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ANALYSIS OF PROPERTIES OF PLYWOOD FOR SOME AREAS OF USAGE IN WOODEN CONSTRUCTIONS

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ABSTRACT
For production wooden floors, walls, roofs and concrete panels use plywood, that different in their properties. Choice property of plywood depends of area use.
In this paper show analysis of properties of plywood for some characteristic case of use in wooden constructions.
Key words: properties of plywood, wooden construction, usage, analysis

1. INTRODUCTION
The most important raw material for plywood is a renewable natural resource - wood. For production plywood use deciduous (beech, poplar, birch and other) and conifer (for example spruce, pine) veneers. The standard plywood is made up of thin multiple cross-banded veneers. In addition to standard cross-banded construction a range of orientated special constructions, aimed at specific end uses are available.
There are several types of plywood: deciduous or conifer plywood – deciduous or conifer veneers throughout the construction; combi plywood - two deciduous veneers (for example birch) on each face and alternate inner veneers of conifer and deciduous (birch); combi mirror plywood - one deciduous (birch) veneer on each face and alternate inner veneers of conifer and deciduous (birch).
The vast majority of plywood is of cross-banded construction bonded with phenol resin adhesive. Normal gluing quality is suitable for use in exterior (service class 3) situations when properly protected. A small part cross-banded plywood production is bonded with urea formaldehyde glue. These boards are suitable for use in dry (service class 1) or humid (service class 2) conditions. The phenol formaldehyde gluing fulfils the requirements of EN 314-2 class 3 exterior. Phenol formaldehyde glued plywood products exhibit very low levels of formaldehyde emissions. Urea formaldehyde glued products have slightly higher values but they still fulfill the requirements of the most demanding European standards relating to formaldehyde emission and content.
Deciduous, combi, combi mirror and conifer plywood panels can all be supplied overlaid or coated to meet specific user requirements. The main types of surfaced panels manufactured by the plywood industry are as follows: phenolic film faced, smooth or textured, painting film faced, melamine film faced, special products: painted and stained plywood, veneered plywood, CPL or HPL laminate faced plywood, polypropylene plastic foil coated plywood, glass fiber reinforced surfaces, metal and mineral aggregate faced plywood and plywood provided with sound insulation.
Plywood produced by nominal thickness at 4 – 50 mm and standard size 1200/1200 mm to 3050/3660 (4000) mm.

2. SOME PRINCIPLES OF DESIGN OF PLYWOOD

Criteria for the structural design and appraisal of structures or structural elements made from wood or wood products are provided in European Standards. Technical properties of plywood are determined by EN 310 to EN 13986. The design guidance given is based on the limit state design principles of Eurocode 5 (ENV 1995-1-1) published in 1993. The design is carried out for strength limit states to assure that the effect of factored loads, determined by a structural analysis of the effect of the applicable types of loads and load factors, does not exceed the factored resistances calculated from specified strengths of materials adjusted by the appropriate factors affecting the specified strengths. For serviceability limit states (such as deflection), design ensures that the effect of specified loads results in structural behavior that falls within the specified limits. The limit state design approach is to provide adequate resistance to certain limit states, namely the ultimate limit state and the serviceability limit state. Ultimate limit state refers to the maximum load carrying capacity of the construction while serviceability limit state refers to the normal use of the construction. In ultimate limit state design it shall be verified that the design stress σ_d is less than the design strength f_d . The design stress σ_d is calculated using the design value of the load F_d . For design situations with only one variable load, for example snow or impose load, the design load is given by

$$F_d = 1.35\ F_{k,perm} + 1.5\ F_{k,var}. \quad (1)$$

For design situations with two or more variable loads the design load is given by

$$F_d = 1.35 F_{k,perm} + \Sigma 1.35\ F_{k,var} \quad (2)$$

where $F_{k,perm}$ is the characteristic value of the permanent load and $F_{k,var}$ is the characteristic value of the variable load. The most unfavourable design load shall be used. The design strength f_d is given by

$$f_d = k_{mod} \cdot f_k / \gamma_m \quad (3)$$

where f_k is the characteristic value of strength and γ_m is the partial safety factor for the material. For plywood as for other wood and wood based materials the value of γ_m is 1,3 k_{mod} is a factor taking into account the effect of duration of load and moisture content (service class). The partial safety factors for loads γ_q given in equations may be reduced from 1,35 to 1,.20 and from 1,.5 to 1,35 for one-storey constructions with moderate spans that are only occasionally occupied.

Floors are usually designed to service class 1 and load duration class medium-term. The design strength f_d is given values of $k_{mod} = 0,80$, $k_{def} = 0,25$, $\gamma_q = 1,5$ and $\gamma_m = 1,3$

Properties of plywood depend on load cases, for example: a uniformly distributed load or a concentrated load over an area of 50 x 50 mm on a continuous plate strip with one and two equal span lengths, a uniformly distributed load or a concentrated load over an area of 50 x 50 mm on a simply supported plate. If there are high loads over a small contact area, compression perpendicular to face of plywood could be critical. In most practical cases the following values can be used: birch plywood 9 [N/mm^2], combi plywood 5 [N/mm^2], spruce plywood 4 [N/mm^2] for bearing on face

Roofs are usually designed to service class 2 and load duration class medium-term. Consequently, the same load resistance values given for floors can be used. Furthermore, the deflection values shall be multiplied by $k_{def,\ corr} = 1,04$.

Vehicle floors are designed to service class 2 and load duration class shortterm. Based on general design principles, tabulated load resistance values for floors exposed to loads from wheels of different spans and thicknesses are given. Design the load resistances and deflections were calculated according to the following assumptions: $\gamma_q = 1,0$, $\gamma_m = 1,.0$, $k_{mod} = 0, 90$, $k_{def} = 0,00$.

The majority of plywood used in concrete formwork is phenol film surfaced. The strength of the formwork board depends on the type of plywood used. Based on general design principles, tabulated load resistance values for continuous plate strips with equal spans used as concrete formwork. The load resistances and deflections were calculated according to the following assumptions: $\gamma_q = 1.2$, $\gamma_m = 1.3$, $k_{mod} = 0.70$, $k_{def} = 0.40$. The plywood used in concrete formwork are designed to service class 3 and load duration class short-term

3. ANALYSIS OF PROPERTIES OF PLYWOOD

In addition to strength, modulus of elasticity and shear modulus the density and section properties are needed as input values in the design process.

The mass of plywood primarily depends on the wood species, but is also affected by the in service moisture content. For practical design purposes, typical values range from 500 to 600 [kg/m^3] for Douglas Fir plywood, and 400 to 500 [kg/m^3] for Canadian Softwood plywood, 680 [kg/m^3] for ,

Birch plywood, 620 [kg/m^3] for combi plywood, 520 kg/m3 for conifer plywood (thin veneers) and 460 kg/m3 for conifer plywood (thick veneers).
The moisture content of plywood is normally 7-12 % when leaving the mill. After delivery the moisture content of plywood may change (usually increasing) during transportation, storage and further processing. Like all other wood-based materials, plywood is a hygroscopic product and exhibits viscous-elastic mechanical behavior. For these reasons, it is necessary to take moisture conditions into consideration when loading plywood. Plywood has balanced moisture content under given conditions of relative humidity (RH) and air temperature (T). In the basic condition defined in Eurocode 5: with T = 20°C and RH = 65 %, the equilibrium moisture content of thin-veneer plywood (birch, combi and conifer) is around 12 % and thick-veneer conifer plywood 10 %. An increase in moisture content will result in a decrease in the strength, modulus of elasticity and shear modulus values. Unlike some other wood-based panel products, exterior quality plywoods will normally revert to their original strengths and modules when returned to their original moisture content.
The dimensional changes in and across the face grain direction of exterior plywood averages 0,015 % increase per 1 % increase of moisture level of plywood, throughout the working range of moisture content of 10 - 27 %. Changes in board thickness over the same working range of moisture content will average 0.3-0.4 % increase per 1 % increase of moisture level. The moisture permeability of panels is important in, for example the design of composite external walls and roofs of buildings. Transmission rate for combi plywood thickness 6,5 – 21 mm is g/(m^2·24h) 7,0 – 16,4 for film-faced combi plywood thickness 6,5 – 21 mm is 2,9 – 3,5 and average 14,8 for conifer plywood thickness 9 mm. Value of transmission rate increase with thickness reduction of panels. The vapour permeability of plywood is dependent on its moisture content. When the moisture content of plywood increases, the vapour permeability is also greater.
The thermal conductivity of plywood is dependent on its moisture content. Plywood has excellent dimensional stability under heat, far superior to that of metals and plastics. In practice, the thermal deformation of plywood is so small, that it can generally be disregarded. Standard plywood and most coated plywood products are suitable for use at temperatures of 100°C and many up to 120°C. Plywood has an optimal dimensional stability under heat and a low rate of combustion, better than solid wood. The temperature at which plywood will ignite when exposed to a naked flame is about 270°C whilst a temperature of over 400°C is needed to cause spontaneous combustion. When exposed to a fully developed fire, plywood chars at a slow and predictable linear rate (about 0.6 mm per minute), which enables it to be used in certain fire resisting constructions. This property can be improved by impregnation or coating the plywood with proprietary formulations or by facing with non-combustible foils. Plywood is a good insulating material in relation to its weight. The sound insulation of plywood can be improved by using sandwich construction and by avoiding gaps between elements.
Formaldehyde emission from phenol formaldehyde and urea formaldehyde resin adhesive bonded plywood determined according to EN 717-2, the formaldehyde emission from unsurfaced exterior plywood and limits of EN 1084.
The majority of plywood used in concrete formwork is phenol film surfaced. The strength of the formwork board depends on the type of plywood used. Every types of plywood have characteristic value of properties. Table 1. show values for several properties of birch Finnish plywood.
Birch plywood is characterised by its excellent strength, stiffness and resistance to creep. It has a high planar shear strength and impact resistance, which make it especially suitable for heavy-duty floor and wall structures. Oriented plywood construction has a high wheel carrying capacity. Birch plywood has excellent surface hardness, damage and wear resistance. Sanded birch plywood has a smooth and durable surface. Its pleasant, light-coloured visual appearance offers the best base for finishing. Properly surfaced and edge sealed birch plywood also offers excellent weather and moisture resistance. Panel shear about 9,5 [N/mm^2] and modulus of rigidity $G_{V\,II}$ = 620 [N/mm^2] . Typical end uses of birch plywood are concrete formwork systems, floors, walls and roofs in transport vehicles, container floors, floors subjected to heavy wear in various buildings and factories, scaffolding materials, shelves, load bearing special structures, traffic signs, furniture and die boards.
Combi plywood is characterized by its strength and stiffness properties which are in many respects virtually the same as those of birch plywood. The strength and stiffness properties on its major axes are quite similar, which ensures a balanced structure. An exception to this is planar shear, where the

strength in the cross-grain direction of the face veneer is clearly inferior to the strength in the grain direction.

Table 1. Lay-up, thickness, area, and section modulus, second moment of area as well as bending, tension and compression properties of cross sections of sanded Finnish birch plywood

Table 3-2. Birch plywood							Characteristic strength						Mean modulus of elasticity			
	Section properties						Bending		Compression		Tension		Bending		Tension and compression	
Lay-up	Nominal thickness	Number of plies	t mean mm	A mm²/mm	W mm³/mm	I mm⁴/mm	$f_{m\,\parallel}$ N/mm²	$f_{m\perp}$ N/mm²	$f_{c\,\parallel}$ N/mm²	$f_{c\perp}$ N/mm²	$f_{t\,\parallel}$ N/mm²	$f_{t\perp}$ N/mm²	$E_{m\,\parallel}$ N/mm²	$E_{m\perp}$ N/mm²	$E_{t/c\,\parallel}$ N/mm²	$E_{t/c\perp}$ N/mm²
|—|	4	3	3.6	3.6	2.16	3.89	65.9	10.6	31.8	20.2	45.8	29.2	16471	1029	10694	6806
|—|—|	6.5	5	6.4	6.4	6.83	21.8	50.9	29.0	29.3	22.8	42.2	32.8	12737	4763	9844	7656
|—|—|—|	9	7	9.2	9.2	14.1	64.9	45.6	32.1	28.3	23.7	40.8	34.2	11395	6105	9511	7989
|—|...|—|	12	9	12.0	12.0	24.0	144	42.9	33.2	27.7	24.3	40.0	35.0	10719	6781	9333	8167
|—|...|—|	15	11	14.8	14.8	36.5	270	41.3	33.8	27.4	24.6	39.5	35.5	10316	7184	9223	8277
|—|...|—|	18	13	17.6	17.6	51.6	454	40.2	34.1	27.2	24.8	39.2	35.8	10048	7452	9148	8352
|—|...|—|	21	15	20.4	20.4	69.4	707	39.4	34.3	27.0	25.0	39.0	36.0	9858	7642	9093	8407
|—|...|—|	24	17	23.2	23.2	89.7	1041	38.9	34.4	26.9	25.1	38.8	36.2	9717	7783	9052	8448
|—|...|—|	27	19	26.0	26.0	113	1465	38.4	34.5	26.8	25.2	38.7	36.3	9607	7893	9019	8481
|—|...|—|	30	21	28.8	28.8	138	1991	38.1	34.6	26.7	25.3	38.5	36.5	9519	7981	8993	8507
|—|...|—|	35	25	34.4	34.4	197	3392	37.6	34.7	26.6	25.4	38.4	36.6	9389	8111	8953	8547
|—|...|—|	40	29	40.0	40.0	267	5333	37.2	34.7	26.5	25.5	38.3	36.8	9296	8204	8925	8575
|—|...|—|	45	32	44.2	44.2	326	7196	37.0	34.7	26.5	25.5	38.2	36.8	9259	8241	8914	8586
|—|...|—|	50	35	48.4	48.4	390	9448	36.8	34.8	26.4	25.6	38.1	36.9	9198	8302	8895	8605

Combi plywood has a smooth and durable birch face and surface hardness and damage resistance are comparable to those of birch plywood. Its pleasant, light-coloured visual appearance offers a good base for finishing. Bending about f_{mll} = 29,9 - 50,8 [N/mm^2] and $f_{m\perp}$ = 29,0 – 34,6 [N/mm^2], compression f_{cll} = 19,5 – 24,5 [N/mm^2] and $f_{c\perp}$ = 22,8 – 25,3 [N/mm^2], tension f_{tll} = 15,1 – 19,1 [N/mm^2] and $f_{t\perp}$ = 32,8 – 36,5 [N/mm^2]. Panel shear about 7,0 [N/mm^2] and modulus of rigidity G_V = 581 – 600 [N/mm^2] . Typical end uses of combi plywood are concrete formwork systems, floors, walls and roofs in housing constructions, farm buildings and related structures, vehicle floors, walls and roofs, furniture, fixtures and shelves, scaffolding materials and packages.

Spruce plywood is characterised by its less dense surface when compared with birch, a prominent grain structure and a larger number of knots. The panel has a low weight and is easy to work and nail. Strength and stiffness properties are reasonably good and dimensional changes when subjected to moisture variations are minimal. Bending about f_{mll} = 21,8 – 37,6 [N/mm^2] and $f_{m\perp}$ = 6,0 – 19,8 [N/mm^2], compression f_{cll} = 18,5 – 22,0 [N/mm^2] and $f_{c\perp}$ = 14,0 – 17,5 [N/mm^2], tension f_{tll} = 14,4 – 17,1 [N/mm^2] and $f_{t\perp}$ = 10,9 – 13,6 [N/mm^2]. Panel shear about 7,0 [N/mm^2] and modulus of rigidity G_V = 530 [N/mm^2]. Typical end uses of spruce plywood are floors, walls and roofs in house constructions, wind bracing panels, vehicle internal body work, packages and boxes, hoarding, fencing and temporary works.

4. CONCLUSION

Plywood with modern construction is good used widely in constructions.

The characteristics are as follows: bending about f_{mll}=21,8–65,9 [N/mm^2] and $f_{m\perp}$=6,0–34,8 [N/mm^2], compression f_{cll}=18,5–31,8 [N/mm^2] and $f_{c\perp}$=14,0–25,6 [N/mm^2], tension f_{tll}=14,4–45,8 [N/mm^2] and $f_{t\perp}$=10,9–36,9 [N/mm^2]. Panel shear about 7,0–9,5 [N/mm^2] and modulus of rigidity G_V =530–620 [N/mm^2].

Definite the development of plywood construction opens wide range of usage: formwork systems, floors, walls and roofs in transport vehicles, container floors, scaffolding materials, shelves, load bearing special structures, traffic signs, furniture and die boards

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