Long-Term Test on Timber Trusses

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Abstract

The paper deals with the results of exceptional experimentation, which focuses on the long-term loading of metal plate connected wood trusses. The uniqueness of research project is given by real dimensions of long-span samples and by the term of loading over one year. The aims of long-term experimentation were detection of two main parameters. The magnitude of additional deflections and time of load action needed for their development. In the paper the deflection curves are presented, namely time dependence of deflections. Recommendations for producers of metal plate connected wood trusses and for structural engineers are mentioned. The purpose of that research project is to increase the safety and reliability of timber load-bearing structures.

Keywords: Long-term loading, experimental investigation, rheology, creep, nail plate, timber truss

1. Introduction

The investigated types of girders are applied on roof structures with long-spans. These roof structures are in many cases loaded by heavy cladding and many of them are located in regions with long-term action of snow. Since a lot of software does not take the additional deformations into consideration (caused by the deformations of joints and the creep behavior of wood), the intention of research was the verification of deformation characteristics of trusses over time. The experiments were executed directly in the producer`s company Tectum Novum. The cooperation between Slovak University of Technology in Bratislava and the producer of timber trusses appeared as mutually beneficial in the common research project. The mutual cooperation in the field of research lasts since 2010. In the same year the first experimentation was carried out, which focused on the short-term resistance of trusses. The conclusions of that first investigation were applied to the production. The modified trusses had been afterwards subjected to long-term test. The research project was aimed to observation of deflection changes and to the determination of real operation by long-term loading. At the end of experimentation the degree of permanent deformations and by additional loading subsequently the resistance of trusses had been investigated.

2. Investigation

On the ground of earlier examinations, focused on the short-term resistance (Sandanus, [1]), some changes in production of metal plate connected wood trusses had been applied. The conclusion of that research emphasizes the selection of sawn timber for extremely loaded joints. Exceptionally attention was needed by all conditions of visual sorting to avoid the knots, resin pockets in critical locations of joints and avoid the elements with a spiral grain orientation. Therefore the producer decided for the type of sorted, kiln dried and finger jointed sawn timber known under abbreviation KVH. Moreover the product has a guaranteed strength class and the cross sections exact dimensions. This caused also modifications in the dimensions of cross sections – the original trusses had widths 50mm and the trusses made of KVH timber have width 45mm. The width reduction caused an increase of element's height to remain the appropriate the section's areas. The first diagonal had to be strengthen by additional element (Fig. 2). The span and height of trusses had been remained, in order to have comparable results of short and long-term test.

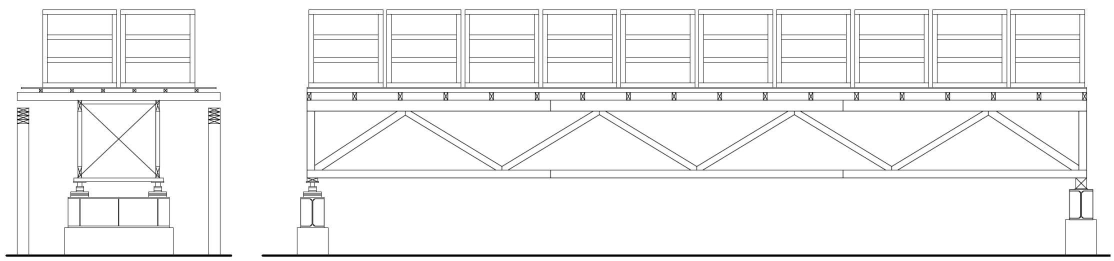

Figure 1: Sketch of investigated trusses with the loading platform and safety supports on sides.

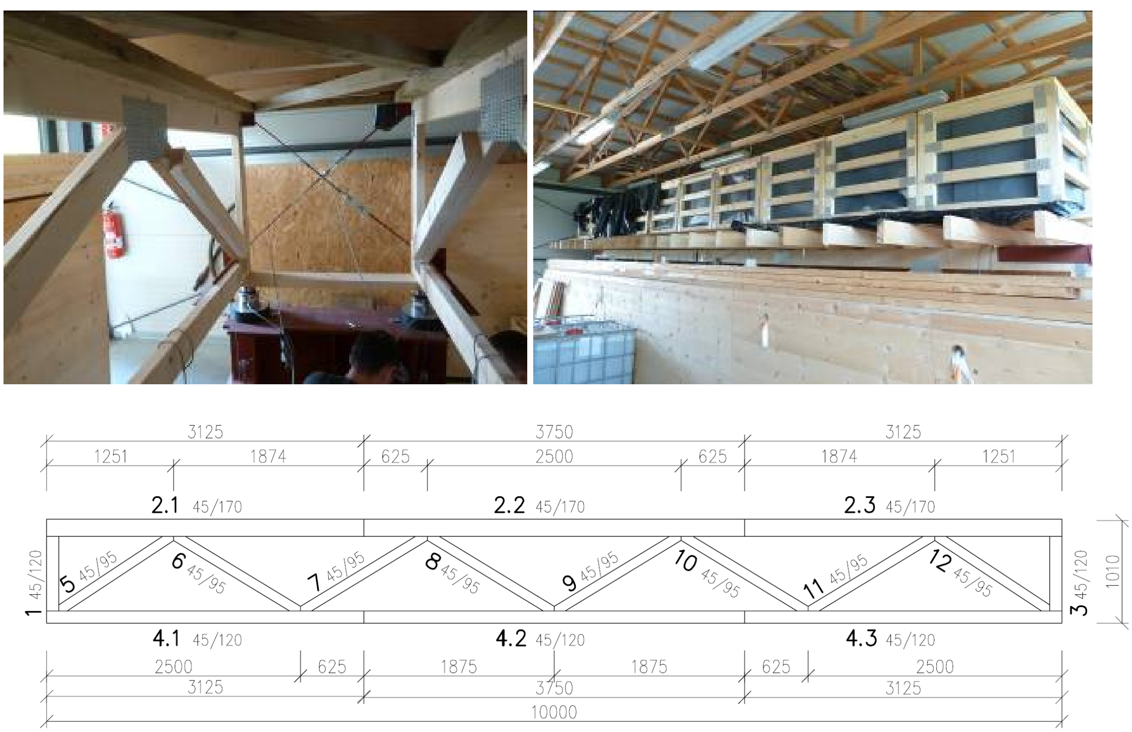

Figure 2: Investigated samples and platform with containers at the top of trusses.

The experiences from the previous short-term test had not significant influence on the arrangement of loading equipment for bending test. Two trusses were connected together by a horizontal oriented truss that creates a stabilizing stiffener in the plane of upper flanges. By the supports a vertical stiffener had been installed, composed of steel draw-bars. The loading had been ensured by water pumped into containers. The containers had been installed on the platform, situated on the top flanges of trusses. The platform composed of timber beams with cross sections 50/140mm with axial distance 600mm, laths 50/40mm a500mm and finally OSB board 12mm thick.

The level of loading was designed to be 90% of the beam's short-term resistance. To ensure the constant level of loading and avoid the water evaporation, the containers were covered by plastic foil. The level of water in containers was checked from time to time.

Electrical and also mechanical transducers had been installed on the trusses. Electrical transducers had been used by loading and by every change in level of loading. Here the force transducers were involved, which served for the load-level control, and inductive displacement transducer, which served for recording of deflections. Mechanical transducers had been used by measurement of deflections by constant load-level. These had been installed in the same locations as the electrical displacement transducers.

3. Results

The calculated instant deflection was 10.4mm determined by software Truss from company Fine. The observed deflection was over 15mm. Here can be mentioned that the calculations did not involve the deformations of joints, which can increase the deflection about 45%.

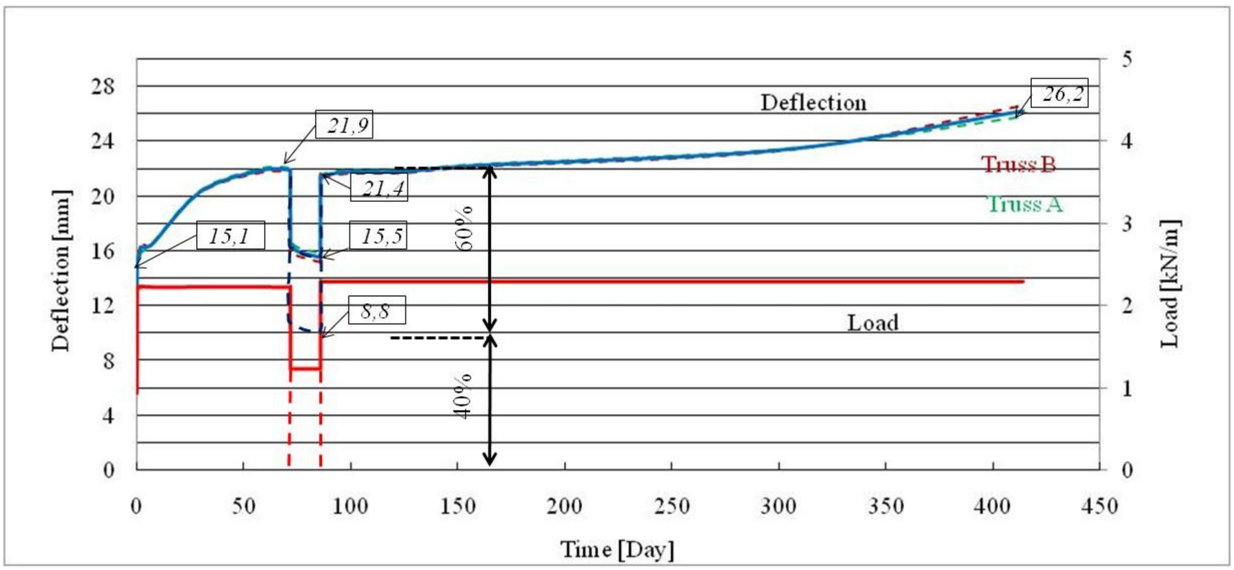

Figure 3: The course of creep.

Marked development of additional deflections was being observed during the first months of loading (Fig.3). It is visible that the deflection had been increased about another 45% of its instantaneous value. The load had been decreased and the slow backward deformation was observed after 72 days of constant load-level. The phase of backward deformation lasted for 13 days. At the end of this period the permanent deformation could be determined.

In the next phase of loading the increase of additional deflection was less sudden. Till the end of the test, thus in 414 days, the deflection 26.2mm was measured in its average value. It can be mentioned that by the long-term loading it is necessary to calculate with the double value of instantaneous deflection.

The final deflection can be obtained according to formula (1), mentioned in the standard STN EN 1995-1-1,where the instantaneous value is multiplied by the factor k_{def} increased by number 1. The factor k_{def} is dependent on material and on the surrounding conditions. The experimentation took place in an industrial hall without the possibility of heating. For such a conditions the k_{def}=0.8 can be assumed. Substituting the appropriate k_{def} to the formula (1) the final deflection 27.2mm can be obtained. The real measured value is smaller in comparison to the expected, so it can be mentioned that the measured deflection are fulfilling the valid standard. Simply to say, the expected final deflection can be approximately double value of its instantaneous.

$$f_{fin} = f_{inst}\,(1+k_{def}) \qquad (1)$$

, where f_{fin} is the final deflection,
f_{inst} is the instantaneous deflection,
k_{def} is the deformation factor.

The trusses had been lightened two times during the course of long-term test. After 72 days of loading, than at the end phase of experimentation. The slow backward deformation and the value of permanent, irreversible deflection had been measured. Because the total load decreasing was not possible, the deflection values for the case of total lightening were calculated proportionally (Tab.1).

Tab. 1: Characteristic deflection values

Date	Deflection	Truss A [mm]	Truss B [mm]	Average [mm]
18.7.2012	Instantaneous	15,0	15,2	15,1
28.9.2012	After 72 days	22,1	21,7	21,9
	Creep deflection after 72 days			**6,8**
28.9.2012	Immediately after load decreasing	16,8	16,1	16,5
12.10.2012	13 days after load decreasing	15,8	15,2	15,5
	Delayed elastic deformation			**1,0**
	Calculated deflection in case of total lightening			**8,8**
12.10.2012	Instantaneous after second loading	21,4	21,4	21,4
5.9.2013	329 days after second loading	25,8	26,6	26,2
5.9. 2013	Instantaneous after load decreasing	20,4	20,9	20,6
	Calculated deflection in case of total lightening			**13,0**

It was found out that the value of backward deflection is dependent on the time of loading. While after 72 days the elastic deformation was about 60% of the total deflection, after 414 days it was only 50%. It can be mentioned that the elastic deformation decreases with the time of loading. The plastic irreversible deformation is increasing at the same time.

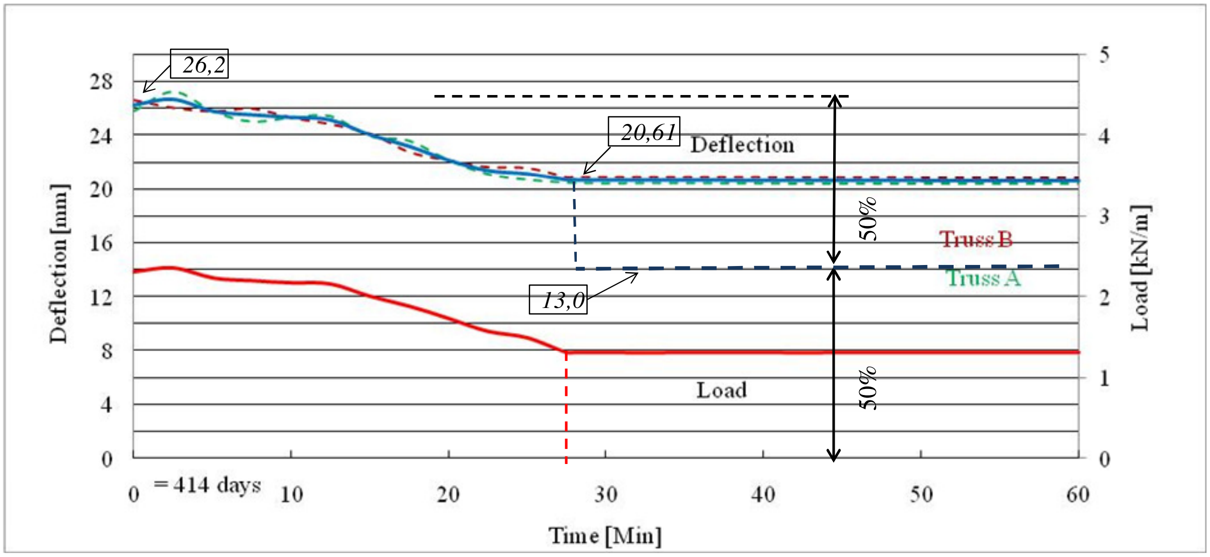

Figure 4: The course of second load decreasing.

In the last phase the trusses were being loaded subsequently up to their break. The aim was to investigate, how the long-term loading can influence the resistance of trusses. Despite of previous long-term loading the modified trusses had about 26% higher resistance than it was by the first short-term tests. The trusses were designed for the total load 2,6kN/m. The first samples broke by the level 3,8kN/m, but the next trusses were destroyed by 4,7kN/m.

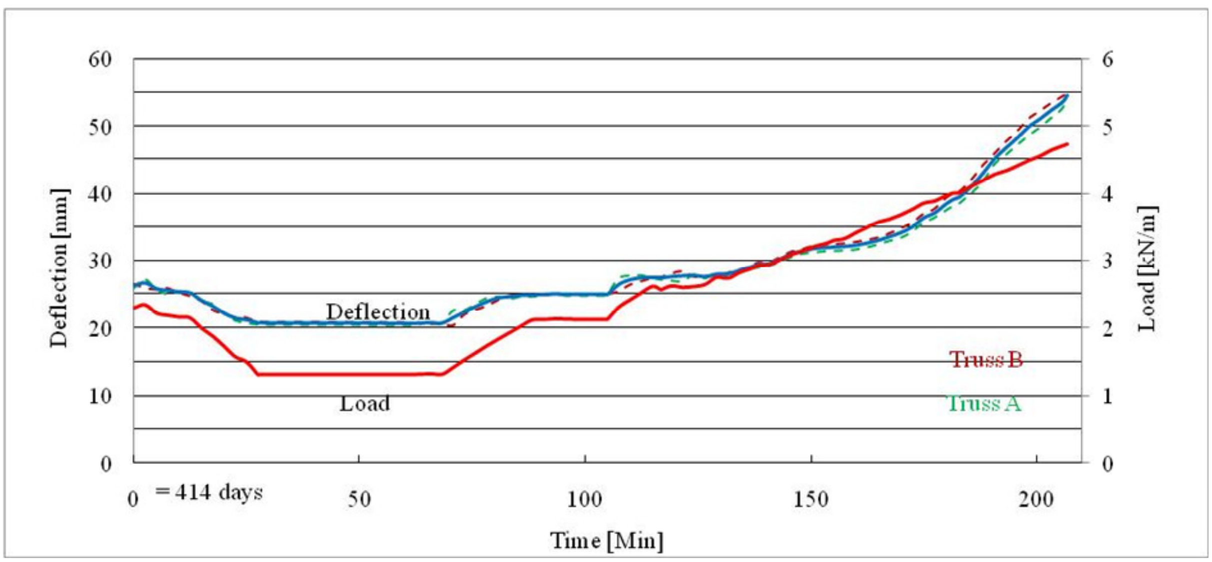

Figure 5: The course of final loading.

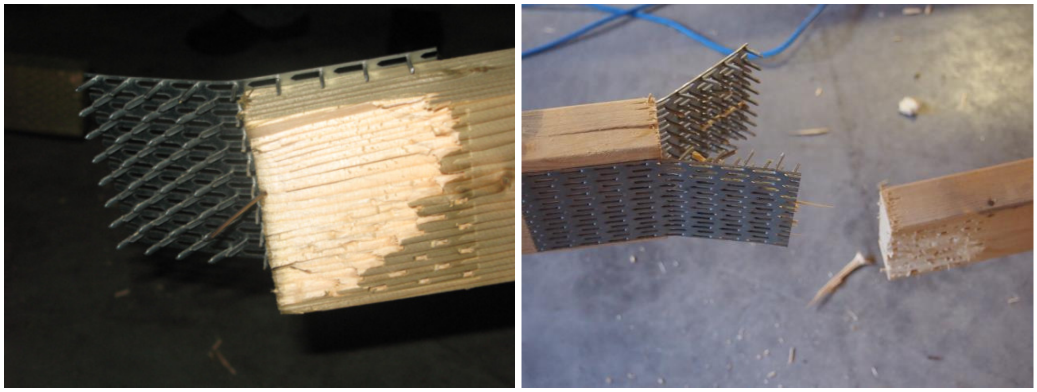

Figure 6: Damage of lower flange joint by original truss made of non sorted timber (left) and by new truss made of sorted timber.

Figure 6 illustrates the typical breaks of original trusses made of unsorted timber and the characteristic damage of new trusses made of sorted timber. On the ground of damage characters it can be demonstrated that critical member is no longer the wood, but the steel nail plate. The safety of metal plate connected timber trusses could be higher by thicker steel nail plates. That can be the task of next research project.

4. Conclusion

The paper deals with the unique experimental research of metal plate connected wood trusses subjected to long-term loading. The experimental investigation confirmed the safety of metal nail plate connected wood trusses also by long-term loading. But the results show marked values of additional deformations, which are corresponding to the valid standard for the design of timber load-bearing structures. On the other hand it seems not enough to consider only the elastic deformations by the structural design, seeing that the final deflection can be approximately two times higher after long-term loading. The irreversible, plastic deformation has a significant value and their values are dependent on the time of loading. This represents about 50% of total deflection after 414 days of constant loading. Fortunately the truss structure is not sensitive to deflections. The final deflection was satisfying the criteria of valid standard for the serviceability limit state. But the additional deflection can influence the entirety lower ceilings or the slope of flat roofs.

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