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INFLUENCE CONSTRUCTION AND PROPERTIES OF PLYWOOD ON AREAS OF THEIR APPLICATION IN WOODEN CONSTRUCTIONS

mr sc Minka Ćehić
Technical faculty in Bihać
University of Bihać
Bosnia & Herzegovina

Prof.dr. Salah-Eldien Omer
SAG CONSALTING
Zagreb
Croatia

mr.sc. Atif Hodžić
Technical faculty in Bihać
University of Bihać
Bosnia & Herzegovina

ABSTRACT
Choice wooden board for some construction bases on property and construction this board applicable in determined area of application in civil engineered and on basis experience constructors wooden constructions or on basis recommendations producers boards. Producer's recommendation bases on previous experiences in implementation and application these constructions of boards for determined area of application. Use rules of Eurocode 5 can to help in decision.
In papers be exhibit influence of construction and properties of plywood on choice area of application in wooden construction
Keywords: construction and properties of plywood, wooden construction, application

1. INTRODUCTION
The demand for engineered wood products (such as plywood, chipboard, HDF board, oriented strand board, glulam and laminated veneer lumber - LVL) has increased due to a constant increase in the global population.
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) and overlaid or coated plywood.

2. THE PROPERTIES OF PLYWOOD
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/m^3 for conifer plywood (thin veneers) and 460 kg/m^3 for conifer plywood (thick veneers).
The moisture content of plywood is normally 7-12 % when leaving the mill. 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). 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 %. 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. 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.

Birch plywood is characterized 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 wears resistance. Sanded birch plywood has a smooth and durable surface. Its pleasant, light-colored visual appearance offers the best base for finishing. Properly surfaced and edge sealed birch plywood also offers excellent weather and moisture resistance. Bending about f_{mll} = 36,8 – 65,9 [N/mm^2] and $f_{m\perp}$ = 10,6 – 34,8 [N/mm^2], compression f_{cll} = 26,4 – 31,8 [N/mm^2] and $f_{c\perp}$ = 20,2 – 25,6 [N/mm^2], tension f_{tll} = 38,1 – 45,8 [N/mm^2] and $f_{t\perp}$ = 29,2 – 36,9 [N/mm^2]. Panel shear about 7,0 [N/mm^2] and modulus of rigidity G_V = 581 – 600 [N/mm^2] . Panel shear about 9,5 [N/mm^2] and modulus of rigidity $G_{V\ ll}$ = 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. 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-colored 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 characterized 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.

Table 1. Strength properties and density of radiata pine plywood

Thickness (mm)	Values	Density (kg/m^3)	Strength properties [N/mm^2]							
			Bending		Compression		Tension		Rolling shear	
			0	90	0	90	0	90	0	90
12	mean	552	37,9	18,0	25,5	20,6	21,4	12,5	3,2	2,9
	cov(%)	5	22	23	9	12	22	34	19	17
	charact.	471	22,2	10,1	21,8	16,7	12,7	5,0	2,1	2,0
15	mean	554	37,2	23,0	27,6	23,0	22,3	15,0	3,0	2,6
	cov(%)	6	22	26	7	14	19	25	18	18
	charact.	472	22,2	11,8	23,5	17,4	14,3	8,0	2,0	17
18	mean	587	33,1	27,0	26,6	25,8	19,5	17,3	2,8	2,2
	cov(%)	5	16	23	12	8	22	23	25	18
	charact	500	23,4	15,3	21,0	22,0	11,5	10,0	1,5	1,4
21	mean	541	29,6	26,9	25,5	23,3	20,3	16,2	2,8	2,4
	cov(%)	5	21	22	9	10	15	30	17	21
	charact	461	17,7	13,9	21,7	19,9	14,6	7,3	2,0	1,4

3. DESIGN CONSTRUCTION IN ACCORDING REQUIREMENTS OF EUROCODE 5

The European Union (EU) has promoted in all fields of construction several books of rules which are strong recommendations for designers. In field timber construction the EUROCODE 5 (EC5) applies together with EUROCODE 1 (EC1), which is the basic reference for loading of structure.

This design code includes in design a part of failure probability. This is very important because timber exhibit a high degree of variability its properties. Moreover, it introduces two states in design: the Service Limit State and Ultimate Service State. The first one considers loadings in usual cases and the last one is for exceptional, but still safe loading.

During design wooden construction need take into account the following: different material properties (e.g. modulus of elasticity, strength and failure mode), different time dependent behavior of the materials (creep), different climatic conditions for the materials (temperature, moisture variations) and different design situations (stages of construction, change of support conditions).

The design value X_d of a strength property shall be calculated as:

$$X_d = k_{mod} \cdot X_k / \gamma_M \qquad (1)$$

where: X_k is the characteristic value of a strength property γ_M is the partial factor for a material property, specified in National Annexes $k$mod is a modification factor taking into account the effect of the duration of load and moisture content.

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

$$F_d = 1,35\ F_{k,perm} + 1,5\ F_{k,var}. \qquad (2)$$

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

$$F_d = 1,35F_{k,perm} + \Sigma 1,35\ F_{k,var} \qquad (3)$$

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 unfavorable design load shall be used. The design strength f_d is given by

$$f_d = k_{mod} \cdot f_k / \gamma_m \qquad (4)$$

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).

In serviceability limit state design it shall be verified that the design deflection u_d is less than a pre-set deflection value u_{preset}

$$u_d < u_{preset} \qquad (5)$$

The design deflection u_d is given by

$$u_d = (1 + k_{def}) \bullet u_{inst} \qquad (6)$$

where k_{def} is a factor taking into account the effect of duration of load and moisture content. The instantaneous deflection u_{inst} is calculated using the design value of load F_d given by

$$F_d = F_{k,perm} + \Sigma F_{k,var} \qquad (7)$$

Furthermore, the design modulus of elasticity and shear modulus values equal to the mean values are used.

$$f_d = k_{mod} \cdot f_k / \gamma_m \qquad (8)$$

The pre-set deflection value depends on the construction and it is usually given as a deflection related to the span (L), for example L/300 or L/200. However, absolute preset deflection values may also be given.

The design value R_d of a resistance (load carrying capacity) shall be calculated as:

$$R_d = k_{mod} \cdot R_k / \gamma_m \qquad (9)$$

where: R_k is the characteristic value of a load carrying capacity γ_M is the partial factor for a material property, k_{mod} is a modification factor taking into account the effect of the duration of load and moisture content.

4. SOME RECOMMENDATIONS FOR DESIGN WOODEN CONSTRUCTION

Based on the general design principles, tabulated load resistance values for floors of different spans and thicknesses are given. Furthermore, information is given as to whether the bending or shear strength is design governing. Finally, the deflection related to the load resistance is given. The load resistances and deflections were calculated according to the following assumptions: γ_q = 1.5, the partial safety factor for load, γ_m = 1.3, the partial safety factor for the material k_{mod} = 0.80, the factor taking into account the effect of duration of load and moisture content k_{def} = 0.25, the factor taking into account the effect of duration of load and moisture content. Hence, the characteristic load acting in service class 1 and load duration class medium term shall not exceed the tabulated values. For other assumptions the tabulated load resistance values shall be multiplied by a correction factor $k_{load,\ corr}$ given by

$$k_{load,\ corr} = (k_{mod} / \gamma_m \gamma_q) \bullet (1,3 \cdot 1,5 / 0,80) \quad (10)$$

while the tabulated deflection values shall be multiplied by a correction factor $k_{def,\ corr}$ given by

$$k_{def,\ corr} = [(1+k_{def}) \bullet k_{load,corr}] / (1+0.25) \quad (11)$$

Roofs are usually designed to service class 2 and load duration class medium-term. Consequently, the same load resistance values given for floors. The deflection values of properties (thickness and strength) shall be multiplied by

$$k_{def,\ corr} = (1+0.30) \bullet 1 / (1+0.25) = 1.04 \quad (12)$$

Based on general design principles, tabulated load resistance values for vehicle floors exposed to loads from wheels of different spans and thicknesses are given. Also, information is given whether the bending or shear strength is design governing. Finally, the deflection related to the load resistance is given. Since it is reasonable to use a lower reliability in design the load resistances and deflections were calculated according to the following assumptions: γ_q = 1.0 , γ_m = 1.0 . k_{mod} = 0.90 , k_{def} = 0.00 .
Hence, the characteristic load acting in service class 2 and load duration class short–term shall not exceed the tabulated values. For other assumptions the tabulated load resistance values shall be multiplied by a correction factor $k_{load,}$
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 are given, The load resistances and deflections were calculated according to the following assumptions: γ_q = 1.2 , γ_m = 1.3 , k_{mod} = 0.70 , k_{def} = 0.40 . The characteristic load acting in service class 3 and load duration class short-term shall not exceed the tabulated values. For other assumptions the tabulated load resistance values shall be multiplied by a correction factor $k_{load,}$

4. CONCLUSION

The characteristic's properties of plywood are as follows: bending about $f_{m\parallel}$=21,8–65,9 [N/mm^2] and $f_{m\perp}$=6,0–34,8 [N/mm^2], compression $f_{c\parallel}$=18,5–31,8 [N/mm^2] and $f_{c\perp}$=14,0–25,6 [N/mm^2], tension $f_{t\parallel}$=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.
Use rules of Eurocode 5 can to help in decision. The general procedure uses determination partial coefficients which apply multiplication factors to the characteristic value strength

$$f_d = k_1 \cdot k_2 \cdot \ \dots\ f_{x,k} \quad (13)$$

f_d is design strength value, $f_{x,k}$ is characteristic value.
For different areas usage plywood are different recommendations partial coefficients.

5. REFERENCES

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