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THE NEW BRAZILIAN TIMBER STRUCTURES CODE NBR7190: 2022

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ABSTRACT: The first Brazilian Timber Structures Code was published in 1951 under the name of NB11: Design and construction of timber structures, with a deterministic design method and composed of 16 pages without annex. In February of 1982, it was renamed NBR7190: 1982 without any modifications. In 1992 start the new study of this code using the limit states design method. This version, using the load and resistance factored design (LRFD), was published in 1997 by the Brazilian Association of Technical Standards with the emphasis on the utilization of hardwoods. A new study started in 2013 in order to consider all the new wood composite industrialized materials and connections. Considering the huge amount of hardwoods in Brazil, new test methods were developed in order to calibrate the new materials. This paper aims to present the New Brazilian Code for Timber Structures Design, NBR7190: 2022, relating the new revision for structural grading recommendations for softwoods and hardwoods planted in Brazil. Details of structural and constructive systems, Glulam, CLT, fire and preservation recommendations for design and new types of connections are also presented.

The New Brazilian Timber Structures Design Code NBR7190: 2022 is composed of 7 parts, that are: Part 1: Design criteria; Part 2: Test Methods for visual and mechanical grading of structural lumber; Part 3: Test Methods for characterization of defect-free specimens for native timber; Part 4: Test Methods for characterization of structural lumber; Part 5: Test Methods for determination of strength and stiffness of connections; Part 6: Test Methods for characterization of glued laminated timber; Part 7: Test Methods for characterization of cross laminated timber.

These six test methods for structural properties, grading, quality control of Glulam and CLT, and connections are also presented in related papers. Part of these codes is based on international codes such as EUROCODE and ISO.

KEYWORDS: Brazilian timber design code, timber structures, timber structural properties

1 INTRODUCTION

The Brazilian Timber Design Code is based on the Limit States Design concept used with the partial factor method, moving from an Allowable Stress Design of 1982 to a Probabilistic Limit States Design in 1997 using a calibration coefficient to convert tabulated medium strength properties to characteristic 5% values of load effects and resistances.

This paper aims to present the New Brazilian Code for Timber Structures Design, NBR7190: 2022, relating the new revision for structural grading recommendations for softwoods and hardwoods planted in Brazil. Details of structural and constructive systems, Glulam, CLT, fire and preservation recommendations for design and new types of connections are presented.

The global objective of the code is to fix the general conditions that must be followed in the design, construction and control of current timber structures, namely: bridges, buildings, roofs, decks and formworks.

2 MATERIAL PROPERTIES

The properties to consider in the design of timber structures are: density, strength, stiffness and moisture content. The specified properties of strength and stiffness correspond to the class of moisture content of 12%, that is 20 degrees Celsius and 65% of relative humidity.

2.1 CHARACTERIZATION OF TIMBER PROPERTIES

The new code considers two types of characterization of material properties based on defect-free specimens for native wood and structural samples for reforestation and

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native species. The second type corresponds to the characterization of structural lumber based on the commercial lumber with all the defects like knots, fissures, slope of grain, warp, etc.

2.2 STRENGTH CLASSES

The two types of strength classes are simply a group of species/strength grade combinations that have similar properties. For native hardwoods five classes are defined: D20, D30, D40, D50 and D60. These numbers represent the characteristic value of compression parallel to grain stress for each strength class based on the characterization of small defect-free specimens. These strength classes represent the values of the strength and stiffness properties of forty-two tropical hardwood timbers grown in Brazil with adequate statistical analysis according to researches since 1980's to define the five classes for hardwoods, as we can observe in Table 1.

Table 1: *Strength classes of native wood defined with clear samples.*

Classes	$f_{c0,k}$ MPa	$f_{v0,k}$ MPa	$E_{c0,m}$ MPa	Density (12%) kg/m³
D20	20	4	10 000	500
D30	30	5	12 000	625
D40	40	6	14 500	750
D50	50	7	16 500	850
D60	60	8	19 500	1 000

Source: ABNT NBR 7190: 2022

For reforestation species, the strength classes are based on tests of structural lumber as an alternative for native timber. The strength classes are based on bending strength with 12 strength classes for softwoods and 8 strength classes for hardwoods according to Table 2 and Table 3.

Table 2: *Strength classes for C14 to C24 softwoods.*

Softwoods C14 a C24	C14	C16	C18	C20	C22	C24
Resistance properties (MPa)						
$f_{m,k}$	14	16	18	20	22	24
$f_{t,0,k}$	8	10	11	12	13	14
$f_{t,90,k}$	0,4	0,4	0,4	0,4	0,4	0,4
$f_{c,0,k}$	16	17	18	19	20	21
$f_{c,90,k}$	2,0	2,2	2,2	2,3	2,4	2,5
$f_{v,k}$	3,0	3,2	3,4	3,6	3,8	4,0
Stiffness properties (GPa)						
$E_{0,med}$	7	8	9	9,5	10	11
$E_{0,05}$	4,7	5,4	6,0	6,4	6,7	7,4
$E_{90,med}$	0,2	0,3	0,3	0,3	0,3	0,4
G_{med}	0,4	0,5	0,6	0,6	0,6	0,7
Density (kg/m³)						
ρ_k	290	310	320	330	340	350
ρ_{med}	350	370	380	390	410	420

Source: ABNT NBR 7190: 2022

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Table 3: *Strength classes for C27 to C50 softwoods.*

Softwoods C27 a C50						
	C27	**C30**	**C35**	**C40**	**C45**	**C50**
Resistance properties (MPa)						
$f_{m,k}$	27	30	35	40	45	50
$f_{t,0,k}$	16	18	21	24	27	30
$f_{t,90,k}$	0,4	0,4	0,4	0,4	0,4	0,4
$f_{c,0,k}$	22	23	25	26	27	29
$f_{c,90,k}$	2,6	2,7	2,8	2,9	3,1	3,2
$f_{v,k}$	4,0	4,0	4,0	4,0	4,0	4,0
Stiffness properties (GPa)						
$E_{0,med}$	12	12	13	14	15	16
$E_{0,05}$	7,7	8,0	8,7	9,4	10	11
$E_{90,med}$	0,4	0,4	0,4	0,5	0,5	0,5
G_{med}	0,7	0,8	0,8	0,9	0,9	1,0
Density (kg/m³)						
ρ_k	370	380	400	420	440	460
ρ_{med}	450	460	480	500	520	550

Source: ABNT NBR 7190: 2022

Table 4: *Strength classes for D18 to D70 hardwoods.*

Hardwoods D18 a D70								
	D18	**D24**	**D30**	**D35**	**D40**	**D50**	**D60**	**D70**
Resistance properties (MPa)								
$f_{m,k}$	18	24	30	35	40	50	60	70
$f_{t,0,k}$	11	14	18	21	24	30	36	42
$f_{t,90,k}$	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
$f_{c,0,k}$	18	21	23	25	26	29	32	34
$f_{c,90,k}$	7,5	7,8	8,0	8,1	8,3	9,3	11	13,5
$f_{v,k}$	3,4	4,0	4,0	4,0	4,0	4,0	4,5	5,0
Stiffness properties (GPa)								
$E_{0,med}$	9,5	10	11	12	13	14	17	20
$E_{0,05}$	8	8,5	9,2	10	11	12	14	16,8
$E_{90,med}$	0,6	0,7	0,7	0,8	0,9	0,9	1,1	1,33
G_{med}	0,6	0,6	0,7	0,8	0,8	0,9	1,1	1,25
Density (kg/m³)								
ρ_k	475	485	530	540	560	620	700	900
ρ_{med}	570	580	640	650	660	750	840	1080

Source: ABNT NBR 7190: 2022

2.3 DESIGN CRITERIA

The new code adopts the stability design criteria based on the EUROCODE 5 EN 1995-1-1:2009: Design of timber structures.

Representative Strength and Stiffness Values

The design values X_d of one wood property is obtained from the characteristic value X_k by the following formulae:

$$X_d = K_{mod} \frac{X_k}{\gamma_W} \quad (1)$$

Where γ_w the partial safety is factor of wood properties and K_{mod} is the modification factor that considers the influences that are not accounted in factor γ_w.

Modification Factors

The global modification factors K_{mod} is composed by the product of two partial modification factors, that is:

$$k_{mod} = k_{mod1} \cdot k_{mod2} \quad (2)$$

The partial modification factor number $K_{mod,1}$ consider the load classes and types of materials used, according to Table 5.

Table 5: *Values of* k_{mod1}.

Load class	Load duration	Wood type: Sawn wood Roundwood Glulam CLT LVL	Wood type: Recomposed wood
Permanent	More than 10 years	0,60	0,30
Long duration	Six months to 10 years	0,70	0,45
Medium duration	One week to 6 months	0,80	0,65
Short duration	Less one week	0,90	0,90
Instantaneous	Momentary	1,10	1,10

Source: ABNT NBR 7190: 2022

The partial modification factor number K_{mod2}, consider the classes of moisture content and types of materials used, according to Table 6.

Table 6: *Values of* K_{mod2}.

Wood moisture class	Wood type: Sawn wood Roundwood Glulam CLT LVL	Wood type: Recomposed wood
(1)	1,00	1,00
(2)	0,90	0,95
(3)	0,80	0,93
(4)	0,70*	0,90

*It is not allowed to use MLCC for humidity class 4.

Source: ABNT NBR 7190: 2022

2.3.1 Partial strength coefficients for Ultimate Limit States

The partial coefficient γ_W for Ultimate Limit States due the normal stresses has the basic value γ_W = 1,4. The partial coefficient for Ultimate Limit States due to shear stresses has the basic value γ_W = 1,8.

2.3.2 Partial coefficient for Serviceability Limit States.

The partial coefficient for Serviceability Limit States has the basic value γ_W = 1,0.

Partial Safety Factors for Ultimate Limit States: - the partial factor for compression parallel and normal to grain is γ_{wc} =1,4, - the partial factor for tension parallel to grain is γ_{wt}=1,8, - the partial factor for shear is γ_{wv}=1,8, Stiffness The design analysis that the safety depends of wood stiffness like the instability in compression elements the elasticity modulus parallel to grain must be taken as:

$$E_{co,ef} = k_{mod1} \cdot k_{mod2} \cdot E_{o,med} \quad (3)$$

And the transversal modulus as:

$$G_{med} = \frac{E_{co,med}}{16} \quad (4)$$

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Design Considerations in Stability of Compression Elements

In the compression design process, slenderness structural elements, may be subject of accidental eccentricity loads and geometrical lumber imperfections and this situation is considered in the code by applying an accidental eccentricity value of L/300. This mean that all the compression members with $\lambda > 40$ must be designed for bending and compression forces, where the bending forces appeared by eccentricity of L/300 multiply by the normal load. The formulas to be applied in the design of compression members are:

$$\sigma_{\mathrm{Nc,d}} = \frac{\mathrm{N}_{c,d}}{A} < \mathrm{f}_{\mathrm{co,d}} \quad (5)$$

3 TIMBER CONNECTIONS

The old code considers only two models for the design of connections using steel dowels, that is, embedment and bending.

The proposed code adopt the models used in EUROCODE 5 EN 1995-1-1:2009: Design of timber structures.

The modes for one and two shear sections using wood-wood and one and two shear sections using steel plate-wood and wood-steel plate-wood.

The main types of connections presented are nails, bolts and steel rings.

4 TEST METHODS

The New Brazilian Timber Structures Design Code NBR7190: 2022 is composed of 6 tests methods, that is:

Test Methods for visual and mechanical grading of structural lumber;

This Part 2 of the code establishes the criteria for visual and mechanical grading of lumber pieces of softwood and hardwood from planted forests for structural use. It aims to assign a strength class to each of the pieces that make up the batch of wood to be used classification by piece. This Part applies to wood pieces whose maximum dimensions of the cross section do not exceed the limits of 60 mm for the smallest dimension and 300 mm for the largest dimension.

Test Methods for characterization of defect-free specimens for timber of native timber;

This Part 3 of the code specifies the test method for characterizing defect-free specimens for wood from native forests. This Part applies to the determination of strength and stiffness properties in order to design of timber structures of native wood, related to complete, minimal and simplified characterization of sawn wood from native forests. Include the clear wood tests of bending, compression parallel and perpendicular, tension parallel and perpendicular, shear, toughness and embedment parallel and perpendicular to grain.

Test Methods for characterization of structural lumber;

This Part 4 of the code specifies test method for sampling and characterization of structural lumber for determining the medium and characteristic values of the structural properties of sawn timber of rectangular cross-section. Includes the tests of bending, compression parallel and perpendicular, tension parallel and perpendicular, shear and the determination of the transversal elasticity G value

Test Methods for determination of strength and stiffness of connections;

This Part 5 of the code specifies methods for the determination of the strength and stiffness of joints with mechanical fasteners used in timber structures (metal-dowel, timber dowel, screws, nails, stamped connectors and rings). It does not apply to the detailed procedures for each type of mechanical connector.

Test Methods for characterization of glued laminated timber;

This Part 6 of the code presents the test methods for the characterization of glued laminated timber (Glulam). The tests available are delamination tests for external and internal exposure, shear test of glue line, tensile strength parallel to the grain of the finger joints, and the amount of adhesive applied. In addition, provides some guidance for the production of finger joints. The delamination and shear of the glue line tests were based on the EN 14080 [4] with some adaptations. On the other hand, the tensile strength parallel to the grain test was based on EN 408 [5], whereas the failure mode of the finger joints was based on ASTM D4688/D4688 [6].

Test Methods for characterization of cross laminated timber

This Part 7 of the code presents the tests for CLT panels, its concepts and fundamental bases, that in part, was based in international codes like European Norms and ISO. Aiming at international standardization of quality control and characterization of CLT panels, some tests were based on established methodologies in the literature and European standards, the most advanced on the subject. Several academic works have been carried out to use international testing methods for Brazilian products, thus validating such methods. The main tests of this part are: strength and effective stiffness to bending perpendicular to the plane test and delamination test.

5 TIMBER STRUCTURES IN FIRE SITUATION

The new version considers the normal fire that represents the temperature elevation as a function of time defined by the Brazilian Code NBR 5628 given by the expression:

$$\theta g = \theta o + 345 \log (8t + 1). \quad (6)$$

The structural safety related to the limit states of fire will be imposed by the safety analysis given by:

$$S_{fi,d} \leq R_{fi,d} \quad (7)$$

Where $S_{fi,d}$ is obtained by exceptional combinations of actions defined by ABNT NBR 8681 or may be designed considering 60% of the design actions in normal situations (20 °C), that is, $S_{fi,d}$ = 0,60 Sd. The value of $R_{fi,d}$ is determined according to:

$$R_{fi,d} = k_{mod,fi} \frac{R_{0,2}}{\gamma_{w,fi}} \quad (8)$$

$k_{mod,fi}$ is 1,0 and includes the effects of the strength reduction and stiffness of wood; $\gamma_{w,fi}$ is 1,0 and $R_{0,2}$ must be designed by the normal design at normal temperature, however considering the area reduction and the mechanical properties substituted by the amount of 20% (20 percentile), that is:

$$f_{0,2} = k_{fi} f_k \quad (9)$$

$$E_{0,2} = k_{fi} E_{0,05} \quad (10)$$

Where k_{fi} is given in a table.

6 WOOD DURABILITY: USE CATEGORIES

According to the ABNT NBR 7190: 2022 wood preservation is a set of preventive and curative measures adopted to control biological agents (fungi, xylophages insects and marine bores), physical and chemical that affect the properties of wood, adopted in the development and maintenance of wood components in the built environment.

In the design of timber structures, the following use categories should be considered:

Use Category 1: Inside buildings, out of contact with the soil, foundations or masonry, protected from weathering, internal sources of moisture and local free from access by subterranean termites or arboreal.

Use Category 2: Interior of buildings, in contact with the masonry, without contact with the soil or foundations, protected from the weather and indoor sources of moisture.

Use Category 3: Interior of buildings, out of contact with the soil and protected from the weather, which can, occasionally be exposed to sources of moisture.

Use Category 4: Outside use, out of contact with the soil and subject to the weathering.

Use Category 5: Contact with soil, fresh water and other situations favorable to deterioration, such as setting in concrete and masonry.

Use Category 6: Exposure to salt water or brackish.

In this way depending on the service condition in which the wood of the structure will be exposed, each corresponding use category must be considered and the susceptibility of attack by bio deteriorating organisms.

Each use category of durability has the correspondent treatment process and preservative product recommended.

7 CONCLUSIONS

The New Brazilian Code for Timber Structures Design, NBR7199: 2022, a load and resistance factored design (LRFD) code considers the structural grading recommendations for softwoods and hardwoods planted in South America with special attention for the production and design for Glulam structural elements. Rules for grading and gluing with the reforestation species are also presented. This new version adopts the connections models design used in EUROCODE 5 EN 1995-1-1:2009: Design of timber structures. The principal idea was to have a very similar code for all the countries of South America.

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REFERENCES

[1] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 – Part 1: Design of Timber Structures

[2] SALES, A.. Hardwood strength classes. Ph.D. thesis Universidade de São Paulo, SP, 2006.

[3] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Timber Structures - Part 2: Test Method; Structural timber. Grading. Requirements for visual and mechanical grading standards

[4] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Timber Structures – Part 3: Test Method for clear samples.

[5] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Part 4: Design of Timber Structures –Test Method - Structural timber. Strength classes.

[6] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Timber Structures – Part 5: Test Method for structural timber. Grading. Requirements for mechanical connections.

[7] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Timber Structures – Part 6: Test Method Structural Glulam members. Requirements delamination, shear glue line strength, finger joint strength.

[8] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR7190: 2022 Timber Structures – Part 7: Test Method Structural cross laminated timber..

[9] ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. ABNT NBR 16143:2013. Preservação de Madeiras – Sistema de Categorias de Uso. Rio de Janeiro, 2013.

https://doi.org/10.52202/069179-0399