Some problems of timber structures solved by forensic control

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Summary

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1 Introduction

The civil engineering practice of today is using highly sophisticated computer programs modern technologies very details codes and rules. In spite of these modern tools in every part of word collapses of structures and malfunctions of structures or their parts occur. Some of these problems have reasons in unpredicted climatic effects, extraordinary loadings or phenomena as are tsunami, hurricanes, earthquake, flooding etc. Mankind is proudly thinking that can take care about all of these natural problems but more skeptical people doubt about it. If we exclude these very extraordinary situations leading to very extreme loadings, still we have enough troubles within everyday design. The reasons for problems have roots in the bad knowledge of codes, bad design usually bad design of joints and connections, errors in technology, in the lack of time for the design, too much architecture with not enough respect to the simple static laws etc. Some examples from the forensic work for jury or insurance companies at the following chapters shows some serious mistakes and errors and trying to give explanations for these problems. Five examples of problems of timber structures from last years are shown. It's fair to say that similar list of problems could be given also for steel and reinforced concrete structures.

2 Some examples of errors of timber structures

2.1 Collapse of laminated timber roof after several years of the performance

2.1.1 Short description of the structure and the problem

The swimming pool of the collage was covered by the half-truss timber roof of the span about 12 m made from laminated wood (Fig.1). About 5 roof beams was forming the roof and laminated purlins for the span about 4 m between the beams. The system of hydro and heat inzulation with ventilation was used. The history of the roof structure started 1992 when the structure of the collage swimming pool was planned and partially designed. The company that produced in this year laminated timber prepared all the purlins and beams. In the same time the companies had economical problems that had roots at political changes in the country and change her status and all the economical and also technical conditions. Due to this changes and troubles with changed laws the members were stored somewhere for about 4 years until 1996. The erection of the roof was done at 1997 and the swimming for the students and also for the public started in same year. After three years of performance was observed by teachers the deflection of several roof beams and they were afraid of the collapse (Fig.2). There was no snow at this time and the outside temperature was mild about

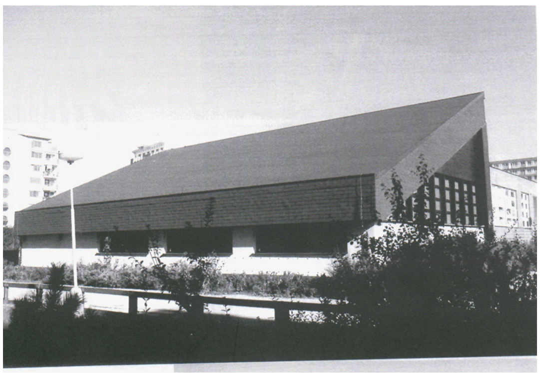

Fig.1 Laminated roof, span 12m over the swimming collage pool

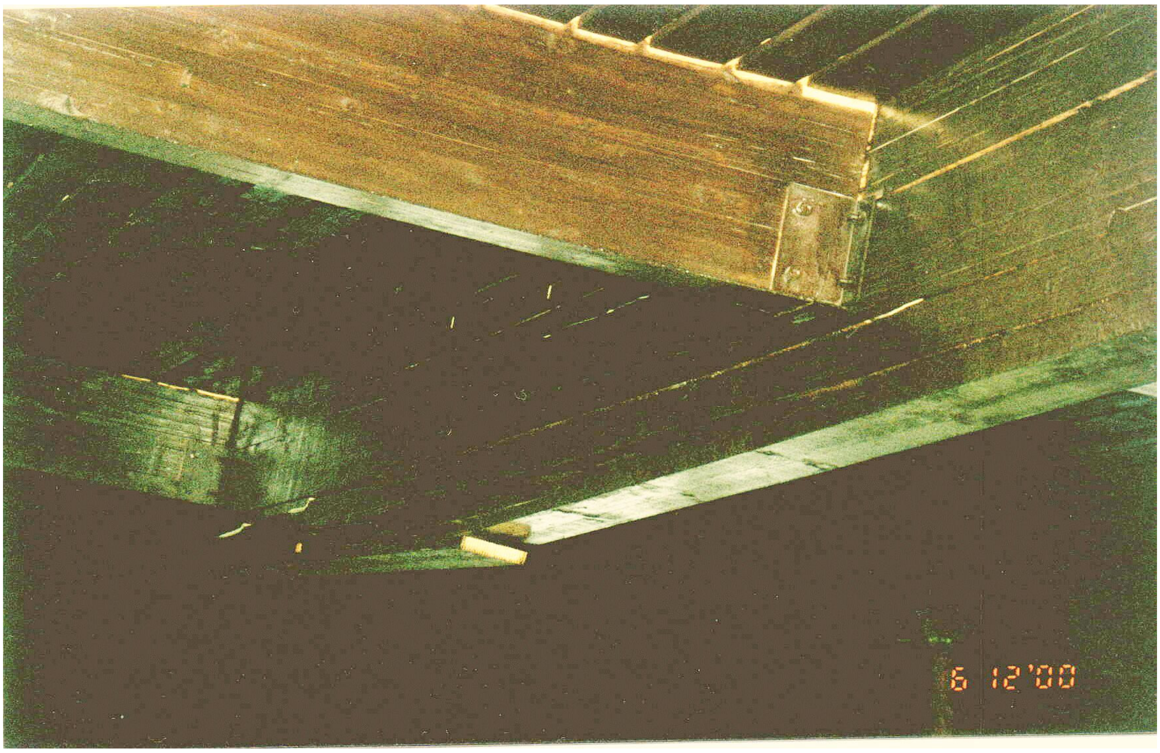

Fig.2 Delaminated roof beam and purlins

12 ^{0} C. The pool was immediately closed after the first visit on 6th December 2000. There was necessity to support the roof as the deflection grows very progressively within several days. On the sides of purlins and beams that were dark brown painted were visible light cracks between lamellas. Lower lamellas on two beams were separated from the beam and also shear crack at the support occurred.

2.1.2 Security steps, temporary and definite solution

The company with the background of workers and technology was chosen by forensic engineer as the situation was very critical and the security work started two days after the first check. The swimming pool was made from steel composed with inner concrete layer. The water from the pool was realized out of the pool. The carrying capacity and also the possibility of local loading were checked and temporary steel supports were used. The purlins in vicinity of cracked beams were fully supported on steel thin supporting columns to ensure maximum unloading of the roof beams (Fig.3). Within a week after that the steel truss support for the roof beams were prepared and installed. The hydraulic jacks and measuring of force was used for the assembly. The reaction of these trusses was transferred to the reinforced concrete columns of the building (Fig.4, Fig.5). The usage of the pool allowed for 6 months for the public. The admission charge to the pool was the important source of the school therefore the pool should work.

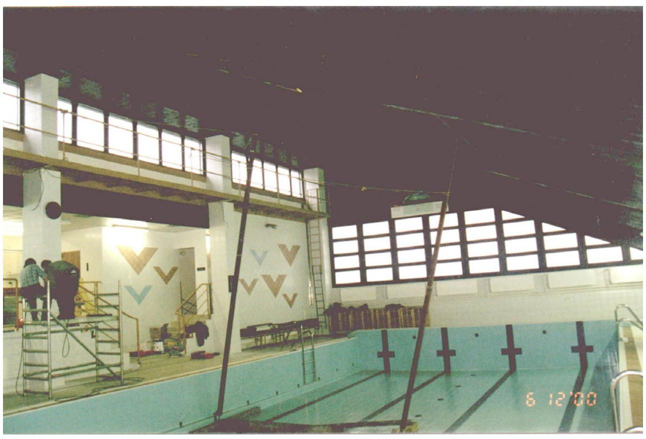

Fig.3 Temporary supports of purlins

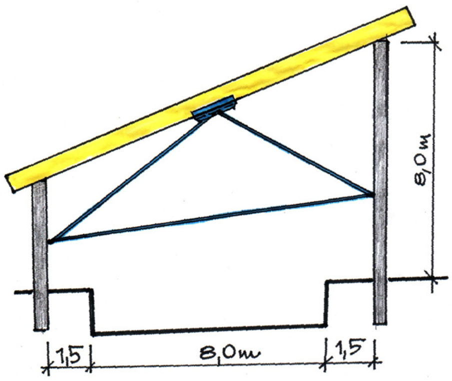

Fig.4 The steel truss support

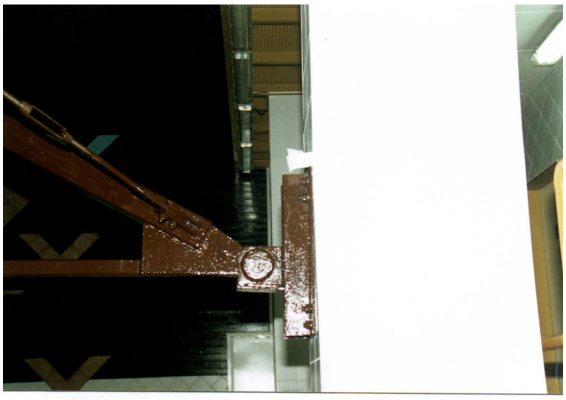

Fig.5 The hinge of supporting truss

2.1.3 Reasons for the collapse and the final solution

Within the preparation of the final strengthening of the structure the thorough check of the history of timber was done up to the technology of the production. From the diary of gluing (that was fortunately found in the rests of documentation of the original producer of timber) were found disproportional times for pressures applied on glued timber. Time was varying from 3 hours to 72 hours. Also from the look of disassembled lamellas was possible to recognise the concentrated parts of polymer as small spheres. Not good uniform layer of glue was provided. Therefore the reason for

Fig.6 The built up truss strenghening system

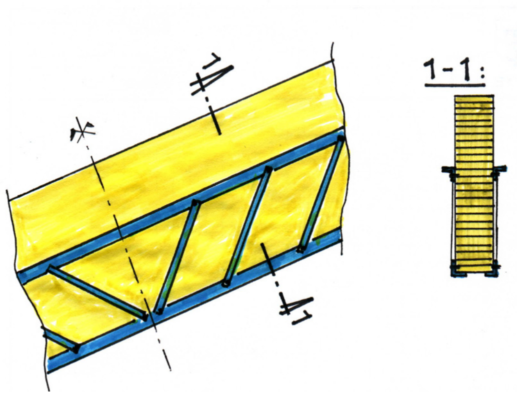

Fig. 7 Scheme of the built up truss strengthening system

the problem was in the bad technology of gluing, probably too much of glue prepared and earlier polymerisation occurred. As the final solution the built up system composed from steel chords and diagonals connected to the timber beams by glued-in rods was designed. Purlins were routed and the plywood splices were glued to the sides (Fig. 6, Fig.7).

2.2 The collapse of the three-hinge laminated timber roof under the snow 2006

2.2.1 Short description of the structure and the problem

Saddle roof with three hinges and tied steel rod for the span 30m over the cotton textile factory hall was designed 1972. The beams about 1200 mm high and 120 mm wide were made from laminated timber. After the snow fall 2005 the large deflection of the ceiling in the hall occurred (Fig.8). Several beams were bended with large deflection, some cracks of lamella and lamella delaminating occurred (Fig.9, Fig.10). The workers realized the deflections and cracks at the ceiling in the late summer 2005, nobody was up to this date at the under roof space (Fig.9) to observe critical situation of the roof truss. The owners start to také care about the insurance, but didnot realise seriousity of the problem. Long administrative procedures caused that the forensic start at the January 2006. In that time was very snowy winter after several years of the mild weather.

Fig.8 The broken ceiling, the ceiling hanger broke the aluminium sheet

Fig.9 The deflected beam, rapture of lamellas, shear cracks

In the mid part at the assumed joint the cracks of timber was noticed. After the first check was realized not only the cracks at the mid points of beams, but also in the middle of three-hinge truss at the place of assumed hinge (Fig.10, Fig.11). The steel plates on both sides of the beams were about 500 mm high and 8 mm thick, about 9 bolts were transferring assumed shear force.

2.2.2 Security steps, temporary and definite solution

The documentation more than 30 years old was incomplete. Analysis was missing. Technical report that was available, was describing three hinges type of the structure with tie rod on that was ceiling hanged. The analysis was done about 1970 without computer program. The three hinge structure with the tie rod was relatively easy to analyze, but probably the effect of shear and normal forces

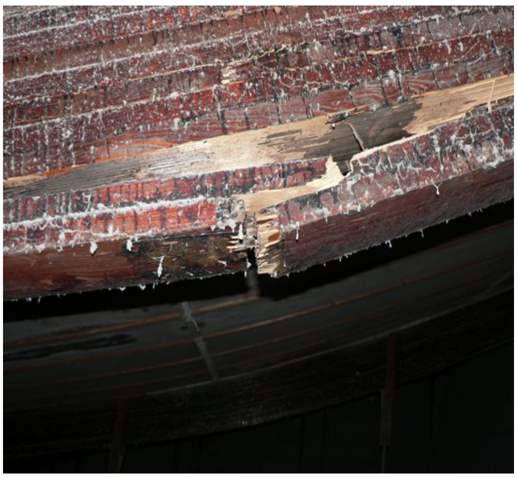

Fig.10 Cracked lamella, not correct layer of the glue

Fig.11 Assumed hinge in the middle of the roof frame, cracks on compressed heads of beams

was not taken into the account. The computer analysis with all the effect on several different models was performed within the forensic check. The snow situation at 2006 was assumed by public that caused a lot of collapses of roofs (there was about 200 failed roofs mentioned at news). Therefore the detail report for last 30 years from meteorological authorities was asked. This report shows far more bugger layers of snow earlier the building was erected (up to the height 1,5 m). The water value of the snow at the winter 2005 was bigger than the code recommendation. In the mean time new strong fall of snow was continuing several weeks. The snow from the roof was with the special safety arrangement taken off and the machinery equipment was moved out of the factory.

2.2.3 Reasons for the collapse and the final solution

Detailed analysis shown that the structure that was by the designer assumed to have hinge in the middle of the roof saddle, was cleverer than the designer. The detail with robust metal sheets and set of bolts was acting together with the contact compression forces on the top of beams as almost

Fig.12 Final situation of beams before total collapse

Fig.13 Destroyed roof after the fall down

rigid connection. The stresses at the compression were on the edge of the strength of the timber at each heavy snow loading. This caused continuing cracking in the saddle of the roof and introducing softening of the contact that became finally the hinge. The dimensions of beam were not enough to carry proposed and real loading by the heavy snow after that and the cracking at the saddle and at the mid spans of beams were rapidly continuing. Because of the situation of other structural parts and highly difficult possibility of the repair of the timber trusses, the decision was to get structure down and to design and erect new system. Due to the continuing heavy snow fall the collapse was continuing and finally the structure fall down (Fig.12, Fig.13).

As the conclusion can be said that the main structural detail was wrongly design, the analysis was not so detail, the safety factor in the time were different from today factors and the maintenance of the structure was also not so good.

2.3 Sudden deflection of the timber roof over the room at dwelling house

2.3.1 Short description of the structure and the problem

Private owner of family house added additional room attached to the three stories family house. The house was made from bricks, the additional room was made from bricks also and the roof was designed from the wood. The structure of the roof was quiet simple with very small down slope. The structural members were cutter timber beams with the distance about 1m and the span about 4 m. The roof cladding was made from timber boards. On boards were several layers of bituminous strip insulation and the gravel layer as final cover. The heat insulation was made from mineral foam between beams. The space of the ceiling was not ventilated. The building was fully heated in the winter time.

After three years of performance large deflection of the ceiling was observed. There was the discussion on the quality of the timber used, or the load by the gravel layer etc.The owner opened the ceiling and found several beams broken and in between them was the sponge bed (Fig.14, Fig.15).

Fig.14 Broken timber beam because of the biological corrossion

Fig.15 Timber roof system destryed by the sponge collony

2.3.2 Reasons for the collapse and the final solution

The leakage of the insulation caused the enormous increase of moisture and rapid grow of fungus started. The funge was identified to be the Trametes ~Antrodia serialis Row Polypore, that needs for the developping 40% až 130% of moistness !! and the temperature from 3 ^{0}C až 37^{0}C, and pH 6. The organisms had excellent conditions for the life, receiving fresh water every rain and snow. The growing deflections in the middle of beams help to find the reason for the problem and ask for the responsibility the contractor. After the rain the small pond on the roof was visible and drops of the water in the deflected part.

Final solution was to change complete roof and design the new system that was chosen by owner to steel and concrete slabs. The real reason was bad technology and quality of the insulation.

2.4 Timber roof structures for the shopping halls subjected to the snow fall 2006

2.4.1 Short description of the structures and the problem

The winter 2006 in Czech Republic was longest within 30 years. There was enough repeated snow

Fig.16 The system of additional bracing against the buckling of truss member out of plane

Fig.17 Additonal sytem of longitudinal global bracing that was not provided

falls with low temperatures and some changes of temperatures at the end of the winter in March and

Fig.18 Bad realization of gangnail connection – thin sheet and bad position of the gangnail

April. The snow amount was laying on the roof melted nad increased by the new snowfall. The weight of the snow could overcome in this way the reccomended value of snow load by code.

After several weeks at several regions fall down relatively big amount of roofs. These were not only the timber but also the steel structures. The TV news and radio emission reports were talking about the unusual amount of the snow that caused the collapses. It is known that about 200 roofs collapsed at Czech Republic. Some of collapsed roofs were roofs of shopping halls of shopping chains. The structures were usually made from gangnail connected trusses with slender members. The stability of members out of the plane was not satisfactory either by design or by the realization.

2.4.2 Reasons for the collapse and the final solution

The search for the collapses and reasons of it was invoked by the governmental offices and is now under the progress. Also the check and revision of the code was started. The euro code gives some different loading cases then the Czech code. The distribution of the snow should depend on the altitude not only on the region. In spite of these procedures some companies that owns shopping halls with large areas of relatively very flat roofs made check of their structures immediately. The shopping halls are usually build for relatively short period, not for hundreds years. The price and the speed of the erection is the most important point for the investor. After the check of several tens of shopping halls was found that the snow is usually not the real reason but just the impulse that is showing error in the structure. On the Fig.16 and Fig.17 and Fig.18 are shown the more often existing problems that was missing or weak bracing ofslim truss structures that were connected by gangnails.

The check of all these civic structures is important because of existing big riscs.

3 Discussion and conclusion

Several problems of some existing timber structures were shown. The problematic were old structures, medium old and new structures. The relatively large structures or the small family type of structure had also problems. The snow load was in several cases only the screening of the quality of the structure. These problems are occurring at all the countries and in all the times. We can memories several big collapses of civil engineer structures in this century already.
The timber is not the material that would have priority for collapses. Problems can be found at all types of structures when the reserves of structures or their part namely the connections are exceeded by the applied loading. We have very sophisticated codes and rules more voluminous then codes about 50 or 7o years ago. We have computer program that allows doing studies and checks very quickly. From the other hand the time pressure applied to the design engineers are very high and the time fro the check of computer input data and output is very short and no machine can usually do it only the static engineer.Effect of very ambicious architectural design can be also unconvinient sometimes.
The simple conclusion is that every work needs proper amount of the time and the check of the bearing structures has always to start with simple basic natural laws. These laws have to be always fullfilled. This is the equilibrium, space rigidity, compatibility and proper validity of material laws. After that we can apply more sophisticated rules from codes. The system of check is still not enough developped in genaral.

4 Acknowledgements

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