NORMS FOR DESTRUCTIVE BENDING MOMENTS OF T-SHAPE CORNER JOINTS OF FRAME STRUCTURAL ELEMENTS MADE OF SOLID SPRUCE WOOD WITH A CROSS-SECTION OF 50 X 30 MM

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ABSTRACT

In the presented research are established the normative values for the destructive bending moments of the most common used T-shape corner joints of frame structural elements made of solid spruce wood with a cross-section of 50 x 30 mm in arm compression bending load.

The established normative values can be used for the needs of the preventive quality control of furniture production as well as for the strength design of the sitting furniture, tables, and beds. For that purpose, it is recommended to draw up these normative values as a normative document which to use in the inner factory control of furniture quality.

Key words: corner joints of frame structural elements, destructive bending moments, solid spruce wood, norms for destructive bending moments of T-shape corner joints.

INTRODUCTION

Solid wood joints, and in particularly T-shape joints have been the subject of extensive research by many authors (Kyuchukov, G., Jivkov, V. 2016). Some of them are experimental, and some are theoretical using the FEM analysis (Genchev et al. 2016, Staneva et al. 2016, Staneva et al. 2018). For better quality control of production, it is necessary to introduce norms for the destructive (ultimate) bending moments of these compounds.

Norms for the destructive bending moments of T-shape corner joints of frame structural elements made of solid spruce wood are worked out based on the experimental research on the same types of joints of frame structural elements with a cross-section of 50 x 30 mm (Kyuchukov G. et al., 2015a). The samples for testing were manufactured from the same solid spruce wood (Piceaabies Karst.) as in the previous papers (Kyuchukov G. et al., 2015; Kyuchukov G. et al. 2016). The basic physical and mechanical properties of timber are: density – 387 kg/m^3; radial, tangential and volumetric shrinkage – respectively 4,0, 8,6 and 12,7%; radial, tangential and volumetric swelling – respectively 4,2, 7,8 and 11,7%; bending strength – 56 N/mm^2; compressive strength parallel to grain – 34 N/mm^2; longitudinal modulus of elasticity – 9 500 N/mm^2 (Kyuchukov G. et al, 1990).

MATERIAL AND METHODS

In the presented research are given data of the normative values for the destructive bending moments of 9 types glued T-shape corner joints of frame structural elements made of solid spruce wood with a cross-section of 50 x 30 mm, according to the Bulgarian State Standard 5527-73 (Kyuchukov G. 1988; Kyuchukov G., Jivkov V., 2016).

The following types of T-shape corner joints were tested:

1. **T-shape corner butt joints** (Figure 1):
   - butt joint at a right angle;
   - butt joint at other than right angle.
2. **T-shape corner mortise and tenon joints** (Figure 2):
   - blind mortise and tenon joint;
   - through mortise and tenon joint.
3. **T-shape corner dovetail mortise and tenon joints** (Figure 3):
   - bilateral dovetail mortise and tenon joint at a right angle;
   - one-sided dovetail mortise and tenon joint at a right angle;
   - one-sided dovetail mortise and tenon joint at other than right angle.
4. **T-shape corner splined joints** (Figure 4):
   - dowel joint;
   - splined joint.

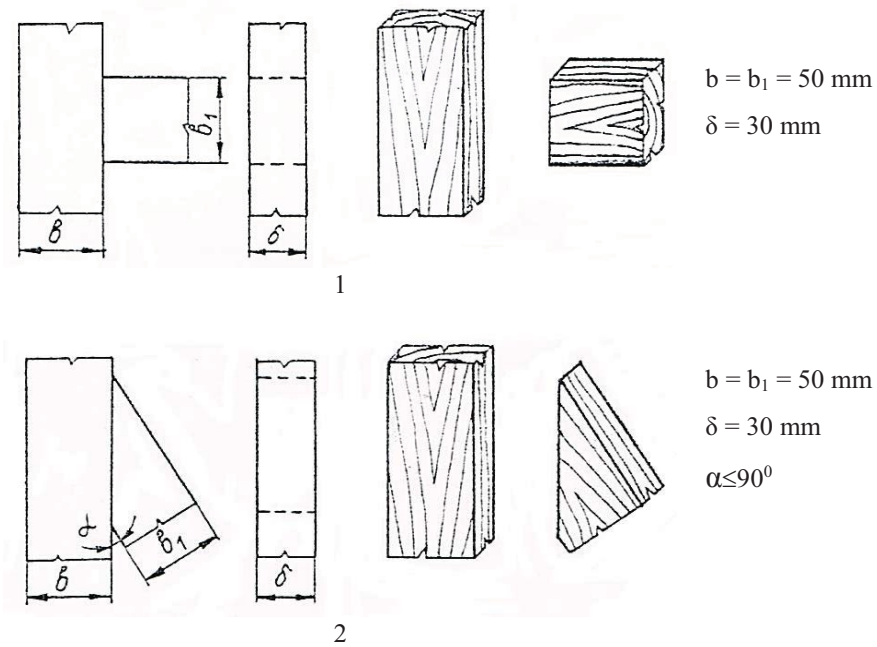


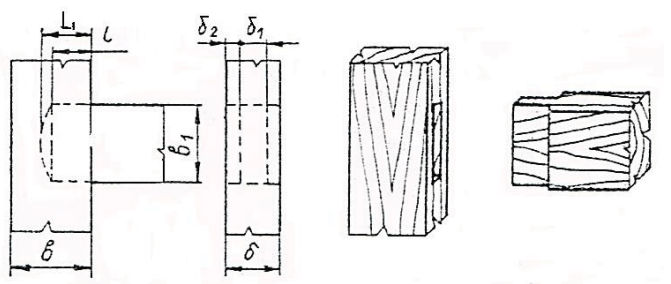
Figure 1: T-shape corner butt joints: 1 – butt joint at right angle; 2 – butt joint at other than right angle

The parameters of the joints correspond to the Bulgarian State Standard 5527-73 and are given at Figures 1 to 4.

The joints of the structural elements were made with polyvinylacetate adhesive (PVAc).

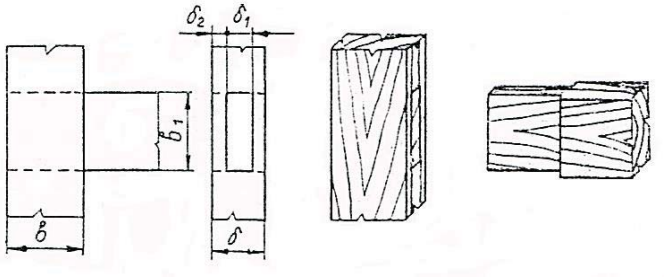
The type and dimensions of the samples are shown on Figure 5. The size L_1 = 141 mm, and L_2 = 332 mm. The other sizes are as shown in Figures 1 to 4.

It is the custom to test the samples under arm compression bending load. By reason of asymmetry of the connecting elements and difference in mutual position of the joined frame structural elements of some of the joints, it is the custom to test them at arm compression bending load in two directions – in the direction of the ends of the arms A ↔ B and in the direction B ↔ C (Figure 5). With a view to this for each joint were manufactured 30 numbers of test samples – at 15 numbers for compression bending load in both directions (see Figure 5).



3

b = b_1 = 50 mm
b_2 = (0,6÷0,8) b_1= 30 mm
δ = 30 mm
δ_1 = 0,4 δ = 12 mm
δ_2 = 0,3 δ = 9 mm
L= (0,5÷0,8) b=35 mm
L_1= L+1÷2 mm = 37mm



4

b = b_1 = 50 mm
δ = 30 mm
δ_1= 0,4 δ = 12 mm
δ_2 = 0,3 δ = 9 mm

Figure 2: T-shape corner mortise and tenon joints: 3 – blind mortise and tenon joint; 4 – through mortise and tenon joint

The schemes of loading of the samples in their testing (Figure 6) correspond to the standardized methodology (BSS 9165-90), worked out at the Laboratory of Furniture Construction at the University of Forestry (Kyuchukov G. 1995; Kyuchukov G., Jivkov V., 2016). The experiment was carried out at universal testing machine at an even speed (5m/min) of loading in the length of (60 ± 30) s from the beginning of the loading and accuracy of reading of the results 1% of the failure force of loading.

Before testing the samples were conditioned seven days and nights at temperature (21 ± 3) ^{0}C and relative air humidity (55 ± 10)%.

The destructive bending moments M_1 under compression bending test in direction A ↔ B and M_2 under compression bending test in direction B ↔ C have been calculated correspondingly by formulas (1) and (2).

$$\boldsymbol{M_1 = F_1 . l_1} \quad \textbf{(1)}$$

$$\boldsymbol{M_2 = F_2 . l_1} \quad \textbf{(2)}$$

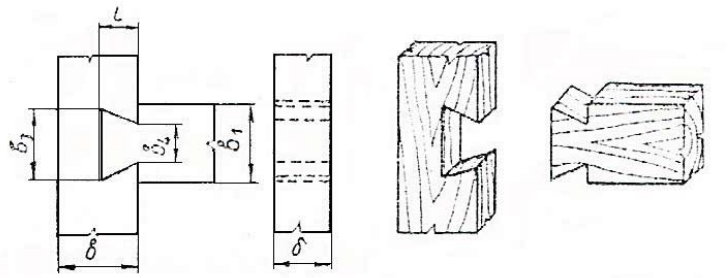
where

F_1 and F_2 are the failure forces in compression bending test (Figure 6) in [N];

l_1 – the corresponding arm of bending in compression bending test under the scheme of loading a, b and c (Figure 6) in [m].

The results from the experiments are processed by the variation statistics methods.

The normative values for the destructive bending moments of the tested corner joints of the frame structural elements made of solid spruce wood are determined by the formulas (3) and (4).



5

$b = b_1 = 50$ mm

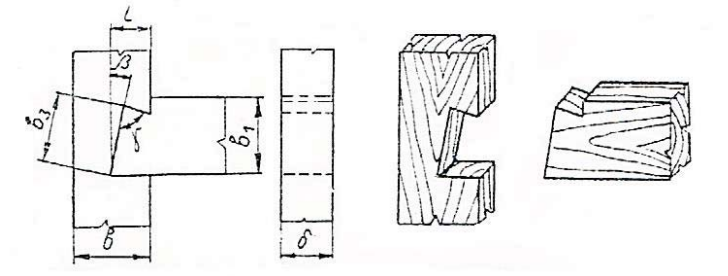
$\delta = 30$ mm

$b_2 = (0{,}6 \div 0{,}8)\ b_1 = 30$ mm

$b_3 = 0{,}85\ b_1 = 42$ mm

$b_4 = 0{,}5\ b_1 = 25$ mm

$l = (0{,}3 \div 0{,}5)\ b_1 = 25$ mm



6

$b = b_1 = 50$ mm

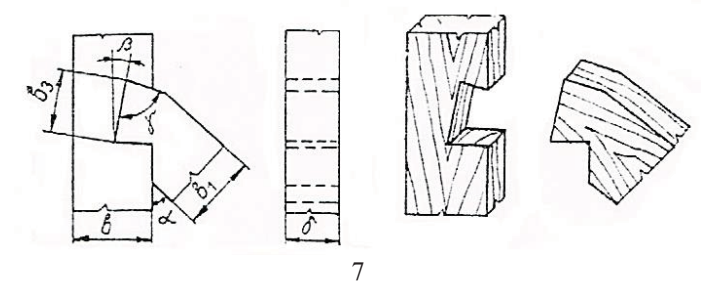
$\delta = 30$ mm

$b_3 = 0{,}925\ b_1 \approx 45$ mm

$l = (0{,}5 \div 0{,}6)\ b_1 = 30$ mm

$\beta = 10^0$

$\gamma = 80^0$



7

$b = b_1 = 50$ mm

$b_3 = 0{,}9\ b_1 = 45$ mm

$\alpha < 90^0$

$\beta = 10^0$

$\gamma = 80^0$

Figure 3: T-shape corner dovetail mortise and tenon joints: 5 – bilateral dovetail mortise and tenon joint at a right angle; 6 – one-sided dovetail mortise and tenon joint at right angle; 7 – one-sided dovetail mortise and tenon joint at other than right angle

$$M_{1\,norm} = \overline{x_1} - \alpha . s_1 \qquad (3)$$

$$M_{2\,norm} = \overline{x_2} - \alpha . s_2 \qquad (4)$$

where

$\overline{x_1}$ is the mean value of the destructive bending moment of the joint at compression bending test in direction A ↔ B, [Nm];

$\overline{x_2}$ – the mean value of the destructive bending moment of the joint at compression bending test in direction B ↔ C, [Nm];

α – the coefficient of uniformity;

s_1 –the mean square deviation at compression bending test in direction A ↔ B, [Nm];

s_2 – the mean square deviation at arm compression bending test in direction B ↔ C, [Nm].

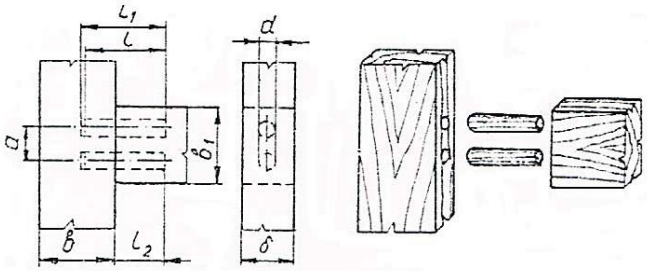
The coefficient of uniformity α specifies the range of the experimental data spread. In the theory of probability, it is given a proof that all the variants of experimental data practically lie into the limits $\bar{x}\pm$ 3s and over 99% of the data lie into the limits $\bar{x}\pm$ 2,5s. On the grounds of that fact it can be assumed that the lower bound $\bar{x}-$ 2,5s can be accepted as a normative bound of the relevant strength characteristic of the tested types of corner joints of the frame structural elements made of solid spruce wood.

The mean square deviation s is a function both of the data spread about the mean value and the number of the tested samples. It is determined the average variational coef-

ficient v_{av} to eliminate the influence of the accidental factors of particular samples of the given type of joint. At compression bending test in direction A ↔ B v_{av} = 11,6%, and at compression bending test in direction B ↔ C v_{av} = 10,5%. On this basis, the value of the mean square deviation for each type of joint is specified by the formulas (5) and (6).

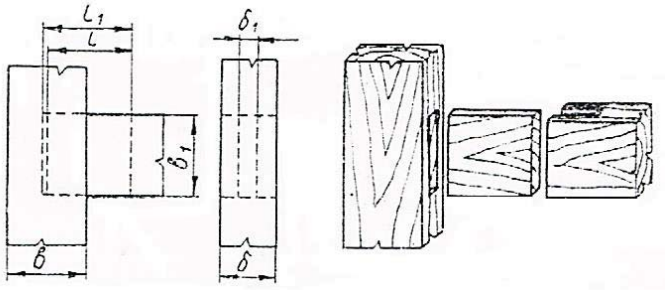
$$s_1 = \frac{v_{av}}{100} \cdot \overline{x_1} \quad (5)$$

$$s_2 = \frac{v_{av}}{100} \cdot \overline{x_2} \quad (6)$$



8

b = b_1 = 50 mm
δ = 30 mm
d = 0,4 δ = 12 mm
l=(2,5÷6)d = 60 mm
l_1=l + (2÷3) mm = 62 mm
l_2= 0,55 l = 33 mm
a ≥2 d = 26 mm



9

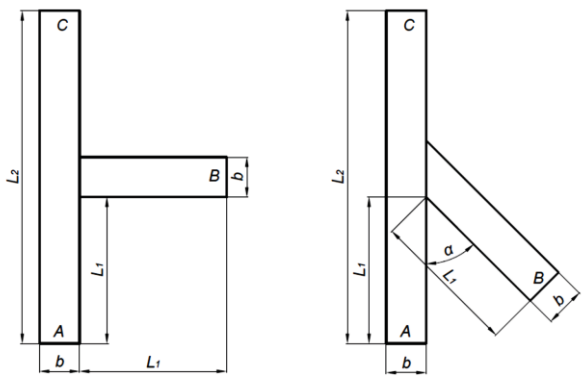
b = b_1 = 50 mm
δ = 30 mm
δ_1=1/3 δ = 10 mm
l = (1÷1,6) b = 65 mm
l_1 = l + (2÷3) mm= 67 mm

Figure 4: T-shape corner splined joints: 8 – dowel joint; 9 – splined joint

The normative values for the destructive bending moments of the tested T-shape corner joints at compression bending tests in both directions A ↔ B and B ↔ C are determined by the formulas (7) and (8).

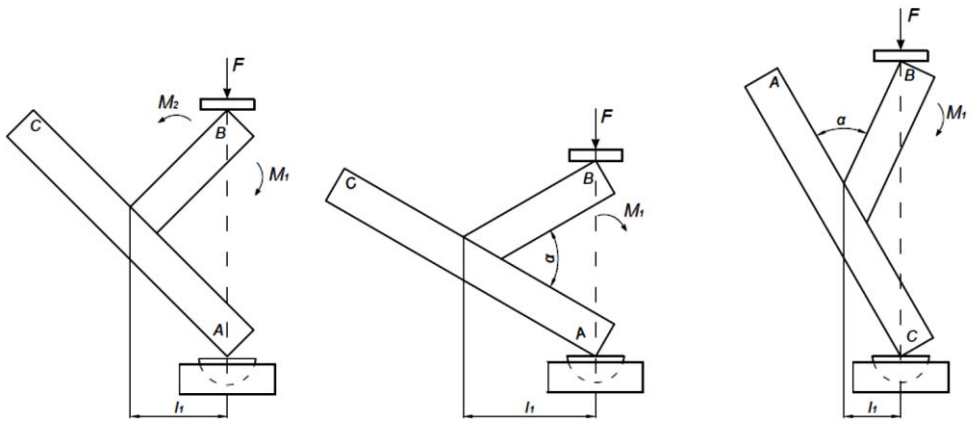
$$M_{1\,\text{normA}\leftrightarrow\text{B}} = \overline{x_1} - 2,5.s_1 \quad (7)$$

$$M_{2\,\text{normB}\leftrightarrow\text{C}} = \overline{x_2} - 2,5.s_2 \quad (8)$$



a **b**

Figure 5: Type and dimensions of the samples for testing the T-shape corner joints of frame structural elements made of solid wood: a – joints at a right angle; b – joints at other than right angle



a b c

Figure 6: Schemes for testing of samples of the T-shape corner joints at compression bending load: a **– joints at right angle;** b **– joints at other than right angle in direction A ↔ B;** c **– joints at other than right angle in direction B ↔ C, where l_1 is the arm of the joints**

COMPARATIVE ANALYSIS OF THE EXPERIMENTAL RESULTS

The results from the research are presented graphically in Figures 7 and 8. From the data shown in the figures, it is obvious that the destructive bending moment depends mainly on the type of joint. This is determined by the type and dimensions of the connecting elements and the area of the contacting surfaces of the joints, i.e. the area of the glue line.

The influence of the scheme at which the joint was loaded is very less – on the average underneath 1%.

The T-shape corner through mortise and tenon joint, blind mortise and tenon joint, dowel joint and one-sided dovetail mortise and tenon joint at right angle are destroyed at a comparatively high bending moment.

The normative values for the destructive bending moments of the tested corner joints follow the same dependencies as the experimental data.

The normative values for the destructive bending moments of the tested T-shape corner joints at compression bending tests in both directions A ↔ B and B ↔ C are on the average about 68% from the experimentally established values.

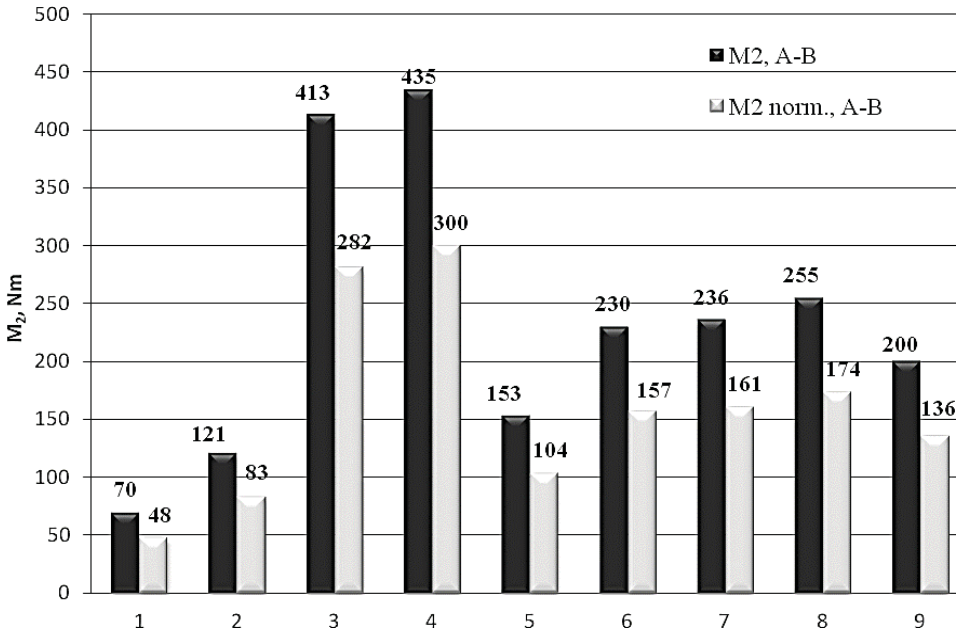


Figure 7: Destructive bending moments and norms for T-shape corner joints of frame structural elements made of solid spruce wood with a cross section of 50 x 30 mm at compression bending test in direction A ↔ B: 1 – butt joint at right angle; 2 – butt joint at other than right angle; 3 – blind mortise and tenon joint;4 – through mortise and tenon joint; 5 – bilateral dovetail mortise and tenon joint at right angle; 6 – one-sided dovetail mortise and tenon joint at right angle; 7 – one-sided dovetail mortise and tenon joint at other than right angle; 8 – dowel joint; 9 – splined joint

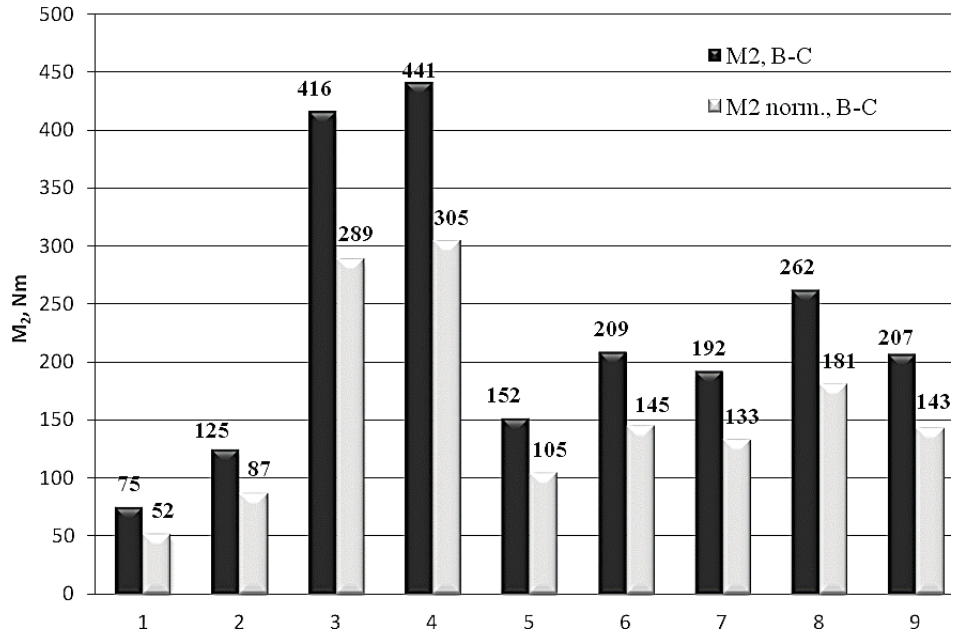


Figure 8: Destructive bending moments and norms for T-shape corner joints of frame structural elements made of solid spruce wood with a cross-section of 50 x 30 mm at compression bending test direction B ↔ C: 1 – butt joint at right angle; 2 – butt joint at other than right angle; 3 – blind mortise and tenon joint;4 – through mortise and tenon joint; 5 – bilateral dovetail mortise and tenon joint at right angle; 6 – one-sided dovetail mortise and tenon joint at right angle; 7 – one-sided dovetail mortise and tenon joint at other than right angle; 8 – dowel joint; 9 – splined joint

CONCLUSION

The established normative values for the destructive bending moments of the T-shape corner joints of frame structural elements made of solid spruce wood with a cross-section of 50 x 30 mm can be used for the needs of the preventive quality control of furniture production as well as for the strength design of the sitting furniture, tables and beds. For that purpose it is recommended to draw up these normative values as a normative document which to use in the inner factory control of furniture quality.

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