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RESULTS OF RHEOLOGICAL TEST ON TIMBER TRUSSES

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ABSTRACT

In the paper the results of exceptional experimentation are presented, 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. In the paper the 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: Rheology, long-term loading, creep, experimental investigation, nail plate, timber truss.

INTRODUCTION

The elements of investigated trusses are connected by steel nail-plates, creating a semi-rigid connection. The trusses are often 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. The mentioned connectors are used in composite timber-concrete ceiling structures too (Agel and Lokaj 2014), where the ratio of permanent load could be higher and also the development of additional deformations significant.

Since a lot of software does not take the additional deformations into consideration (caused by the deformations of joints and the creep behaviour 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. Results show that monitoring of modern timber structures can give important design information and contribute to create a database that can be used for future design optimisation (Fink and Kohler 2011).

At the end of experimentation the degree of permanent deformations and by additional loading subsequently the resistance of trusses had been investigated. The investigation was based on experiences of domestic (Kanócz and Bajzecerová 2014) and foreign institutions (Callahan 1994).

MATERIAL AND METHODS

On the ground of earlier examinations, focused on the short-term resistance (Sandanus et al. 2011), 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 (C24) and the cross sections exact dimensions. This caused also modifications in the dimensions of cross sections – the original trusses had widths 50 mm and the trusses made of KVH timber have width 45 mm. 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. 1).

The span and height of trusses had been remained, in order to have comparable results of short and long-term test.

Fig. 1: Investigated samples and platform with containers at the top of trusses.

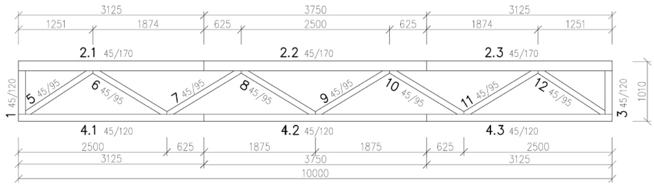

Fig. 2: Geometry of investigated samples.

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 50/140 mm with axial distance 600 mm, laths 50/40 mm a 500 mm and finally OSB board 12 mm thick (Fig. 3).

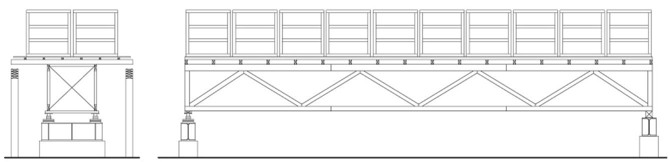

Fig. 3: Geometry of investigated trusses with the loading platform and safety supports on sides.

The loading process followed the rules mentioned in the standard STN EN 380 (1998). 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.

RESULTS

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

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.

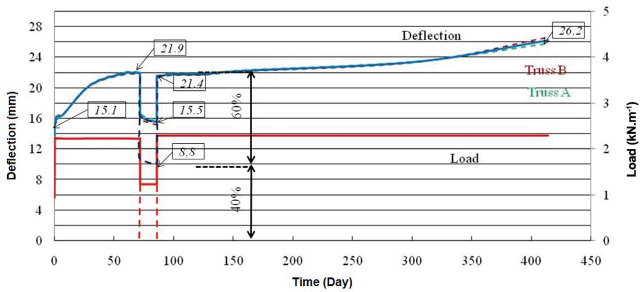

Fig. 4: The course of creep.

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 26.2 mm 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 Eq. 1, mentioned in the standard STN EN 1995-1-1 (2008), 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 Eq. 1 the final deflection 27.2 mm 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.

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

where: f_{fin} - the final deflection,
f_{inst} - the instantaneous deflection,
k_{def} - 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).

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.

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**

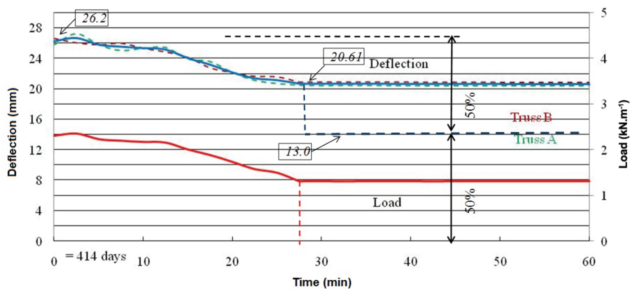

Fig. 5: The course of second load decreasing.

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 2.6 kN.m^{-1}. The first samples broke by the level 3.8 kN.m^{-1}, but the next trusses were destroyed by 4.7 kN.m^{-1}.

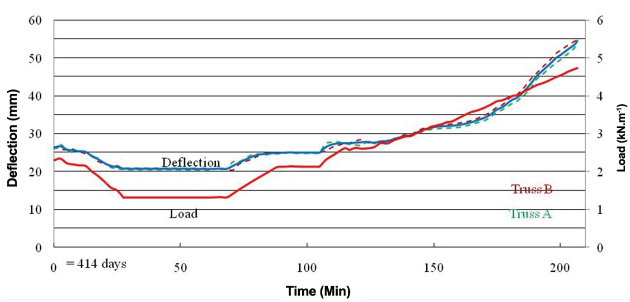

Fig. 6: The course of final loading.

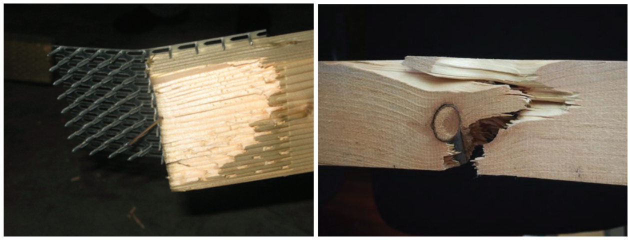

Fig. 7: Damage of original samples made of non sorted timber.

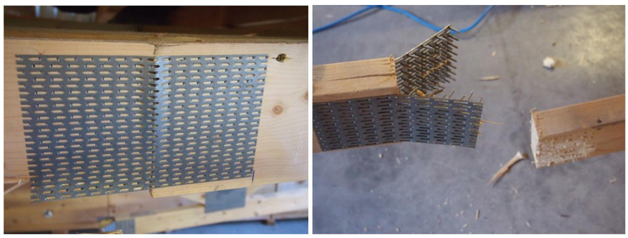

Fig. 8: Damage of upper and lower flange of new trusses made of sorted timbe.r

Fig. 7 illustrates the typical breaks of original trusses made of unsorted timber and Fig. 8 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.

DISCUSSION

The valid standard STN EN 1995-1-1 (2008) has a rule for calculation of final deflection, where the instantaneous deflection is multiplied by the factor k_{def} increased by number 1. The deformation factor for the given surrounding condition can be taken as 0.8. Thereafter the expected final deflection can be 1.8 times its instantaneous value. In the listed examination the maximum achieved deflection was 26.2 mm, which is of 1.73 times the initial deflection. The obtained results have been determined for the observation time 414 days. It is likely that the additional deflection is going to increase its value over time. This can result in increasing the value of deformation factor and it can exceed the value 1.8. Other researchers had also observed higher deflections of timber structural elements than listed in the standards (Moorkamp 2002). The larger creep coefficients compared to the rules in standards was confirmed by older (Rautenstrauch 1989) and also newer (Schänzlin 2010) studies in Germany.

The real deflection at the end of observed period represents the 1/380 of span. Just before the collapse the span – deflection ratio achieved the value 180, which is on the edge of valid standard`s criterion.

The obtained results were in good compliance to earlier examinations in metal plate connected wood trusses too (Callahan 1994), where the total deflection was of 2.5 times the initial deflection after 10 years of loading. The total deflection was related to the rigidity of the joints. Most of the creep occurred during the first stages of loading. The deflection values were still at an acceptable level, satisfying the criterion for span divided by 360.

After long-term loading no appreciable effect upon strength had been observed. The resistances of trusses were 1.5 up to 1.8-times the designed level.

Further evaluation is going to deal with the comparison of the measured values according to rheological models and prediction of the long-term deformations for the period of 50 years (Torati 1992). In the first phase of loading most of the rheological models can show a good correlation with the measured values (Leivo 1991). Differences in models are expected by prediction for the period of 50 years (Schänzlin 2010).

CONCLUSIONS

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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