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Optimum design of timber structures under fire using metaheuristic algorithm

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Research Paper

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Optimum design of timber structures under fire using metaheuristic algorithm

One of the major tasks of structural engineers is to reduce the building cost. Thus, an effective optimization of structural elements is gaining in importance every day. The teaching-learning-based optimization (TLBO), which is one of metaheuristic algorithms, for an optimum design and analysis of timber structures under fire in accordance with EN 1995 1-2 (Eurocode 5: Design of Timber structures - Part 1- 2 General structural fire design), is proposed in this study. The objective function in this algorithm is the building cost of timber structures under fire, considering premature collapse of the structure and limitation of fire spread. A structure made of wood is investigated under different times of fire exposure in order to determine the cross-section and wood type of structural elements. In conclusion, the cross section and strength of structural elements made of wood can be effectively and rapidly optimized with TLBO according to EN 1995 1-2.

Key words:

timber structures, fire design, metaheuristic algorithms, Eurocode 5

Prethodno priopćenje

Serdar Ulusoy

Optimalni projekt drvenih konstrukcija izloženih djelovanju požara uporabom metaheurističkog algoritma

Jedan je od glavnih zadataka konstrukcijskih inženjera smanjiti troškove građenja. Zato je svakim danom sve važnija učinkovita optimizacija konstrukcijskih elemenata. U ovom istraživanju predlaže se optimizacija koja se temelji na podučavanju i učenju (TLBO), a koja je jedan od metaheurističkih algoritama za optimalno projektiranje drvenih konstrukcija izloženih djelovanju požara koji su u skladu s normom EN 1995 1-2 (Eurocode 5: Projekt drvenih konstrukcija - Dio 1-2 Opći projekt konstrukcije izložene djelovanju požara). Objektivna je funkcija u ovom algoritmu trošak građenja drvenih konstrukcija izloženih djelovanju požara, uzimajući u obzir preuranjeni krah konstrukcije te granice širenja vatre. Proučava se drvena konstrukcija s različitim vremenom trajanja izloženosti požaru kako bi se odredio poprečni presjek i vrsta konstrukcijskih elemenata. Zaključak je da TBLO omogućava da se u kratkom vremenu učinkovito optimizira poprečni presjek i čvrstoća konstrukcijskih drvenih elemenata prema normi EN 1995 1-2.

Ključne riječi:

drvene konstrukcije, projekt požara, metaheuristički algoritmi, Eurocode 5

1. Introduction

Some applications and simplifications have been developed and used in recent years in engineering instead of traditional mathematical methods in order to overcome difficulties in solving complex problems. Among these applications, the most important advantage of metaheuristic algorithms, which calculate the maximum or minimum value of the objective function, is that they can rapidly produce effective solutions to engineering problems considering the balance between the safety and cost.
Metaheuristic algorithms inspired by events in nature are divided into three different groups: evolutionary algorithms, swarm intelligence, and other metaheuristic algorithms. The most important representatives of these algorithms are genetic algorithms [1] for evolutionary algorithms, the particle swarm optimization (PSO) [2], ant colony optimization (ACO) [3], bat algorithm [4], flower pollination algorithm (FPA) [5], and artificial bee colony (ABC) [6] for the swarm intelligence, and the teaching-learning-based optimization (TLBO) [7], Jaya algorithm (JA) [8], and harmony search algorithm (HS) [9] for other metaheuristic algorithms. Also, all metaheuristic algorithms have distinctive features in their mathematical expressions but the random selection of design variables, and selection of the best objective function, are the features that are common to all algorithms [4].
The existing or new-generation metaheuristic algorithms are widely used in various structural engineering applications, such as in thin-wall structures, cantilever retaining walls, structural control devices (passive, active or base isolation), and the steel and reinforced-concrete structural elements. An optimum design of post-tensioned axially symmetric cylindrical reinforced concrete walls using the harmony search algorithm [10] and novel hybrid metaheuristic methods (Jaya using Lévy flights, Jaya using Lévy flights with probabilistic student phase (JALS), JA using Lévy Flights with consequent student phase (JALS2)), with different height and load cases [11], and the design of cantilever soldier pile retaining walls via the harmony search algorithm [12], are some examples of the use of such algorithms in thin-wall and cantilever retaining wall structures. Optimum parameters of a tuned mass damper for seismically excited structures are determined using several metaheuristic algorithms such as the ant colony optimization, harmony search algorithm, flower pollination algorithm, and bat algorithm [13-16]. The widespread use of metaheuristic algorithms is proposed not only in passively controlled structures, but also in actively controlled structures (determination of parameters of the Proportional-Derivative-Integral (PID) type controllers using teaching-learning-based optimization [17, 18] and harmony search [19]). Also, the use of metaheuristic algorithms for an optimum design of various structural elements made of steel and reinforced concrete is gradually gaining momentum. Examples include: optimum design of the reinforced concrete footing dimensions [20], optimum design of reinforced concrete continuous beams and reinforced concrete multi-storey multi-span frame structures [21, 22], optimization of reinforced concrete biaxially loaded columns [23], optimum weight design of steel space frames with semi-rigid connections and steel frame [24-25], optimum design of steel plate girders [26], and the analysis of steel truss structures [27] and plane-stress members [28, 29].
Wood is one of the oldest building materials used by humans. It has been widely applied on the top floors of buildings as a roof carrying system to protect the structure from external factors such as rain and snow. Nowadays, timber structures are designed with even larger spans in accordance with appropriate engineering regulations. The cross section and strength of these timber structures are generally determined according to the experience of engineers, the objective being to obtain the bending-stressed beams and pressure-stressed columns. Therefore, the building cost according to appropriate regulations will differ depending on the engineering judgement.
In this study, teaching-learning-based optimization is proposed to balance the safety and cost of a timber structure under the fire situation lasting 30 and 60 minutes. The design of this structure is conducted in accordance with Eurocode 5: Design of Timber structures - Part 1- 2 General structural fire design.
This paper shows that the fire resistance time of the structure increases with an increase in cross section and strength of structural elements, while also explaining how much this increase in cross-section and strength should be for each structural elements to obtain optimum results for different fire times, such as 30 or 60 minutes, i.e., what cross-section and strength of each structural element are required for an optimum design.

2. Design of timber structures under fire

Although timber structures are made of combustible material, they have a remarkably high fire resistance if their cross-sectional dimensions are sufficiently large. Such favourable fire behaviour is caused by excellent properties of wood, i.e. their outer zones are charred to form a protective layer that has low thermal conductivity and slows down further propagation of fire [30]. The outer zones of timber structure under different times of exposure to fire are given in Figure 1.

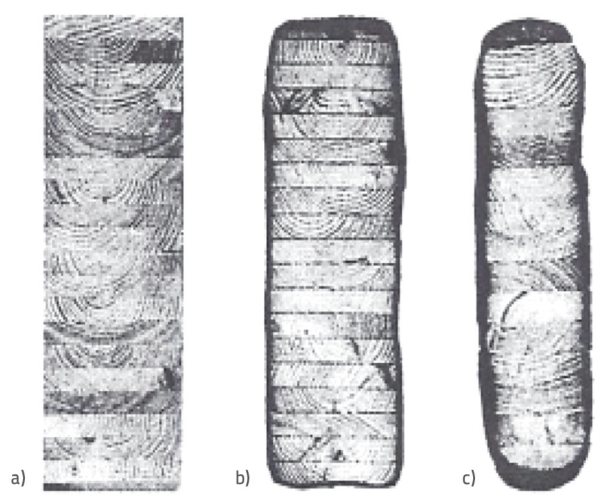

Figure 1. Timber structure: a) before fire test b) after 30 minutes c) after 60 minutes

In the event of fire, the decisive protection property of structural elements is the fire resistance time, i.e., how long such elements can resist the fire such as F30-B (fire resistance duration in excess of than 30 min.), F60-B (fire resistance duration in excess of 60 min.) and F90-B (fire resistance duration in excess of 90 min.) [31].

Important basics for the fire protection design of timber structures are mechanical effects in the case of fire, which are presented in Eq.1 according to combined rules given in EN 1990:2002 (Eurocode: Basis of structural design) [32] and in EN 1995-1-2 (Eurocode 5: Design of timber structures - Part 1- 2 General structural fire design) distinguishing between direct and indirect actions [33]. The indirect actions need not be taken into account if they have only a slight influence on the load-bearing behaviour, or can be absorbed by an appropriate design of supports [34].

$$E_{d,fi} = \sum \gamma_{GA} \cdot G_k + \psi_{1,1} \cdot Q_{k,1} + \sum \psi_{2,i} \cdot Q_{k,i} + \sum A_d(t) \quad (1)$$

$E_{d,fi}$ is the design effect of actions for a fire situation, γ_{GA} is the partial factor for permanent actions in accidental design situations and is equal to 1.0, G_k is the characteristic value of a permanent action, $\psi_{1,1}$ is the combination factor for the frequent value of a variable action, $Q_{k,1}$ is the characteristic value of the leading variable action, $\psi_{2,i}$ is the combination factor for the quasi-permanent value of a variable action, $Q_{k,i}$ is the characteristic value of the additional variable action, and $A_d(t)$ is the design value of indirect actions.

Design values of the strength and stiffness properties under fire shall be determined from Eq. 2. The 20 % fractile of a strength property at normal temperature is calculated by multiplying the characteristic strength property by the factor according to EC 1995-1-2. This factor is given in Table 1 for various materials.

$$f_{d,fi} = k_{mod,fi} \frac{f_{20}}{\gamma_{M,fi}} \quad (2)$$

$F_{d,fi}$ is the design strength in fire, $k_{mod,fi}$ is the modification factor for fire, f_{20} is the 20 % fractile of a strength property at normal temperature, and $\gamma_{M,fi}$ is the partial safety factor for timber in fire and is equal to 1,0.

The EC 1995-1-2 offers two methods for dimensioning of beams and columns in the case of fire. One of these methods, known as the reduced cross-section method, provides a design with an effective cross-section and the other, known as the reduced properties method, provides a design with reduced strength and stiffness values. In this study, the reduced properties method is used for the dimensioning of beams and columns in the case of fire, as illustrated in Equations 3-8.

$$k_{mod,m,fi} = 1 - \frac{1}{200} \frac{p}{A_r} \quad (3)$$

$$k_{mod,c,0,fi} = 1 - \frac{1}{125} \frac{p}{A_r} \quad (4)$$

$$k_{mod,E,fi} = 1 - \frac{1}{330} \frac{p}{A_r} \quad (5)$$

$$f_{m,d,fi} = \frac{k_{fi} \cdot k_{mod,m,fi} \cdot f_{m,k}}{\gamma_{M,fi}} \quad (6)$$

$$f_{c,0,d,fi} = \frac{k_{fi} \cdot k_{mod,c,0,fi} \cdot f_{c,0,k}}{\gamma_{M,fi}} \quad (7)$$

$$E_{fi} = \frac{k_{fi} \cdot k_{mod,E,fi} \cdot E_{005}}{\gamma_{M,fi}} \quad (8)$$

Here, p is the perimeter of the fire-exposed residual cross-section, A_r is the area of the residual cross-section, $f_{m,k}$ is the characteristic bending strength, $f_{c,0,k}$ is the characteristic compressive strength, E_{005} is the modulus of elasticity, $f_{m,d,fi}$, $f_{c,0,d,fi}$ and E_{fi} are the design bending strength, design compressive strength, and modulus of elasticity in case of fire, respectively.

Table 1. Values of k_{fi}

Material	k_{fi}
Solid timber	1.25
Glued-laminated timber	1.15
Wood-based panels	1.15
LVL	1.10
Connections with fasteners in shear with side members of wood and wood-based panels	1.15
Connections with fasteners in shear with side members of steel	1.05
Connections with axially loaded fasteners	1.05

The charring depth, which is the distance between the original outer surfaces of the section and the position of the char-line, as shown in Figure 2, is decisive for calculating the perimeter of the fire-exposed residual cross-section and the area of the residual cross-section. It is calculated as a function of the time of fire exposure. The relevant charring rate is given in Table 2. Also, one-dimensional and notional charring depths are given in equations 9 and 10, respectively. t is the time of fire exposure, β_0 is the one-dimensional design charring rate, and β_n is the design notional charring rate under standard fire exposure.

$$d_{char,0} = \beta_0 \cdot t \quad (9)$$

$$d_{char,n} = \beta_n \cdot t \quad (10)$$

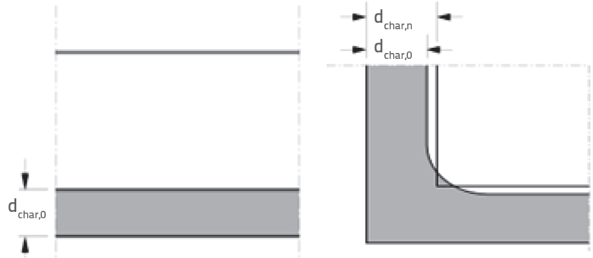

Figure 2. Charring depth $d_{char,0}$ for one-dimensional charring and notional charring depth $d_{char,}$

Table 2. Design charring rates β_0 and β_n of timber, LVL, wood panelling and wood-based panels

Material	β_0	β_n
a) Softwood and beech		
Glued laminated timber with a characteristic density of ≥ 290 kg/m³	0,65	0,70
Solid timber with a characteristic density of ≥ 290 kg/m³	0,65	0,80
b) Hardwood		
Solid or glued laminated hardwood with a characteristic density of ≥ 290 kg/m³	0,65	0,70
Solid or glued laminated hardwood with a characteristic density of ≥ 450 kg/m³	0,50	0,55
c) LVL		
with a characteristic density of ≥ 480 kg/m³	0,65	0,70
d) Panels		
Wood panelling	0,90	-
Plywood	1,00	-
Wood-based panels other than plywood	0,90	-

The maximum bending, tensile and compressive stress must be smaller than the bending, tensile and compressive strength to ensure safe design in the case of fire. These mathematical expressions are given in equations 11-13. Combined tensile and bending stress or compressive and bending stress are defined using equations 14 and 15, respectively. k_m is the reduction factor, and it amounts to 0.7 for the rectangular cross-section.

$$\sigma_{m,d,fi} \le f_{m,d,fi} \tag{11}$$

$$\sigma_{c,0,d,fi} \le f_{c,0,d,fi} \tag{12}$$

$$\sigma_{t,0,d,fi} \le f_{t,0,d,fi} \tag{13}$$

$$\frac{\sigma_{t,0,d,fi}}{f_{t,0,d,fi}} + \frac{\sigma_{m,y,d,fi}}{f_{m,y,d,fi}} + k_m\left(\frac{\sigma_{m,z,d,fi}}{f_{m,z,d,fi}}\right) \le 1 \tag{14}$$

$$\left(\frac{\sigma_{c,0,d,fi}}{f_{c,0,d,fi}}\right)^2 + \frac{\sigma_{m,y,d,fi}}{f_{m,y,d,fi}} + k_m\left(\frac{\sigma_{m,z,d,fi}}{f_{m,z,d,fi}}\right) \le 1 \tag{15}$$

The coefficient $k_{c,y,fi}$ of buckling about the y axis, and the utilization factor of the member that is subjected to compressive and bending stress in the case of fire, are determined as follows:

$$\lambda_{y,fi} = \frac{l_{ef,fi}}{i_{y,fi}} \tag{16}$$

$$\lambda_{rel,y,fi} = \frac{\lambda_{y,fi}}{\pi} * \sqrt{\frac{f_{c,0,k}}{E_{005}}} \tag{17}$$

$$k_{y,fi} = 0,5 \cdot \left[1 + \beta_c \cdot \left(\lambda_{rel,y,fi} - 0,3\right) + \lambda_{rel,y,fi}^2\right] \tag{18}$$

$$\beta_c = \begin{cases} 0,2 & \text{za puno drvo} \\ 0,1 & \text{za lijepljeno lamelirano drvo} \end{cases}$$

$$k_{c,y,fi} = min\left\{\frac{1}{k_{y,fi} + \sqrt{k_{y,fi}^2 - \lambda_{rel,y,fi}^2}};1\right\} \tag{19}$$

$$\frac{\sigma_{c,0,d,fi}}{k_{c,y,fi} * f_{c,0,d,fi}} + \frac{\sigma_{m,y,d,fi}}{f_{m,y,d,fi}} + k_m\left(\frac{\sigma_{m,z,d,fi}}{f_{m,z,d,fi}}\right) \le 1 \tag{20}$$

$i_{y,fi}$ is radius of gyration about the y axis, $\lambda_{y,fi}$ is the slenderness ratio about the y axis and $l_{ef,fi}$ is the buckling length of compressed element about the y axis. Euler cases are usually used to calculate $l_{ef,fi}$ buckling length of a structural element such as beam or column.

3. The proposed methodology

Metaheuristic algorithms are developed to optimize the objective function of the complex problems encountered in engineering fields by using design variables. Once the initial design variables are randomly determined, these values reach their optimum values taking into account design constraints during the optimization process. In this study, the teaching-learning-based algorithm developed by Rao et al. is used to optimize the cross section and wood type of structural systems under fire. In this algorithm, the solution of the objective function is considered as a teacher who has the best knowledge of the subject matter taught in the class. After the subject matter is passed on to the students by the teacher, the students continue to develop among themselves, and the student who has acquired a better command of the subject matter is appointed as a new teacher. Thus, an optimum objective function is obtained for this subject matter. The teaching-learning algorithm consists of two phases (teaching phase and learning phase). Mathematical expressions for both phases are given in equations (21) and (22), respectively.

$$x_{new} = x_{old} + rnd(1)(x_{teacher} - TFx_{mean}) \tag{21}$$

$$x_{new} = \begin{cases} x_{old} + rnd(1)\left(x_j - x_k\right) \; if\, f\left(x_j\right) < f\left(x_k\right) \\ x_{old} + rnd(1)\left(x_k - x_j\right) \; if\, f\left(x_k\right) < f\left(x_j\right) \end{cases} \tag{22}$$

x_{new} is the new solution, x_{old} is the existing solution, rnd (1) is a random number between 0 and 1, $x_{teacher}$ is the best solution defined as a teacher, TF is the teaching factor that assumes a value of 1 or 2, x_{mean} is the average of all solutions, and x_j and x_k are two randomly chosen solutions defined as learners. The flowchart of the optimization process using TLBO is presented in Figure 2.

The optimization code of the timber structures under fire is written in Matlab [35] using the teaching-learning-based algorithm. In the optimization process, a range of sixteen design variables with 10 population numbers (design variables create a solution set that is collected in a matrix), and design constraints with a penalty function shown in tables 3-4, are considered to calculate the objective function (unit cost of the timber structure). After calculation of the first randomly objective function, the optimization process continues for 100000 iterations to obtain optimum results. The objective function can be written as:

$$\text{Min } F(x) = C_T \cdot V_t \tag{23}$$

C_T and V_T are the unit cost of timber and the volume of timber, respectively

Table 3. Design variable of timber structure under fire

Structure	Description	Design variables [mm]	
Roof structure	the width of the structural element 1 the height of the structural element 1 the width of the structural element 2 the height of the structural element 2	$80 \le b_1 \le 240$ case 1 $80 \le h_1 \le 240$ case 1 $80 \le b_2 \le 240$ case 1 $80 \le h_2 \le 240$ case 1	$130 \le b_1 \le 240$ case 2 $130 \le h_1 \le 240$ case 2 $130 \le b_2 \le 240$ case 2 $130 \le h_2 \le 240$ case 2
Single span beams and columns	the width of the structural element 3 the height of the structural element 3 the width of the structural element 4 the height of the structural element 4 the width of the structural element 5 the height of the structural element 5 the width of the structural element 6 the height of the structural element 6	$80 \le b_3 \le 240$ case 1 $80 \le h_3 \le 240$ case 1 $80 \le b_4 \le 240$ case 1 $80 \le h_4 \le 240$ case 1 $80 \le b_5 \le 240$ case 1 $80 \le h_5 \le 240$ case 1 $80 \le b_6 \le 240$ case 1 $80 \le h_6 \le 240$ case 1	$130 \le b_3 \le 240$ case 2 $130 \le h_3 \le 240$ case 2 $130 \le b_4 \le 240$ case 2 $130 \le h_4 \le 240$ case 2 $130 \le b_5 \le 240$ case 2 $130 \le h_5 \le 240$ case 2 $130 \le b_6 \le 240$ case 2 $130 \le h_6 \le 240$ case 2
Frame structure	the width of the structural element 7 the height of the structural element 7 the width of the structural element 8 the height of the structural element 8	$120 \le b_7 \le 1000$ case 1 $120 \le h_7 \le 1000$ case 1 $120 \le b_7 \le 1000$ case 1 $120 \le h_7 \le 1000$ case 1	$120 \le b_7 \le 1000$ case 2 $120 \le h_7 \le 1000$ case 2 $120 \le b_7 \le 1000$ case 2 $120 \le h_7 \le 1000$ case 2

Table 4. Design constraints of timber structures

Element	Description	Design constraints
All structural elements	Safety of normal stress under tension and bending	See Equation (14)
	Safety of normal stress under compression and bending	See Equation (15)
	Safety of buckling load	See Equation (20)

Table 5. Length and actions of all structural elements

Elements	1	2	3	4	5	6	7	8	Unit
l_s	6.43	4.00	3.00	2.00	4.00	2.00	4.00	10.24	[m]
G_k	0.75	0.20	1.00	1.00	-	-	-	3.00	[kN/m]
Q_k (snow)	0.85	-	0.85	0.85	-	-	-	-	[kN/m]
Q_k (live)	-	0.35	1.5	1.5	-	-	-	4.5	[kN/m]

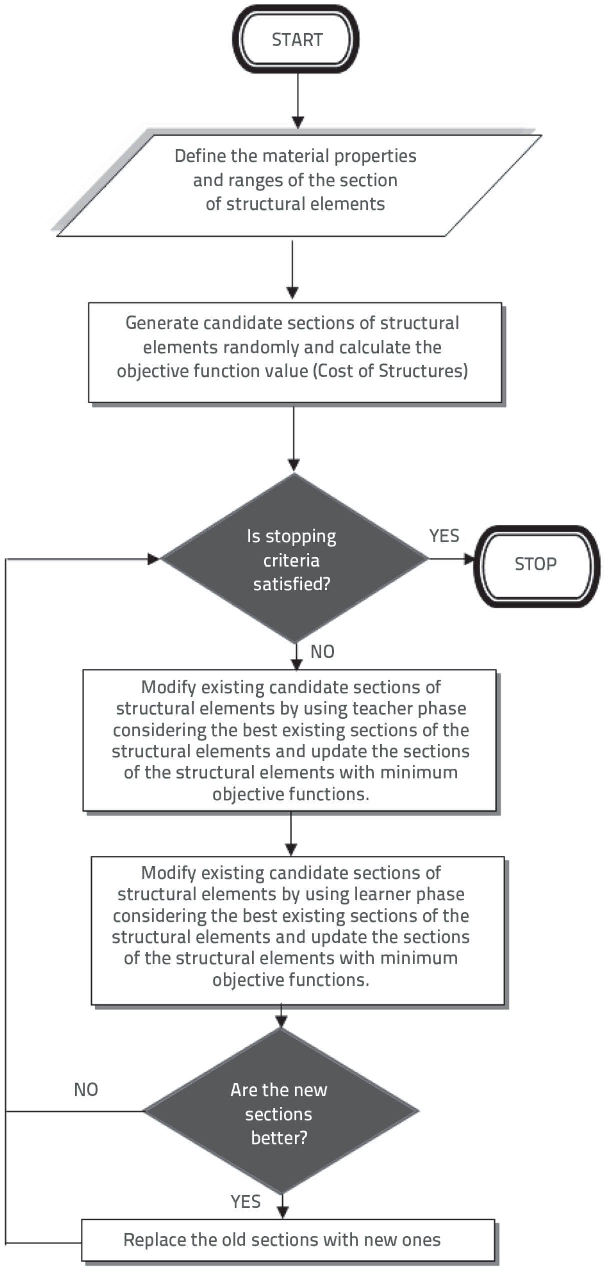

Figure 3. Flowchart of optimization process

4. Numerical examples

In this study, a structure made of wood (shown in Figure 4) is investigated for two different cases, i.e., the fire situation with 30 minutes fire exposure (Case 1), and the fire situation with 60 minutes fire exposure (Case 2). The geometry of the symmetrical roof structure is taken from the book 'Holzbau 2: Dach- und Hallentragwerke nach DIN 1052 (neu 2004) und Eurocode 5 [36]. The length l_s of structural elements, the permanent action G_k and the variable action $Q_{k,i}$ (live load and snow load) are presented in Table 5. The design load for the structural elements in a fire situation is calculated by means of Equation 1. Different types of wood are used to optimally design the structural elements. In the event of fire, 4-sided fire exposure of structural elements 2, 5, 7, and 8 is assumed, while other structural elements are exposed to 3-sided fire. The cost in EUR/m³, the modulus of elasticity E_{005}, the characteristic compressive strength $f_{c,0,k}$, the characteristic tensile strength $f_{t,0,k}$, the bending strength $f_{m,k}$, and the self-weight of different wood types, are given in Table 6. In the optimization process, the solid wood is used for the roof structure (structural elements 1 and 2) as well as for single span beams and columns (structural elements 3, 4, 5, and 6), while the glued laminated wood is used for the frame structure (structural elements 7 and 8).

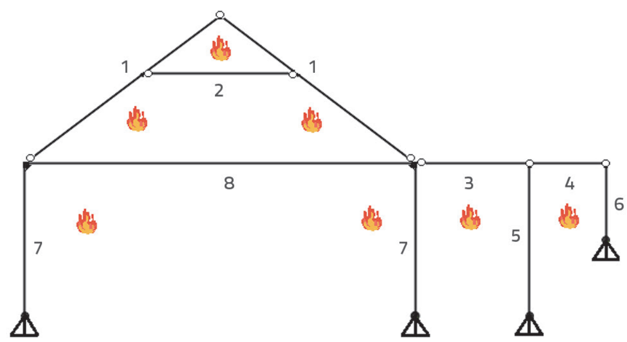

Figure 4. Geometry of timber structure

Optimum cross sections and wood types of structural elements under the 30- and 60- minute fire exposure are given in Table 7. Also, the time-dependent utilization factors of normal stress and buckling are given in figures 5-8 for each case.

Table 6. Material characteristic values of different wood types [N/mm²]

Strength class		C24	C30	C35	C40	GL24h	GL28h	GL32h
Bending	$f_{m.k}$	24	30	35	40	24	28	40
Modulus of elasticity	$E_{0.05}$	7400	8000	8700	9400	9500	10200	11100
Tension parallel	$f_{t.0.k}$	14	18	21	24	16.5	19.5	22.5
Compression parallel	$f_{c.0.k}$	21	23	25	26	24	26.5	29
Self-weight [kN/m³]	g_k	4.2	4.6	4.8	5.0	3.7	4.0	4.2
Cost [EUR/m³]	-	230	240	250	260	230	240	250

Table 7. Optimum cross section and wood type of structural elements under 30- and 60- minute fire exposure

Elements	1	2	3	4	5	6	7	8	6
Case	b1/h1 wood type	b2/h2 wood type	b3/h3 wood type	b4/h4 wood type	b5/h5 wood type	b6/h6 wood type	b7/h7 wood type	b8/h8 wood type	Cost [EUR/m³]
Case 1	120/120 C40	110/110 C40	90/110 C40	80/100 C35	100/120 C24	80/90 C24	180/180 GL32h	120/350 GL28h	254.83
Case 2	170/170 C24	160/160 C24	130/150 C35	130/130 C30	150/170 C24	130/130 C24	230/230 GL32h	120/480 GL28h	410.36

The use of solid wood C40 and C24 of optimum cross section is suitable for obtaining optimum results for the roof structure under the 30- and 60- minute fire exposure, respectively. In both cases, the use of different types of wood (C30, C35, and C40) with an optimal cross-section leads to more optimal results in single beams, while the change of the cross-section of the wood type C24 in columns leads to optimal results. Also, glued laminated wood types such as GL32h and GL28h, with higher strength compared to GL24h, are used for an optimum design of the frame structure under fire.

The optimum cross-section and the type of wood are determined considering the normal stress and buckling of the structural elements. In both cases, the normal stress is decisive for structural elements 2, 3, 4, 7 and 8. In Case 1, a significant increase in the utilization factor of both normal stress and buckling occurs after 25 minutes. This occurs in Case 2 after 50 minutes.

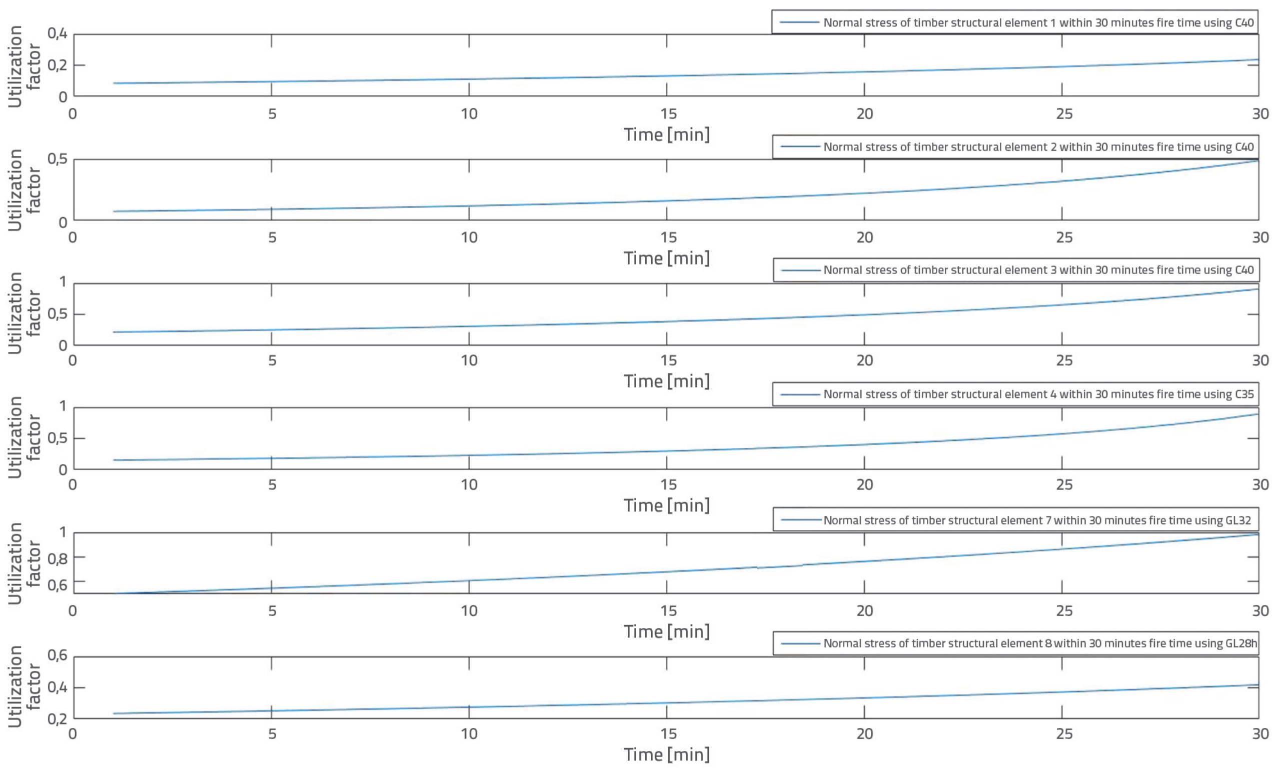

Figure 5. Time-dependent utilization factor of normal stress of structural elements under 30 minutes fire exposure using optimum type wood and section

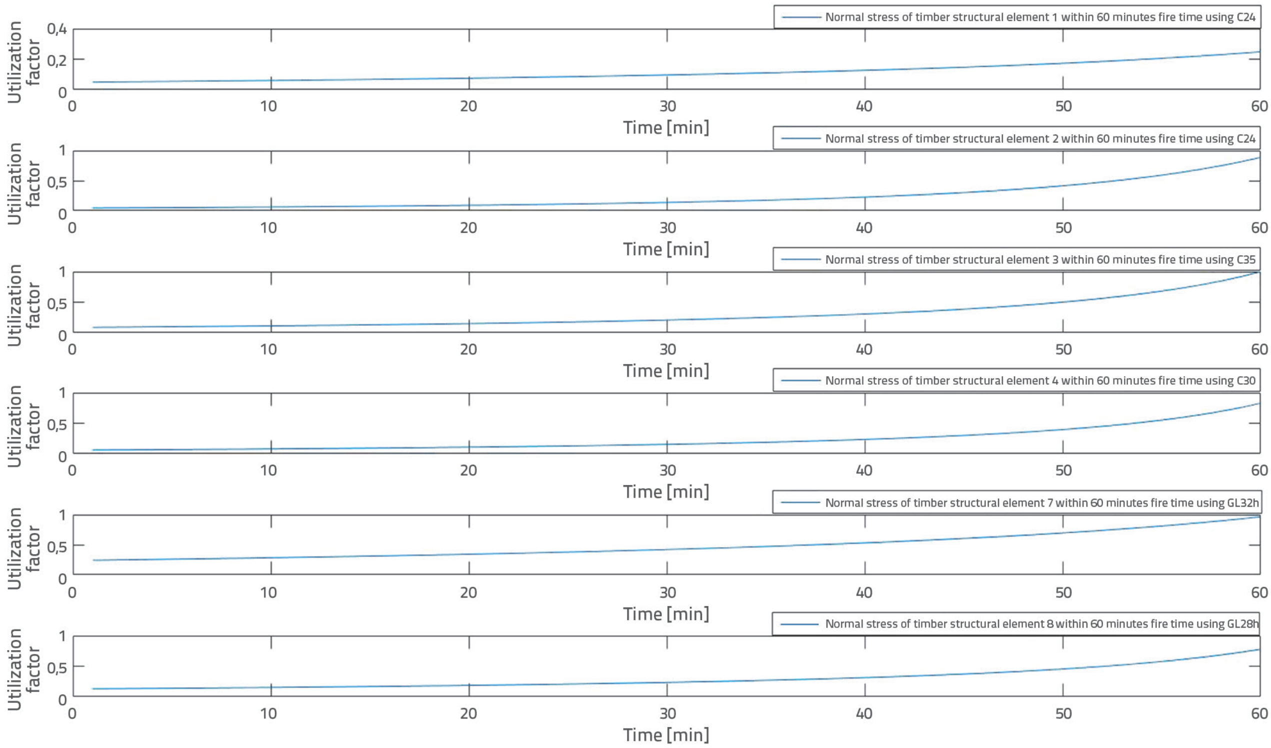

Figure 6. Time-dependent utilization factor of normal stress of structural elements under 60 minutes fire exposure using optimum type wood and section

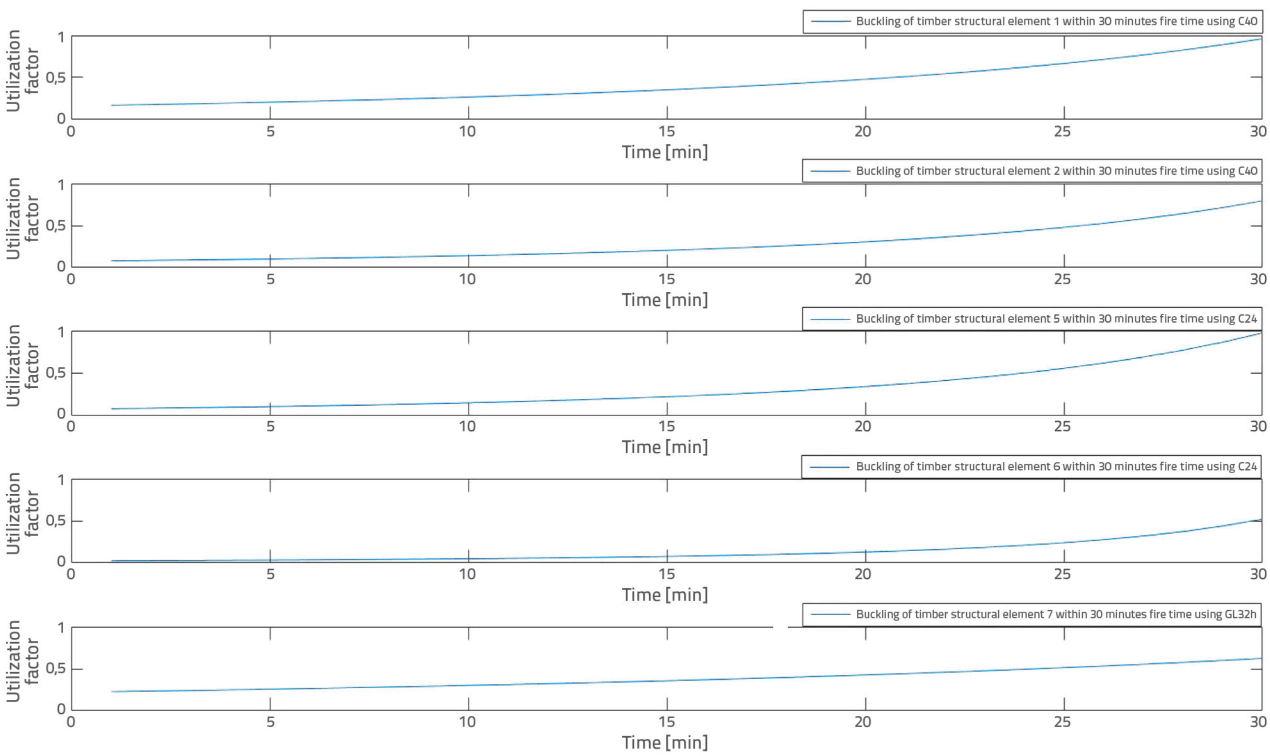

Figure 7. Time-dependent utilization factor of buckling of structural elements under 30 minutes fire exposure using optimum type wood and section

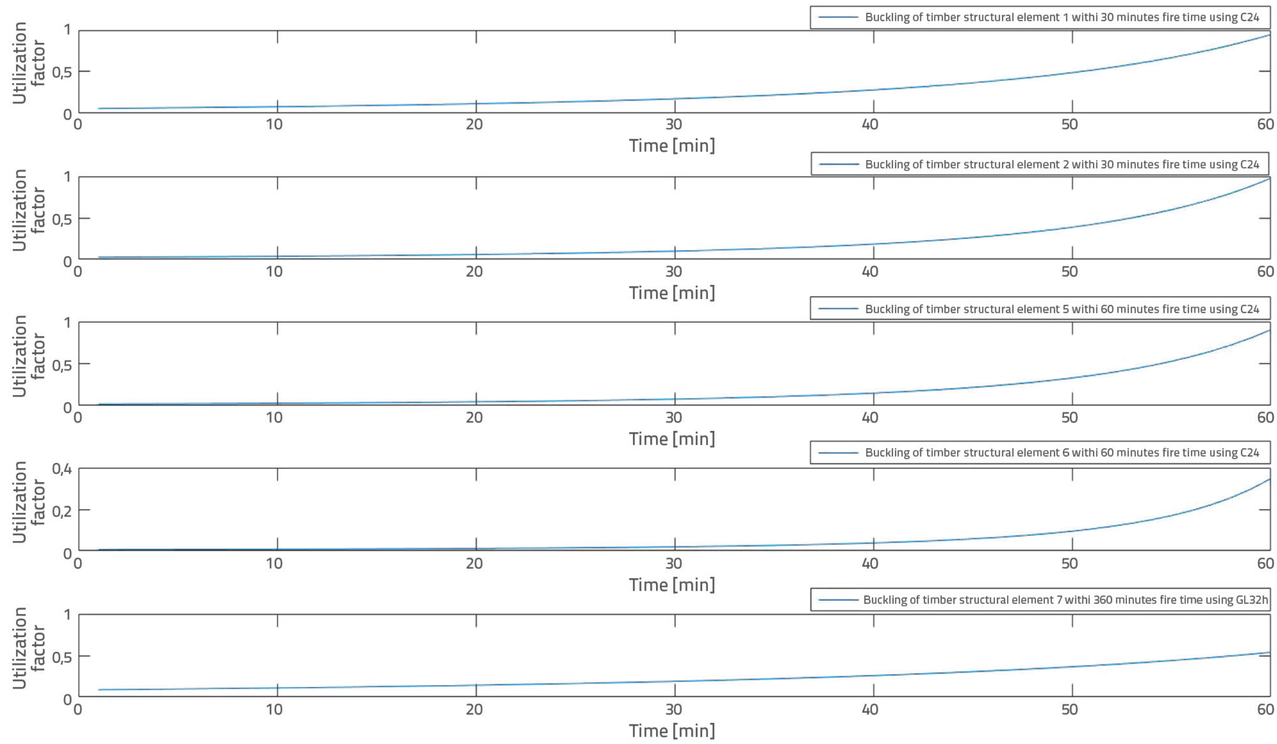

Figure 8. Time-dependent utilization factor of buckling of structural elements under 60 minutes fire exposure using optimum type wood and section

5. Conclusion

The load cases, the structural system, the cost of the wood, the cross-section, and the strength of the wood type, play an important role in the building cost. There is no optimal mathematical solution for calculating the building cost. For this reason, a numerical algorithm such as TLBO is required to optimally design the timber structure which has different mechanical features at each step of the fire.

In this study, TLBO is proposed for the design and analysis of a timber structure under 30 and 60 minutes of exposure to fire.

The conclusions of this study are:

- Optimum sections of structural elements and materials are calculated faster by means of the teaching-learning-based algorithm, when compared to a traditional method.
- The changing buckling and normal stress of structural elements because of the reduction of cross-section in case of fire is detectable through time-dependent capacity ratios.
- This study involving different type of sections, cases, and materials, is not only a theoretical study, but is also useful in practical fields for proper establishment of the cost and safety.

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