		12.0	18.0
S^2	6.0	11.0	12.9		12.1	7.5
S	2.5	3.5	3.6		3.5	2.7
S%	20.8	22.7	27.6		4.9	16.1
$L^q_{5\%}$	8.4	10.2	6.1		64.2	13.0
$U^q_{5\%}$	16.2	19.1	17.0		79.3	21.6

Table 21. Statistical evaluation of MOE in bending strength (N/mm²) of analysed boards

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
Longitudinal direction						
$\overline{x}$	20,186.7	15,126.2	18,720.28	15,659.7	18,368.73	13,317.98
n	15	8	14	10	12	18
S^2	8,129.921	5,442.380	1,580.087	730.212	2,955.937	1,031.280
S	2,851.302	2,332.891	1,257.015	854.525	1,719.28	1,015.52
S%	14.1	15.4	6,714.726	5.5	9.4	7.6
$L^q_{5\%}$	15,483.8	11,464.2	16,816.08	14,387.0	14,875.00	10,757.37
$U^q_{5\%}$	23,719.4	18,600.3	20,552.04	16,781.3	20,390.91	15,222.64
Cross direction						
$\overline{x}$	2,292.7	2,335.6	1,863.1		14,613.39	5,162.90
n	16	8	14		12	18
S^2	153,129	248,977	114,680		361,300	262,851
S	391.317	498.976	338.644		601.08	512.69
S%	17.1	21.4	18.2		4.1	9.9
$L^q_{5\%}$	1,186.2	1,664.2	1,330.1		13,673.48	4,401.87
$U^q_{5\%}$	2,936.5	2,895.4	2,468.7		15,431.98	6,123.16

Table 22. Values of correlations of density and bending strength or MOE in bending of particular analysed boards

	Equation of regression	Correlation
Correlation of density and bending strength of three-layer boards in longitudinal direction	$f_m = 106.41 - 0.1120 . \rho$	$r = -0.1296$
Correlation of density and bending strength of plywoods in longitudinal direction	$f_m = -8.038 + 0.11794 . \rho$	$r = 0.57261$
Correlation of density and bending strength of OSB in longitudinal direction	$f_m = -27.69 + 0.10149 . \rho$	$r = 0.62877$
Correlation of density and MOE of three-layer boards in longitudinal direction	$E_m = 6{,}057.1 + 29.752 . \rho$	$r = 0.11724$
Correlation of density and MOE of plywoods in longitudinal direction	$E_m = 24{,}508 - 14.37 . \rho$	$r = -0.3245$
Correlation of density and MOE of OSB panels in longitudinal direction	$E_m = -1{,}339 + 23.810 . \rho$	$r = 0.72122$

Table 23. Values of hardness of three-layer boards according to Janka

Sample No.	Doka 3 SO			Dokadur		
	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)
1	457.414	3,240	32.438	477.140	3,094	30.977
2	476.798	3,737	37.414	580.282	3,049	30.526
3	466.751	2,965	29.685	495.413	2,841	28.444
4	424.967	2,621	26.241	562.715	3,597	36.012
5	444.454	2,693	26.962	524.651	3,332	33.359
6	459.320	2,865	28.684	481.683	2,253	22.557
7	445.903	2,847	28.504	535.600	3,429	34.330
8	437.873	3,285	32.889	503.984	2,857	28.604
9	472.199	3,102	31.057	492.909	3,119	31.227
10	450.195	3,057	30.606	496.233	3,096	30.997
11	445.656	2,867	28.704	473.878	3,133	31.367
12	419.942	2,228	22.306	510.806	2,551	25.540
13	465.970	2,501	25.040	482.912	2,639	26.421
14	462.286	3,379	33.830	518.823	2,797	28.003

Table 24. Values of hardness of bioboards according to Janka

Sample No.	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)
1	509.460	2,420	24.229
2	416.468	2,140	21.425
3	439.873	2,612	26.151
4	439.873	2,491	24.939
5	444.159	2,497	24.999
6	439.215	1,973	19.753
7	454.030	2,468	24.709
8	430.796	2,515	25.180
9	432.276	2,102	21.045
10	434.606	2,842	28.454
11	438.751	2,505	25.080
12	470.907	2,770	27.733
13	421.389	2,189	21.916
14	456.992	3,348	33.520
15	425.279	2,318	23.207

Table 26. Values of hardness of OSB panels according to Janka

Sample No.	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)
1	681.436	4,983	49.889
2	717.451	4,741	47.466
3	603.699	3,913	39.176
4	613.833	4,267	42.720
5	645.478	3,680	36.843
6	642.525	3,979	39.837
7	638.541	3,929	39.336
8	611.388	3,070	30.736
9	633.034	4,369	43.742
10	632.483	4,051	40.558
11	636.031	5,131	51.371
12	646.204	4,852	48.577
13	607.383	4,022	40.267
14	597.006	3,392	33.960
15	643.738	3,694	36.984

Table 25. Values of hardness of plywoods according to Janka

Sample No.	Dokaplex			PlomaFoil		
	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)	Density (kg/m³)	F_{max} (N)	H'_w (N/mm²)
1	668.823	5,924	59.310	649.777	4,691	46.965
2	710.842	5,899	59.060	696.781	4,589	45.944
3	670.408	5,648	56.547	651.791	4,934	49.398
4	685.473	6,466	64.736	710.682	4,572	45.774
5	687.262	6,279	62.864	646.891	4,506	45.113
6	687.098	5,920	59.270	636.765	3,929	39.336
7	674.085	5,763	57.698	629.516	4,137	41.419
8	681.992	5,978	59.851	644.282	4,663	46.685
9	674.569	5,772	57.788	679.155	4,266	42.710
10	686.998	5,760	57.668	666.138	4,830	48.357
11	682.311	6,545	65.527	651.660	4,457	44.623
12	681.638	6,285	62.924	633.305	4,203	42.080
13	695.435	6,520	65.277	643.138	4,776	47.816
14	693.306	5,912	59.190	686.939	4,479	44.843
15	686.308	6,488	64.957	663.459	3,815	38.195

Table 27. Statistical evaluation of hardness of analysed boards H'_W (N/mm²) according to Janka

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
$\bar{x}$	29.883	29.597	24.823	60.844	44.617	41.431
n	14	14	16	16	15	15
S^2	12.927	15.081	11.588	10.113	10.693	34.998
S	3.595	3.883	3.404	3.180	3.270	5.916
$S\%$	12.0	13.1	13.7	5.2	7.3	14.3
$L^q_{5\%}$	22.557	22.306	19.753	56.547	38.195	30.736
$U^q_{5\%}$	36.012	37.414	33.520	65.527	49.398	51.371

Table 28. Values of correlations of density and hardness according to Janka of particular analysed boards

	Equation of regression	Correlation
Correlation and regression of the dependence of Janka hardness on the density of three-layer boards	$H'_w = 1.2455 + 0.05723 \,.\, \rho$	$r = 0.51302$
Correlation and regression of the dependence of Janka hardness on the density of plywoods	$H'_w = -104.4 + 0.23382 \,.\, \rho$	$r = 0.59124$
Correlation and regression of the dependence of Janka hardness on the density of OSB panels	$H'_w = -28.57 + 0.10994 \,.\, \rho$	$r = 0.57701$

Table 29. Values of shear strength and proportions of fracture in the wood of three-layer boards

	Dokadur		Doka 3-SO		Bioboard	
No.	Shear strength (N/mm²)	Proportion of fracture in the wood (%)	Shear strength (N/mm²)	Proportion of fracture in the wood (%)	Shear strength (N/mm²)	Proportion of fracture in the wood (%)
1	0.5	95	0.9	95	1.2	65
2	1.2	100	0.7	95	0.9	60
3	1.3	75	1.3	65	1.0	75
4	1.1	90	0.7	65	1.2	95
5	1.0	100	0.8	50	1.1	50
6	0.8	95	1.1	90	0.9	85
7	0.8	100	0.9	100	0.7	100
8	1.7	90	0.9	70	0.8	95
9	1.1	100	0.8	100	0.9	90
10	1.4	95	0.6	100	1.3	95

PlomaFoil shows nearly 20% better properties. OSB show the worst properties in longitudinal direction. Values measured are 45% lower than the average value of other boards. In cross direction, the majority of boards demonstrates substantially inferior properties as compared with properties in longitudinal direction. It results from the way of using the boards which are placed transversely so that they are not loaded in cross direction. In atypical constructions where transverse load is supposed plywoods are used. Three-layer boards show substantially lower bending strength values in cross direction than in longitudinal direction. In plywoods, values in cross direction are slightly lower. Plywoods are, therefore, ideal for formwork where loading can occur in cross direction. OSB panels correspond to three-layer boards in cross direction.

Moreover, correlation was determined between board density and bending properties in each of the board groups. Therefore, on the ground of higher requirements for properties in longitudinal direction the correlation was determined in this direction only.

Three-layer boards show slight indirect proportion as for bending strength and slight direct proportion as for MOE. It is possible to suppose that bending properties are only little affected by the material density. The board construction will be evidently more important, viz. mainly the thickness of particular layers. Plywoods demonstrate high direct dependence in bending strength and medium dependence in MOE. Thus it is possible to suppose that boards of higher density will show also higher strength. OSB panels show even greater relationships between density and bending properties.

Dependence of bending strength on density is high and dependence of MOE on density is considerably high (Table 22).

Hardness according to Janka

Tables 23–26 give hardness values of particular analysed materials according to Janka. Table 27 gives the statistical evaluation of tests.

Table 28 give values of correlations of density and hardness according to Janka of particular analyzed boards under examination.

Hardness according to Janka is a property which can very significantly affect repeated use (MATOVIČ 1993). As evident from Tables 23–27, three-layer boards show even hardness ranging about a value of 29 N/mm². In original Dokadur boards, their surface is strengthened by a special hardened paint. The paint forms an encrustation protecting the board from dent and thus removes a handicap of boards of this construction as compared with plywood sheets. However, hardness of this encrustation cannot be recorded by the given test. In original Dokaplex plywoods, Janka hardness ranges about 61 N/mm². Thanks to this hardness high number of repeated uses is possible. Hard bearing materials protect a surface frangible foil from dent. Therefore. surface splits do not occur and water does not infiltrate into the board even after its repeated use. As for PlomaFoil boards, they are 25% more inferior (45 N/mm²). OSB panels with their strength 41 N/mm² are like PlomaFoil plywoods.

Table 30. Values of shear strength and proportions of fracture in the wood of plywood sheets

Serial No.	PlomaFoil Shear strength (N/mm^2)	PlomaFoil Proportion of fracture in the wood (%)	Serial No.	Dokaplex Shear strength (N/mm^2)	Dokaplex Proportion of fracture in the wood (%)
1A	0.5	50	1A	2.0	75
2A	1.1	75	2A	1.9	65
3A	0.8	95	3A	0.6	45
4A	0.7	75	4A	0.5	80
5A	0.9	45	5A	1.1	60
6B	1.6	100	6B	1.9	75
7B	1.3	95	7B	1.4	40
8B	1.1	95	8B	1.1	20
9B	0.8	75	9B	1.2	50
10B	1.0	100	10B	1.9	100
11C	1.2	100	11C	1.2	95
12C	1.1	70	12C	1.7	90
13C	1.3	100	13C	1.7	100
14C	1.5	100	14C	0.8	5
15C	1.6	95	15C	1.4	20
16D	1.3	100	16D	1.3	15
17D	1.2	95	17D	1.3	75
18D	1.3	100	18D	1.1	50
19D	1.0	95	19D	0.9	50
20D	1.0	100	21D	1.7	45
21E	0.9	95	22D	1.4	100
22E	1.6	100	23E	1.3	95
23E	1.4	75	24E	1.6	95
			25E	1.7	25
			26E	1.8	70
			27E	0.7	75

Table 31. Statistical evaluation of shear strength (N/mm^2) in bending of tested boards

	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil
$\bar{x}$	1.1	0.9	1.0	1.4	1.1
n	10	10	10	26	23
S^2	0.119	0.037	0.037	0.182	0.089
S	0.345	0.192	0.191	0.426	0.298
$S\%$	31.8	22.2	19.3	31.5	26.2
$L^q_{5\%}$	0.5	0.6	0.7	0.5	0.5
$U^q_{5\%}$	1.7	1.3	1.3	2.0	1.6

With respect to the fact that dependence of Janka hardness on density was supposed correlation analysis was carried out. In all three constructions of boards, high direct proportion was found between density and Janka hardness (Table 28).

Gluing quality, shear strength

Values of shear strength and proportions of fracture in the wood of analysed boards are given in Tables 29–31.

Shear strength is relatively even in all tested boards. Only Dokaplex board showed above-average strength by about 25%.

CONCLUSION

Average values of physical and mechanical properties of analysed boards are given in the aggregate Table 32.

Among three-layer massive boards, no fundamental differences were found as for physical and mechanical

Table 32. Comparison of physical and mechanical properties of analysed boards and costs (average values of properties)

Examined property	Unit	Dokadur	Doka 3-SO	Bioboard	Dokaplex	PlomaFoil	OSB
Density	(kg/m^3)	501	452	440	689	651	634
Bending strength (along)	(N/mm^2)	67.1	47.6	57.1	66.5	81.9	34.8
Bending strength (across)	(N/mm^2)	11.8	14.6	13.0		71.6	17.0
MOE (along)	(N/mm^2)	20,186.7	15,126.2	18,720.3	15,659.7	18,368.7	13,317.9
MOE (across)	(N/mm^2)	2,292.7	2,335.6	1,863.1		14,613.3	5,162.9
Janka hardness	(N/mm^2)	29.9	29.6	24.8	60.8	44.6	41.4
Swelling after 24 h	(%)	4.5	5.26	5.6	5.7	5.4	7.6
Gluing strength (shear)	(N/mm^2)	1.1	0.9	1.0	1.4	1.1	
Cost (without VAT)	(CZK/m^2)	1,850	490	357	2,062	429	384

properties. Bioboards can be compared with Doka 3-SO boards. Their advantage consists in lower density ensuring better and easier handling during assembly. As for the most important property, i.e. bending strength along the grain, the board was placed between 3-SO board and Dokadur board. Its cost CZK 357 (without VAT) is nearly 30% lower than that of 3-SO boards. The board is not, however, supplied with surface finish. In case of using a special paint, the cost would be increased and the price difference would not be so marked. The surface quality would then correspond to Dokadur boards which are, however, several times more expensive. The Dokadur board belongs to the most expensive boards of this construction and generally, it is the second most expensive of all tested boards. The board has been, however, specially developed for the maximum possible number of use. It has very quality surface finish and edges treated using a plastic frame. For big construction companies which have to build large-area ceiling shuttering where atypical forms are not supposed the board can be a profitable investment in spite of its cost thanks to its high service life.

Plywoods are a material for the manufacture of formwork for more difficult elements from the static point of view. They are most often used for example in the construction of bridges. DokaFoil boards showed (in spite of their thickness smaller by 3 mm) 20% higher bending strength in longitudinal direction than Dokaplex boards. Though hardness is 25% lower than that of Dokaplex boards, it is in any case above-average whereas its cost is 80% lower. OSB panels showed bending properties rather slightly below-average. According to catalogue sheets available for boards of this construction values measured in such a way were substantially lower. Their another disadvantage consists in a relatively large change in thickness due to swelling. They show, of course, quality surface finish and hardness comparable with plywoods. According to results of tests the boards can be recommended for less difficult formwork. It is possible to suppose multiple use.

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Analýza vlastností deskových materiálů pro betonářská bednění

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ABSTRAKT: Článek shrnuje výsledky analýzy vlastností na našem trhu dostupných velkoplošných materiálů použitelných pro výrobu betonářských bednění. Materiály byly porovnány z hlediska fyzikálních a mechanických vlastností včetně ekonomického vyhodnocení. Hodnoceny byly materiály od firmy DOKA, která se zabývá výrobou bednících systémů, a to Doka 3-SO, Dokadur a Dokaplex. Tyto materiály byly porovnávány s následujícími materiály dostupnými na našem trhu: Biodeska, povrchově upravená vodovzdorná překližovaná deska, orientovaná třísková deska OSB. Výsledkem práce je porovnání cena/fyzikálně mechanické vlastnosti.

Klíčová slova: bednění; velkoplošné materiály; třívrstvá masivní deska; OSB; stavební překližka; pevnost v ohybu; modul pružnosti v ohybu; smyková pevnost; bobtnání

Betonářské bednění je dočasná konstrukce, sloužící jako forma pro budoucí betonovou konstrukci. Skládá se zpravidla z podpůrné konstrukce a konstrukce vytvářející tvar prvku. Stavebnictví je největším spotřebitelem dřeva a výrobků ze dřeva. Firmy vyrábějící stavební překližky a velkoplošné materiály se neustále snaží vyvíjet nové vhodné materiály pro výrobu betonářských bednění podle požadavků stavebních projektantů. V současné době se nejčastěji používají překližované desky, třívrstvé masivní desky a laťovky. Na fyzikální a mechanické vlastnosti těchto materiálů jsou kladeny specifické požadavky. Výrobní technologie těchto desek jsou velice náročné a finančně nákladné, což vytváří druhotný požadavek, kterým je zaručení vícenásobného použití. Materiály používané na výrobu bednění by měly několikanásobné použití zaručovat. Výroba betonových konstrukcí je tzv. mokrý proces, při kterém je bednění vystaveno agresivnímu prostředí cementu z betonových směsí a také povětrnostním vlivům. Aby nedocházelo k jejich degradaci, musejí se dodržovat určité zásady. Bohužel tyto zásady jsou na stavbách velice často zanedbávány.

Velkoplošné materiály pro bednění jsou na povrchu opatřeny fólií nebo nátěrem chránícím je proti vniknutí vlhkosti. Také hrany bývají natřeny nátěrem se stejnou funkcí. Je-li zapotřebí při montáži bednění tyto materiály z nějakého důvodu zakrátit, musí se vzniklá hrana, která není chráněna, natřít nátěrem zabraňujícím vniknutí vlhkosti. Před samotnou betonáží je třeba povrch bednění natřít ochranným prostředkem, který desky chrání proti vlhkosti a napomáhá odbednění. Pokud by se takový nátěr neprovedl, hrozí při odtržení desky od betonové konstrukce odloupnutí ochranné vrstvy a tím její znehodnocení.

Cílem práce bylo provedení analýzy na trhu běžně dostupných velkoplošných materiálů pro výrobu betonářských bednění. Materiály byly porovnány z hlediska fyzikálních a mechanických vlastností včetně ekonomického vyhodnocení. Hodnotily se materiály od firmy DOKA, která se zabývá výrobou bednících systémů, a to:

– Doka 3-SO – třívrstvá deska podle ÖNORM B 3023
– Dokadur – třívrstvá deska podle ÖNORM B 3023
– Dokaplex – kombinovaná překližovaná deska Dokaplex a PlomaFoil.

Tyto materiály byly porovnávány s následujícími materiály dostupnými na našem trhu:

– Biodeska Agrop
– Povrchově upravená vodovzdorná překližovaná deska
– Orientovaná třísková deska (OSB) Eurostrand.

Na základě ekonomického vyhodnocení jsou doporučeny materiály s optimálním poměrem cena/fyzikálně mechanické vlastnosti.

Průměrná vlhkost analyzovaných desek se pohybuje okolo 4,7–7,5 %. Tyto rozdíly vlhkosti nemohou výrazně ovlivňovat naměřené hodnoty fyzikálních a mechanických vlastností sledovaných desek.

Hustota je nejnižší u třívrstvých masivních desek (452,191 kg/m^3) a nejvyšší u překližek (689,189 kg/m^3) a OSB desek (633,949 kg/m^3). Přitom lze vidět, že desky podobné konstrukce mají i podobnou hustotu. Nízká hustota třívrstvých masivních desek (440, 250 kg/m^3) je způsobena výběrem měkkých dřevin pro konstrukci a pouze dvěma lepenými spárami, takže hustota lepidla celkovou hustotu významně neovlivňuje. U překližek je situace opačná. Pro jejich konstrukci jsou převážně využívány dýhy tvrdších dřevin a mají výrazný podíl lepené spáry, což způsobuje asi o 30 % vyšší hustotu. U OSB desek je podíl lepidla nejvyšší, a to do takové míry, že i přes používání měkkých dřevin je jejich hustota podobná jako u překližovaných desek.

Z tabulek 9–13 vyplývá, že bobtnání je u většiny desek vyrovnané. Výjimku tvoří OSB desky. U OSB desek je bobtnání vyšší asi o 25–30 % ve srovnání s deskami jiných konstrukcí. Při bobtnání vzniká poměrně velký tlak. Tento tlak může způsobit problémy s následným odbedňováním konstrukce. Při nerovnoměrném bobtnání u čerstvého betonu by díky nerovnoměrnému tlaku mohlo dojít k narušení budoucí konstrukce. Z těchto důvodů více vyhovují desky s minimálním tloušťkovým bobtnáním.

V podélném směru mezi třívrstvými deskami vykazuje nejlepší vlastnosti (pevnost v ohybu, modul pružnosti v ohybu) deska Dokadur (tab. 20, 21). Rozdíl mezi deskou Dokadur a Biodeskou je ale minimální. Hodnoty pevnostních vlastností desky Doka 3-SO jsou asi o 30 % nižší než u nejlepší desky dané konstrukce Dokadur. Překližovaná deska Dokaplex vykazuje pevnost téměř stejnou jako deska Dokadur. PlomaFoil má téměř o 20 % lepší vlastnosti. Nejhorší vlastnosti v podélném směru vykazuje OSB deska. Naměřené hodnoty jsou o 45 % nižší než hodnoty ostatních desek. V příčném směru vykazuje většina desek podstatně horší vlastnosti než ve směru podélném. Vyplývá to ze způsobu používání desek, které jsou kladeny příčně, takže nejsou v příčném směru namáhány. U atypických konstrukcí, kde se předpokládá příčné zatížení, se používají překližky. Tomu také odpovídají naměřené hodnoty. Desky třívrstvé konstrukce vykazují podstatně nižší hodnoty pevnosti v ohybu v příčném směru než v podélném. U překližek jsou hodnoty v příčném směru nepatrně nižší. Překližky jsou proto ideální pro bednění, kde může vzniknout zatížení v příčném směru. OSB desky odpovídají v příčném směru deskám třívrstvé konstrukce.

Desky třívrstvé konstrukce vykazují slabou nepřímou úměrnost co se týká pevnosti v ohybu a slabou přímou úměrnost co se týká modulu pružnosti. Dá se tedy předpokládat, že vlastnosti v ohybu hustota materiálu ovlivňuje jen málo. Důležitější bude zřejmě konstrukce desky, a to převážně tloušťka jednotlivých vrstev. Překližky vykazují u pevnosti v ohybu vysokou přímou závislost a u modulu pružnosti závislost střední. Lze tedy předpokládat, že desky s vyšší hustotou budou i pevnější. Desky konstrukce OSB vykazují ještě vyšší závislost hustoty a ohybových vlastností. Závislost ohybové pevnosti na hustotě je vysoká a závislost modulu pružnosti je značně vysoká (tab. 22).

Tvrdost podle Janka je vlastnost, která může velmi výrazně ovlivnit opakovanou použitelnost (MATOVIČ 1993). Jak je zřejmé z tab. 23–28, mají desky třívrstvé konstrukce vyrovnanou tvrdost, která se pohybuje kolem 29 N/mm². U originálních desek Dokadur je povrch zpevněn speciálním tvrzeným nátěrem. Nátěr tak vytváří krustu, která chrání desku proti promáčknutí, a tím vyrovnává handicap, který mají desky dané konstrukce proti deskám překližovaným. Tvrdost této krusty ovšem není možné zachytit danou zkouškou. U originálních překližek Dokaplex se tvrdost podle Janka pohybuje kolem 61 N/mm². Díky této tvrdosti je možný vysoký počet opakovaných použití. Tvrdý nosný materiál chrání povrchovou křehkou fólii proti promáčknutí. Proto nevznikají povrchové trhliny a do desky i opakovaným použitím nezatéká voda. Deska PlomaFoil je v tomto směru o 25 % horší (45 N/mm²). Desky OSB jsou s pevností 41 N/mm² podobné překližkám PlomaFoil.

Mezi deskami třívrstvé masivní konstrukce nebyly zjištěny žádné zásadní rozdíly, co se týká fyzikálních a mechanických vlastností. Při porovnávání se Biodeska dá nejvíce přirovnat k desce Doka 3-SO. Její výhodou je nižší hustota, která zaručuje lepší manipulovatelnost při montáži. V nejdůležitější vlastnosti, kterou je pevnost v ohybu podél vláken, se deska umístila mezi deskou 3-SO a deskou Dokadur. Její cena 357 Kč/m² bez DPH je téměř o 30 % nižší než cena desky 3-SO. Deska ale není dodávána s povrchovou úpravou. Pokud by se použil některý ze speciálních nátěrů, zvýšila by se cena a cenový rozdíl by potom nebyl tak markantní. Kvalita povrchu by přitom odpovídala desce Dokadur, která je několikanásobně dražší. Deska Dokadur je mezi deskami této konstrukce nejdražší a celkově je druhou nejdražší ze zkoušených desek. Deska je ale speciálně vyvinuta pro maximální možný počet použití. Má velice kvalitní povrchovou úpravu a hrany upraveny plastovým rámem. Pro velké stavební firmy, které vytvářejí stropní bednění velkých ploch, u kterých se nepředpokládají atypické tvary, může být tato deska díky vysoké životnosti i přes svou cenu výhodnou investicí.

Překližky jsou materiálem pro výrobu bednění pro staticky náročnější prvky. Nejčastěji se používají např. při stavbě mostů. Deska DokaFoil i přes svou o 3 mm menší tloušťku vykázala o 20 % vyšší pevnost v ohybu v podélném směru než deska Dokaplex. Tvrdost je sice o 25 % nižší než u desky Dokaplex, ale i tak je nadprůměrná. Její cena je přitom o 80 % nižší. Deska konstrukce OSB vykázala ohybové vlastnosti spíše mírně podprůměrné. Podle katalogových listů, které jsou k deskám této konstrukce dostupné, byly takto naměřené hodnoty podstatně nižší. Jejich další nevýhodou je poměrně velká změna tloušťky vlivem bobtnání. Mají ovšem kvalitní povrchovou úpravu a tvrdost srovnatelnou s překližkami. Podle výsledků zkoušek lze tyto desky doporučit pro méně náročná bednění. Dá se u nich předpokládat vysoká obrátkovost.

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