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Timber Strength Grading as Necessary Basis for Structural Design in Ex-YU Region: Part 1

Ocjenjivanje drva prema čvrstoći kao nužna osnova za projektiranje konstrukcija na području bivše Jugoslavije: dio 1.

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ABSTRACT • *Classification of timber for various commercial purposes is essential for its proper application in order to ensure the reliability and economic use. Visual grading of structural timber is commonly used in a number of EU countries, with different grading national standards optimized for locally available wood. Countries in the ex-YU region are traditional partners in wood trade and had the same standards for visual grading, but in most of the regions these standards are not completely compliant with EN requirements. Consequently, that leads to the fact that the most of regionally available structural timber is not assigned into strength classes, which is the starting point for the limit-state concept in design of timber structures. The aim of this paper is to emphasize the lack of strength classification of structural timber in the ex-YU region, which is a prerequisite for the design of timber structures made by civil engineers. Based on an overview of visual classification types with regional experience in grading, relevant EN standards, and differences in design concepts with possible consequences of grading approach, it can be concluded that "quality" grades and "strength" classes are not easily comparable.*

KEYWORDS: *structural coniferous timber; visual grading; strength classes; safety factors; European standards*

SAŽETAK • *Klasifikacija drvne građe za različite komercijalne namjene ključna je za njezinu pravilnu upotrebu kako bi se zajamčila sigurna i ekonomična uporaba. Vizualno ocjenjivanje konstrukcijskog drva obično se provodi u mnogim zemljama EU-a uz pomoć različitih nacionalnih standarda ocjenjivanja optimiziranih za lokalno dostupno drvo. Zemlje bivše Jugoslavije tradicionalni su partneri u međusobnoj trgovini drvom i imale su zajedničke standarde za vizualno ocjenjivanje drvne građe, ali u većini njih ti standardi nisu u potpunosti usklađeni s EN zahtjevima. To posljedično rezultira činjenicom da većina regionalno dostupnoga konstrukcijskog drva nije*

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razvrstana u klase čvrstoće, što je polazište za koncept graničnog stanja u projektiranju drvnih konstrukcija. Cilj rada jest upozoriti na nepostojanje klasifikacije čvrstoće konstrukcijskog drva na području bivše Jugoslavije, a to je preduvjet za projektiranje drvnih konstrukcija, što je posao građevinskih inženjera. Na temelju tipova vizualne klasifikacije i regionalnih iskustava u ocjenjivanju, relevantnih EN normi te razlika u konceptima projektiranja s mogućim posljedicama pristupa ocjenjivanju, zaključeno je da ocjene razreda kvalitete i klase čvrstoće u promatranim zemljama jednostavno nisu međusobno usporedive.

KLJUČNE RIJEČI: *konstrukcijsko crnogorično drvo; vizualno ocjenjivanje; klase čvrstoće; faktori sigurnosti; europske norme*

1 INTRODUCTION
1. UVOD

Wood as a building material has been used for centuries, but during the past few decades, it has been recognized as one of the favourite materials in the construction sector. Renewable sources, availability in the immediate surroundings, relatively low energy consumption to process in addition to continuous construction technology innovation have all contributed to the wider affirmation of wood-based products in modern architecture, providing extraordinary possibilities in the shaping and design of structures, Figure 1.

The built environment generates 47 % of annual global CO_2 emissions: building operations are responsible for 27 %, while building materials and construction (typically referred to as embodied carbon) are responsible for an additional 20 % (Agopian, 2022). Growing awareness leads to wood becoming the trending material of the 21st century, in the form of solid and engineered wood products (EWPs) for structural and indoor/outdoor use. Modern architectural trends in prefabricated residential buildings and large-scale timber construction lead to eco-friendly urbanization, where timber grows in popularity compared to steel, concrete and other mineral-based building materials. According to Hetemaki *et al.,* 2017, the indirect share estimation of timber construction was 15 % in turnover and 19 % in employment of the total EU building construction sector. On the basis of recent decade production of wood fibre insulation boards, glulam, cross-laminated timber and laminated veneer products, the estimation of growth rates is in a range from 2.5 % to 15 % (Hildebrandt *et al*., 2017), which could create an added value by a lower environmental impact throughout the entire life cycle. Previous low economic competitiveness of multi-storey timber buildings has been overcome by technological progress in EWPs production, so the share of timber construction in total building market increases in the EU and world. The share of "wooden houses" depends on the region, forest resources and on tradition of building with timber, as well as on technological opportunities (North and Western Europe N/WE) and/or political and economic opportunities (South Europe SE). It was found that "social and political barriers most typically limit the development of wood construction" (Leszczyszyn *et al.,* 2022), which means that it is necessary to provide the basic knowledge and social conditions for increasing the share of wood in countries where the use of timber is still under the average EU level.

South-Eastern Europe (SEE region) has a long tradition in building with timber, which was first reflected in the craftsmanship and later in industrial approach to construction. Nowadays, structural engineers and architects in the ex-YU region are faced with two challenges: the imperative to increase the use of timber in the construction sector and the harmonization / adjustment of regulations with the recently introduced safety concepts in design. The transition from the concept of global safety factors, which refers to common ex-YU design codes (JUS), to the concept of partial safety factors, which re-

a) b) c)

Figure 1 a) Pancho Aréna Hungary (2014), b) Mjøstårnet tower Norway (2019), c) Mistissini Bridge Canada (2014)
Slika 1. a) stadion Pancho Aréna, Mađarska (2014.), b) neboder Mjøstårnet, Norveška (2019.), c) most Mistisini, Kanada (2014.)

fers to the set of Eurocodes (ENs) in design of timber structures, requires more precise classification of structural timber and products, where cooperation between wood processing industry and civil engineers is necessary, as well as between countries that traditionally trade in timber in the region.

SEE region is considered as the smallest forest area in total (30446·10³ ha) and in forest share (23.5%) compared to the rest of Europe, e.g. the highest forest area share is 53.2 % in NE (Alexandrov and Iliev, 2019). Data on the forestry potentials in the ex-YU countries (Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia as well as Croatia and Slovenia as EU members), as part of the SEE region, are given in Table 1, where the data on coniferous sawn wood as the basic raw material for construction is particularly highlighted. Data is given according to FAO database (FAO, 2022).

Table 2 presents the data about wood product trade i.e. coniferous sawn wood export/import in six ex-YU countries, together with leading trade partners. The data is given according FAOSTAT and INDEXBOX platforms (FAOSTAT, 2021; INDEXBOX, 2022). Strong trade connections between the analyzed countries are evident, besides traditional partner countries (Austria, Germany, Italy) and some new ones (Albania, Turkey, Bulgaria, Slovakia and Czech Republic).

Based on natural recourses, Bosnia and Herzegovina and Slovenia are recognized as the main suppliers of sawn coniferous wood in the ex-YU region, which dates back to the past. The existing trade and interconnection of the countries based on tradition and common regulations for the visual classification of sawn wood in the ex-YU area indicates the necessity to harmonize the quality assessment of structural coniferous timber in the sense of EU requirements and construction industry needs.

This paper is limited to the SEE ex-YU countries because of previous common legislation in construction and forestry domain standards and a number of existing timber structures from earlier period (XX century). Besides, sawn-wood mutual export/import is still

Table 1 Forest area, growing stock and sawn wood production in ex-YU countries (2020/21)
Tablica 1. Površina šuma, drvne zalihe i piljeno drvo u zemljama bivše Jugoslavije (2020./21.)

Country *Zemlja*	**Forest area** *Površina pod šumom*		**Growing stock** *Drvna zaliha*		**Sawn wood** *Piljeno drvo*	
Ex-YU	**Total, 10³ ha** *Ukupno, 10³ ha*	**Of land area, %** *Zemljišne površine, %*	**Total, 10⁶ m³** *Ukupno, 10⁶ m³*	**Coniferous, 10⁶ m³ / %** *Četinjače, 10⁶ m³ / %*	**Total, 10³ m³** *Ukupno, 10³ m³*	**Coniferous 10³ m³** *Četinjače, 10³ m³*
Bosnia & Herzegovina / *Bosna i Hercegovina*	2188	42.7	404.7	n/a	1650	743
Croatia / *Hrvatska*	1939	34.7	427.2	50.6 / 11.8	1298	257
Montenegro / *Crna Gora*	827	61.5	121.4	42.8 / 35.3	109	108
North Macedonia *Sjeverna Makedonija*	1001	39.7	76.4	n/a	7	2
Serbia / *Srbija*	2723	31.1	420.9	27.0 / 6.4	452	99
Slovenia / *Slovenija*	1238	61.5	414.1	172.0 / 41.5	1029	904

Table 2 Wood product trade in ex-YU: coniferous sawn wood (10³ m³) (2021)
Tablica 2. Promet proizvoda od drva na području bivše Jugoslavije: piljena građa četinjača (10³ m³) (2021.)

Country *Zemlja*	**Consumption** *Potrošnja*	**Production** *Proizvodnja*	**Export** *Izvoz*	**Import** *Uvoz*	**Leading partners** *Vodeći partneri*	
					Export *Izvoz*	**Import** *Uvoz*
Bosnia & Herzegovina *Bosna i Hercegovina*	32.3	743.0	717.9	7.2	Serbia, Croatia, Albania, Italy, Austria	Austria, Croatia, Serbia
Croatia *Hrvatska*	343.3	256.5	265.0	351.8	Slovenia, Italy, Austria	Austria, B&H, Slovenia
Montenegro *Crna Gora*	17.4	107.8	93.6	3.2	n/a	B&H
North Macedonia *Sjeverna Makedonija*	45.1	2.0	0.5	43.6	Turkey, Italy, Serbia	B&H, Montenegro, Bulgaria
Serbia *Srbija*	379.0	99.0	15.0	295.0	Italy, B&H, Germany	B&H, Montenegro, Austria
Slovenia *Slovenija*	693.1	904.0	851.6	640.7	Italy, Austria, Croatia	Austria, Czech Rep., B&H, Slovakia

very frequent in the region although two countries are the members of the EU. In order to understand the importance of the transition problem from quality (stress) grades to the system of strength classes of structural timber, and to obtain the relevant conclusions, an overview of visual classification types with regional experience in grading, differences in design concepts, relevant standards, as well as possible consequences, is given in the next chapter. The final goal of the present paper (Part 1) is to emphasize the necessity to assign visual grades and species to strength classes of structural timber in the region. In Part 2 of the paper, the integral procedure for the conversion of the II grade coniferous timber into strength classes is presented and its application is illustrated through the analysis of archive data sample obtained from regional sources.

2 VISUAL GRADING AND TIMBER STRUCTURAL DESIGN
2. VIZUALNO OCJENJIVANJE I PROJEKTIRANJE DRVNIH KONSTRUKCIJA

2.1 Importance and types of timber visual grading
2.1. Značenje i načini vizualnog ocjenjivanja drva

The quality assessment of wood as a material is crucial for engineering design, and therefore for the structure reliability. Without knowledge of the theory and practice of classification, there may be misunderstandings that threaten the structural safety, while the grading system is expected to be as uniform and unified as possible within the European market. For the correct use of timber in constructions, it is necessary to carry out adequate classification, because today civil engineers face two problems: assessing the quality of timber built in existing buildings due to the need for reconstruction, as well as assessing the quality of locally available wood for use in newly designed buildings.

Wood as a material could be classified at different stages of harvesting and/or production using different procedures, which are initially based on visual inspection and appropriate measurement. Thus, after a rough dimensional classification (EN 1315) of timber, when the final use is still unknown, the roundwood classification is made according to quality (classes A, B, C, D) in accordance with EN standard (e.g. EN 1927 or EN 1316) depending on the type/species of wood and the presence, size and distribution of factors that affect quality (EN 1309). These EN standards are officially in force in ex-YU countries, although not-binding, because they are intended for the log trade where different conditions can be agreed in trade contracts (e.g. traditional quality according to previous JUS). Generally, from the forestry aspect, the main difference in the classification of roundwood lies in the fact that EN standards classify according to quality without prejudicing its future purpose, while JUS classified according to its final use. According to ex-YU regulations, in addition to being classified into dimensional grades, logs and round timber had to be classified into quality classes for intended use, where, for structural purposes, the classification of sawmill logs into three categories (I, II, III) is of importance for designers.

Sawn timber could be used for non-structural and structural purposes, so different grading procedures could be applied due to the final use of the material. Generally, the grading process is always based on visual sorting, but opposite to grading of non-structural elements that is exclusively based on (surface) appearance, grading of structural elements also considers determination of relevant strength & stiffness properties, i.e. visual grading is followed by strength classification and testing. Appearance grading is a process of assessing the prescribed number and size of parameters by visual sorting and it is not designed to take into account the final use of timber (e.g.: linings, joinery, packaging or construction). For example, acceptable timber for a structural engineer in terms of bearing strength could be completely unacceptable for an architect in appearance (Swedish wood, 2023).

In the ex-YU region, the structural grading meant assessing the timber grades for construction purposes by adequate appearance requirements (particularly related to size and position of knots and their perceived effects on bending strength and stiffness) as useful indication, performed by experienced operators. Such assessment was often followed by additional testing of load-bearing properties on relevant samples by destructive, non-destructive or semi-destructive methods (Nowak *et al*., 2021). Machine strength grading is not present in the region, while evaluation by non (semi) destructive methods are not widely used, except for research purposes or for *in-situ* evaluation of existing buildings with high importance (Stepinac *et al.,* 2017).

In order to preserve traditional national grading systems, and to provide the necessary unification level as well, EU introduced the standard EN 14081-1 for structural timber of rectangular cross-section with prescribed general requirements. The standard gives general limitations in 3 aspects of strength reducing characteristics that have to be taken into account during visual grading process as basic principles: Limitations for strength and stiffness reducing characteristics (knots, slope to the grain, density and rate of growth, fissures); Limitations for geometrical characteristics (wane, warp); Limitations for biological characteristics (insect and fungal damage).

The existing regional standards for visual grading of timber (ex JUS U.D0.001/1983) are based on

DIN 4074:1958. The changes introduced in DIN during the harmonization with EN 14081-1 were incorporated in national legislation of Slovenia and Croatia (2009), while in the rest of the region the grading standard remained unchanged. Due to new demands in timber industry (use of smaller/slender timber pieces in construction and laminated products), the crucial novelties introduced in DIN 4074-1:2012 are the four kinds of cross-section with different specifications and possibilities of flatwise and edgewise orientation of planks and boards. That imposes that different orientation of the same slender timber element could lead to different "quality" grade because of different criteria due to final position of timber element in the structure. Although this looks very similar compared to previous versions of the standard, the amendment about possibility of edgewise orientation of boards and planks may have significant implications for the timber classification and its use in construction, particularly when designed according to EC5 (EN 1995-1-1, 2004).

2.2 Design concepts of timber structures: global vs. partial safety factors
2.2. Koncepti projektiranja drvnih konstrukcija: globalni nasuprot parcijalnim činiteljima sigurnosti

The safe use of timber in construction is a question of design and quality of chosen timber (products). All engineering design methods can be reduced to the basic concept of safety, according to which the design resistance of structural elements should be greater or equal to the effects of design loads (actions), with adequate safety factors. The way of providing a safety factor determines the concept of design: deterministic ("working" - allowable stress design (ASD) with global safety factor) or reliability-based (semi-probabilistic) design concept (limit states design (LSD), with partial safety factors). In the basic form of ASD, the factor that provides safety is applied only to the resistance of structural material, while loading is generally taken as nominal, with some modifications due to load-duration effects and load combinations. LSD takes into account the uncertainty of inaccurate models and unfavourable deviations associated with strength properties, but also with uncertainties in the assessment of the effects of actions.

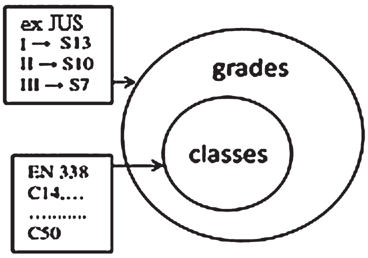
ASD has served for a long time to provide a simple approach to design procedure, with uncertainty in reliability of structures designed with such a procedure. The analysis performed in the ex-YU region showed that: "the previous (JUS) regulations have large deviations in reliability depending on the location of the structure. The reliability of constructions in areas with higher snow load is insufficient..." (Čizmar *et al.*, 2018). That reflects disadvantages in aspects of selection of different factors of safety by "intuition" regarding the variety of materials and by using the same factor of safety for all types of load. Global safety factors for different stress states in the ASD concept are in the range of $n = 2 - 4$, where permissible stress is based on extensive research of properties by testing small clear wood samples. The absence of strength-reducing characteristics and favourable orientation on small clear specimens provide an indication of the upper limit of the expected performance of realistic timber pieces (Crews and Ritter, 1996), so "the critical design criterion is not how strong a piece of timber is, but rather how weak it could be". ASD codes have been focused on providing adequate strength and achieving a proposed level of safety, while LSD ones, besides strength limit state, also recognize other limit states, such as serviceability, stability, fire and fatigue. In LSD, the partial safety factors for strength limit state and timber materials are in the range of γ_m = 1.25-1.30 that indicate lower safety factor and require higher reliability in assessment of relevant timber properties.

The conclusion of rough comparison of ASD and LSD is that global and partial safety factors are different in "composition" and in values. LSD, as advanced and more reliable concept, requires different experimental procedures and statistical distribution models of testing data, followed by improved visual classification of timber.

3 STRENGTH CLASS SYSTEM IN EUROPEAN STRUCTURAL CODES
3. SUSTAV KLASA ČVRSTOĆE U EUROPSKIM KODOVIMA ZA PROJEKTIRANJE

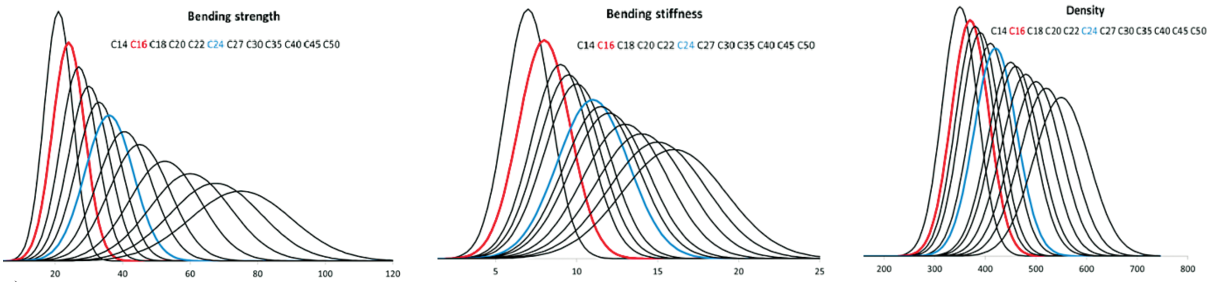
3.1 Visual ("quality" or "stress") grades vs. strength class system
3.1. Vizualne ocjene („kvaliteta" ili „naprezanje") u odnosu prema sustavu klase čvrstoće

In a new era of timber structures design, the first challenge for the engineers is handling the classification of timber as a structural material in order to obtain the input data for calculations. Namely, according to ASD concept, the structural coniferous timber in the region was visually graded into quality "stress" grades (I, II, III) in accordance with DIN 4074 standard (S13, S10, S7). In contrast to that, LSD concept introduced in Eurocode 5, considers the so called "strength class system" (EN 338) of softwood (12 classes - coniferous and poplar), where structural timber is graded based on a set of rules given in EN 14081-1 and supporting ENs. It is obvious and important to emphasise that quality grades are wider terms than strength classes (SC), Figure 2, as well as that "strength classes" are not based only on strength but also on stiffness and density of timber from a particular source and region. "Strength



EU countries	Germany / Austria	Slovenia	Balkan countries	Great Britain	Italy	Nordic
National standards	*DIN / ON 4074-1*	*SIST DIN 4074-1*	*Ex JUS*	*BS 4987*	*UNI 11035-2*	*INSTA 142*
Visual grades	S13 S10 S7	S13 S10 S7	I II III	SS GS	S1 S2 S3	T3 T2 T1 T0

b)



c)

Figure 2 a) Grades vs. strength classes, b) Visual grades according to national standards, c) Strength classes EN338 - class determining properties (Ridley-Ellis *et al*., 2016)
Slika 2. a) Ocjene u odnosu prema klasi čvrstoće, b) vizualne ocjene prema nacionalnim standardima, c) klase čvrstoće EN338 – svojstva koja određuju klasu (Ridley-Ellis *et al*., 2016.)

class system" groups together grades and species with similar strength properties making them interchangeable. Additional species/grades can be incorporated into the system at any time, and engineers could "specify a chosen strength class in their calculations without awareness of costs or availability of alternative species or grades" (EN 338). Due to the number of classes and grading precision, "SC system" is primarily optimized for machine grading (EN 14081:1-5) and large sawmills with huge industrial capacity.

Despite machine grading, visual grading is still in common use in a number of European countries (including ex-YU region), with different national grading standards optimized for locally available wood. Due to diversity of locally spread wood, it is impossible to lay down a single standard for all EU Member States, so the prescribed general requirements for structural timber (within EN 14081-1) have to be met by national standards. It is necessary to respect EN 14081 recommendations in order to avoid large inconsistency in classification criteria and further application of timber (Prka *et al.,* 2001; Ištvanić *et al*., 2008). Due to evident overlapping of SCs, Figure 2c, and economic reasons, it is useful to adopt a small number of SCs in design practice (Bather, 2021).

3.2 Relevant EN standards for testing and quality control of structural timber
3.2. Relevantni EN standardi za ispitivanje i kontrolu kvalitete konstrukcijskog drva

In order to provide an adequate and consistent basis for the introduction of "SC system" in design of timber structures and on the EU market, a set of standards for testing and statistical procedures are established, accompanied with a standard that allows the assignment of visual grades and species of locally spread wood into strength classes. Harmonized normative standards that follow general requirements in EN 14081-1 are:

- EN 338: Structural timber - Strength classes (provides characteristic values of strength, stiffness and density for softwood and hardwood, where the dominant classification is made by designation due to characteristic value of bending strength).
- EN 408: Timber structures - Determination of some physical and mechanical properties (specifies test methods for determining the structural properties).
- EN 384: Structural timber - Determination of characteristic values of mechanical properties and density (provides a procedure to derive characteristic values that are comparable in terms of population. The standard permits the use of as much existing test data as possible from various sampling and testing techniques).
- EN 14358: Timber structures - Calculation and verification of characteristic values (gives statistical methods for the determination of characteristic values from test results on a sample drawn from a clearly defined reference population. In case of solid timber, it combines with specific adjustment factors given in EN 384).
- EN 1912: Structural timber - Strength classes - Assignment of visual grades and species (national document that lists visual strength grades, species and sources of timber specifying the strength classes to

which they are assigned according to tradition and adequate quality control).

Evaluation of structural timber of the ex-YU region from visually established 3 quality grades (ASD) into numerous strength classes (LSD) is a demanding but necessary task for structural designers in the region that implies knowledge about standardized testing methods and statistical procedures for converting the archive data and proper analysis of newly obtained data. In ASD, the leading parameter of classification was the mean value of bending strength, tested by 3-point test on small clear specimens, while stiffness parameter (bending modulus of elasticity II to the grains) together with density were given as general mean values that slightly differ for solid and glulam timber. In LSD concept, a detailed procedure of quality assessment is based on 3 reference material properties (5 % characteristic bending strength, mean stiffness and 5% characteristic density), where the minimum value is relevant for strength class estimation (EN 338). The reliability basis for strength class system is given in JCSS Probabilistic model code: preferred theoretical distributions and desirable coefficients of variations (CoV) of referent properties, while the established relationships with other relevant material properties are given in Table 2 (EN 384). Test methods (EN 408) for "key" strength and stiffness properties in bending (overall span 18 times the specimen depth, including full size specimens) are based on 4-point test. Modulus of elasticity (*MoE*), considered as "the best single indicator of timber quality" (Bostrom, 1999), could be measured as local and global, which gives the opportunity to use the archive data from previous tests where the *MoE* is measured as global. Determination of wood density is provided on small defect free specimens (EN 408), which is consistent with the previous JUS standards.

Once properties are determined through EN 408, standards EN 384 and EN 14358 give the necessary statistical basis and methods for determining the characteristic values of mechanical properties and density for defined populations of visual grades and/or strength classes of machine graded structural timber. These standards provide the possibility of assessment by "calculation" of archive data results obtained from previously conducted test under different load arrangements from defect-free specimens or from products of structural size.

Finally, by applying to CEN/TS 124 with a documented report, EN 1912 will publish the list of assignments of local wood to strength classes according to EN 14081-1 and EN 338. This list is not exhaustive, but in every moment gives good guidelines for the quality of trade market and input data for architectural and civil engineers' design projects. With an insight into prEN 1912:2022, it can be concluded that only Slovenia, of all the ex-YU countries, has implemented this procedure and has classified its national timber resources into strength classes guided by national SIST standards (mixed spruce/fir of grade S10 is assigned to C24, of grade S7 to C18, while only fir of grade S7 is assigned to C16).The official assignment is very useful for structural engineers because some provisional explanations could be found in the regional documents (e.g. JUS grade I is sometimes assigned to series of SCs from C30 to C50, II grade as C24-C27, while III as C22). That kind of "assignment" overestimates the structural timber from regional recourses and could mislead the designers.

Regardless of the fact that the classification of timber into the strength class is not a prerequisite for trade, it is a condition for the CE marking and for placing timber on the EU market (Negro *et al.,* 2013). In the ex-YU region, apart from large glulam factories (e.g. "Voćin", Croatia) that closely cooperated with EU companies, strength classified timber is not offered in the regional trade. That requires a mutual effort in which structural engineers and engineers from forest-based industries should participate in order to ensure proven quality for the design and additional trade value.

4 CONCLUSIONS
4. ZAKLJUČAK

The consideration of EN standards, JUS visual grading rules and practice, limit state design approach with sensitivity on consistent grading, leads to the following conclusions:

The substantial improvement of the regional visual grading rules must take into account the future position of the element in the structure i.e. visual assessment has to be conducted for edgewise and/or flatwise orientations of the boards. In addition, in a lack of machine grading, the regional visual grading of structural timber must be consistent and stricter in application of EN requirements because of smaller safety material factors in structural design compared with the previous global ones.

The proclaimed SC system with classes from C14 to C50 (although the highest recognised timber class in EU is C35 with limited application) is established by statistical tools with overlaps in relevant parameters and it is optimized for machine grading. In visual grading it is practical and effective to have only a few SC with consistent grading rules defined by final purpose in structure (e.g. Sweden established classes with structural description of use: C14, C18, C24 for normal structural use and C30, C35 for extra load-bearing purposes but not for elements of large dimensions).

It is important to notice that SC classification of coniferous solid timber boards directly influences the production and classification of glued laminated products (glulam and cross-laminated timber), the prefabricated products that are the essence of modern building with timber.

Although the strength classification of timber is not necessary for regional trade, for structural engineers and designers it is of high importance to have a framework of available construction timber in the ex-YU region (Part 2). Otherwise, the overestimation or underestimation by random selection of SC could lead to inadequate or low quality projects, as well as to high prices and conflicts with investors and suppliers.

The joint efforts between civil and wood processing engineers are necessary in order to classify regional structural timber according EN requirements. One of the first tasks is to assign visual grades and regional species of structural timber to strength classes according to EN 1912.

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5 REFERENCES
5. LITERATURA

1. Agopian, N., 2022: Countering climate change: Building decarbonization + Building resiliency = Improved human condition. RenewAire White Paper, 6 p.
2. Alexandrov, A. H.; Iliev, I., 2019: Forests in South-Eastern Europe. Poplar, 203: 79-85.
3. Bather, M., 2021: Technical note on the use of visual grading codes for the appraisal of individual in situ structural timber elements. University of Liverpool, 43 p.
4. Bostrom, L., 1999: Determination of modulus of elasticity in bending of structural timber – comparison of two methods. HolzalsRoh und Werkstoff, 57: 145-149. https://doi.org/10.1007/s001070050030
5. Crews, K.; Ritter, M., 1996: Development of Limit State Design Procedures for Timber Bridges. In: National conference on wood transportation structures, Madison, USA, pp. 292-300.
6. Čizmar, D.; Serdarević, Š.; Volarić, I.; Gelo, D., 2018: Reliability assessment of timber purlins. Polytechnic & Design, 6 (2): 74-84. https://doi.org/10.19279/TVZ.PD.2018-6-2-02
7. Hetemäki, L.; Hanewinkel, M.; Muys, B.; Ollikainen, M.; Palahí, M.; Trasobares, A., 2017: Leading the way to a European circular bioeconomy strategy. From Science to Policy 5. European Forest Institute. https://doi.org/10.36333/fs05
8. Hildebrandt, J.; Hagemann, N.; Thrän, D., 2017: The contribution of wood-based construction materials for leveraging a low carbon building sector in Europe. Sustainable Cities and Society, 34: 405-418. https://doi.org/10.1016/j.scs.2017.06.013
9. Ištvanić, J.; Antonović, A.; Pervan, S.; Jambreković, V.; Benković, Z.; Kavran, M., 2008: Sawmilling in Croatia. Part 2. Croatian Sawmilling in New Millennium (in Croatian). Drvna industrija, 59 (4): 169-180.
10. Leszczyszyn, E.; Heräjärvi, H.; Verkasalo, E.; Garcia-Jaca, J.; Araya-Letelier, G.; Lanvin, J.-D.; Bidzińska, G.; Augustyniak-Wysocka, D.; Kies, U.; Calvillo, A.; Wahlströmh, M.; Kouyoumji, J.-L., 2022: The future of wood construction: opportunities and barriers based on surveys in Europe and Chile. Sustainability, 14 (7): 4358: 1-29. https://doi.org/10.3390/su14074358
11. Negro, F.; Cremonini, C.; Zanuttini, R., 2013: CE Marking of structural timber: the European standardization framework and its effects on Italian manufacturers. Drvna industrija, 64 (1): 55-62. https://doi.org/10.5552/drind.2013.1214
12. Nowak, T.; Patalas, F.; Karolak, A., 2021: Estimating mechanical properties of wood in existing structures – Selected aspects. Materials, 14 (8): 1941:1-26. https://doi.org/10.3390/ma14081941
13. Prka, T.; Ištvanić, J.; Mekić, S., 2001: Application of standards in unedged oak board classification (in Croatian). Drvna industrija, 52 (1): 7-22.
14. Ridley-Ellis, D.; Stapel, P.; Bano, V., 2016: Strength grading of sawn timber in Europe: an explanation for engineers and researchers. European Journal of Wood and Wood Products, 74: 291-306. https://doi.org/10.1007/s00107-016-1034-1
15. Stepinac, M.; Rajčić, V.; Barbalić, J., 2017: Inspection and condition assessment of existing timber structures. Građevinar, 69 (9): 861-873. https://doi.org/10.14256/JCE.1994.2017
16. ***DIN 4074-1:2012 Strength grading of wood. Part 1: Coniferous sawn timber. German National Standard.
17. ***Drvene konstrukcije: https://www.drvene-konstrukcije.hr/ (Accessed Jan 27, 2023).
18. ***EN 338:2016 Structural timber – Strength classes. European Committee for Standardization, Brussels.
19. ***EN 384:2016 Structural timber – Determination of characteristic values of mechanical properties and density. European Committee for Standardization, Brussels.
20. ***EN 408:2012 Timber structures – Structural timber and glued laminated timber – Determination of some physical and mechanical properties. European Committee for Standardization, Brussels.
21. ***EN 1309-1:2000 Round and sawn timber – Method of measurement of dimensions. Part 1: Sawn timber. European Committee for Standardization, Brussels.
22. ***EN 1315:2010 Dimensional classification of round timber. European Committee for Standardization, Brussels.
23. ***EN 1316-1/2:2012 Hardwood round timber – Qualitative classification. Part 1: Oak & beech / Part 2: Poplar. European Committee for Standardization, Brussels.
24. ***EN 1927-1:2008 Qualitative classification of softwood round timber. Part 1: Spruces and firs. European Committee for Standardization, Brussels.
25. ***EN 14081-1:2016 Timber structures – Strength graded structural timber with rectangular cross section. Part 1: General requirements. European Committee for Standardization, Brussels.
26. ***EN 14358:2016 Timber structures – Calculation and verification of characteristic values. European Committee for Standardization, Brussels.
27. ***EN 1995-1-1:2004 Eurocode 5: Design of timber structures. Part 1-1: General – Common rules and rules for buildings. European Committee for Standardization, Brussels.

28. ***FAO, 2022: Global Forest Resources Assessments. Country Reports. https://www.fao.org/forest-resources-assessement/fra-2020/country-reports/en/ (Accessed Sep 2, 2022).
29. ***FAOSTAT 2021: Forestry Production and Trade. https://www.fao.org/faostat/en/#data/FO (Accessed Sep 5, 2022).
30. ***Imre Makovecz & Tamas Dobrosi: https://www10.aeccafe.com/blogs/arch-showcase/2014/08/29/pancho-arena-in-felcsut-hungary-by-dobrosi-tamas/ (Accessed Sep 21, 2022).
31. ***INDEXBOX: https://app.indexbox.io/ (Accessed Sep 10, 2022).
32. ***JCSS, 2006: Probabilistic model code. Part 3.5: Timber. Joint Committee on Structural Safety, 16 p.
33. ***prEN 1912:2022 Structural timber – Strength classes – Assignment of visual grades and species. European Committee for Standardization, Brussels.
34. ***Stantec company: https://www.nordic.ca/en/projects/structures/mistissini-bridge (Accessed Sep 21, 2022).
35. ***Swedish wood: https://www.swedishwood.com/wood-facts/about-wood/wood-grades (Accessed Jan 27, 2023).
36. ****Voll Arkitekter:* https://www.inexhibit.com/case-studies/clt-goes-tall-high-rise-buildings-in-cross-laminated-timber/ (Accessed Sep 21, 2022).
37. ***Zbirka jugoslovenskih pravilnika i standarda za gradjevinske konstrukcije, 1995. Knjiga 4: Drvene konstrukcije. Beograd, 687 p.

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