ABSTRACT: In Europe and elsewhere in the world, timber is being used for bigger and more ambitious structures. The engineer has to bear greater responsibilities in the design, supervision of construction and - lately increasingly – on the monitoring of the performance of the structure in use. The paper discusses new design requirements such as robustness and some important aspects of the supervision of the construction. Finally, the authors wish to share the experience the Bern University of Applied Sciences has made in the use of equipment to monitor sensitive structures in service.

KEYWORDS: Robustness, Construction, Checks, Monitoring

1 INTRODUCTION

Timber structures are growing in size. In Switzerland, timber is increasingly being used for new bridges and buildings, for building alterations or expansions. Higher, longer and greater stresses are the trends: 100m spans are becoming familiar. The exigencies on the structural analysis and on the construction work increase disproportionately. For maintenance purposes, sensitive structures should be regularly checked. The Bern University has made some headway in the monitoring of structures with the use of electronic equipment.

2 DESIGN FOR ROBUSTNESS

In addition to the classical design for the limit and service state, the engineer also needs to ensure that the structure should be robust and reliable for a long time.

A dictionary typically defines „robust“ as durable, strong, tough and stable. Structural engineers usually understand “robustness” as an aspect of the ultimate load design: the structure should not react disproportionately to a local failure [1]. According to Poetzl [2], structural robustness can be considered to be a comprehensive quality attribute. Hence this paper considers the two to be interconnected.

The classical recommendations for robustness in structures are: increase redundancy and ductility, avoid brittleness. Where ductile materials and structural systems are used, local overloading in statically indeterminate systems will not lead to total collapse. The timber truss bridge of Dietfurt in Germany is a good example. It was designed as a three-span continuous beam with a much larger central span. An inspection revealed that a joint over an intermediate support had failed. This local weakening had not led to collapse; the bridge was still in service. From the structural point of view, the loads had been redistributed and the structure was now a beam with an internal hinge.

In brittle continuous systems, however, local failure may have catastrophic effects. The fate of the Ice Sports Stadium of Bad Reichenhall, Germany, is bad publicity for timber [3]. The very stiff secondary beams were rigidly connected to the main beams. Local failure led to a chain reaction because it was not possible for that roof section to go down alone, so it dragged the rest down.

The authors recommend simplicity in design. Practical experience shows that those structures which are difficult to calculate and had intimidating drawing details are also often the ones which are difficult to construct with quality. Ultimately, such structures cannot be robust.

Robust structures should cost less to maintain. It is important to design so that the timber members and connections can be readily checked visually. Robustness can be enhanced by avoiding negative influences on the durability of the members with a very good constructive protection from the climate. Space should be provided around them so that they can dry in case they get wet. Building physics should be observed: a heat insulating layer placed outside a wall is preferable to one placed indoors: heat bridges can cool and wet sensitive members.

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3 BUILD WITH CHECKS AND CONTROLS

Highly stressed members of large structures should be built with quality products. Timber and steel nails, screws or bolts should be purchased from certified companies which continuously test their products according to internationally recognized quality management systems.

The members should be inspected periodically in the workshop to check the quality and dimensions. Detail checks include welding joints of steel connector plates. In addition to the control of the type of adhesive used, the engineer should occasionally also glance through the quality control entries of the producing company. In the case of highly stressed and new types of members, it may be advisable to include in the call for bids, the preparation of specimens for block shear or delamination tests.

In Switzerland, the VKF Swiss Fire Protection guidelines of 2003 [4] and the Lignum guidelines [5] have proved to be very useful for the quality management of multi-storey timber buildings. These guidelines may be expanded to cover other structural types as well.

4 MONITORING

With regard to existing buildings, the Swiss code SIA 269 [6] differentiates between service conservation measures (inspections and monitoring) and the technical checking of the structure by professionals (report on structural condition).

The inspection is done about once a year by the owner or his caretaker for obvious flaws or damage. The report includes entries for the important members with regard to deformations, cracks, moistness, discolouring or corrosion.

The technical checking of the structure is done by experienced professionals (engineer, technician or draughtsman) and has different stages. A general check covers the entire structure and is done every two to five years. If something unusual is observed, then a detailed check will be done by an experienced engineer.

It is possible to install measuring devices to monitor certain developments in the structure. In timber structures the climate and in particular the moisture content can be quite central. The monitors are quite economic and an early warning can help to save repair costs.

The Bern University of Applied Sciences has contracted to build monitoring systems on selected structures. One of the monitored structures is the timber bridge which was built in 2007 over the Ilfis River in the village of Odermatt, Canton Bern. In 2011, the monitor reported an increased timber moisture content in a timber member near the bridge transition at the abutment. An inspection revealed that a steel plate which was meant to deflect rain water away from the timber had not been bent properly. The flaw could be speedily repaired before real damage had been done to the timber member.

5 CONCLUSIONS

The success stories of timber for larger structures means a greater responsibility for the engineer. Apart from the classical design for limit and service states, the design has to take new developments such as robustness into account. The higher loading stresses in the members and connections mean that there is a greater need for a quality control of the materials and that the construction work also needs higher levels of control management. Modern electronic devices can be installed in critical points of the structure and thus help to monitor its condition and report suspicious readings. The Bern University of Applied Sciences is contributing to this new research area. The experience of the authors indicates that design, construction and structural maintenance are all intertwined and should be planned as a unit straight from the start.

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