Strengthening of wooden ceiling constructions

Strengthening of Wooden Ceiling Constructions

Renforcement de constructions avec des plafonds en bois

Verstärkung von Holzdeckenkonstruktionen

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SUMMARY

The loading capacity and the stiffness of wooden ceiling constructions in historical buildings is usually not sufficient for modern demands. A method for strengthening of such wooden ceilings is recommended by coupling the wooden beams with an additional reinforced-concrete slab over them. After this strengthening the loading capacity and the stiffness increases cca 4x.

RESUME

La limite de charge et la solidité de constructions avec des plafonds en bois, dans les bâtiments historiques, ne sont en général pas suffisantes pour les besoins modernes. Le rapport propose un procédé de couplage de poutres en bois avec une dalle en béton armé supplémentaire posée dessus. Par ce renforcement la limite de charge et la solidité est à peu près quadruplée.

ZUSAMMENFASSUNG

Die Tragfähigkeit und die Durchbiegungen von Holzdecken in historischen Gebäuden entsprechen heutzutage nicht den modernen Anforderungen. Eine neue Methode zur Verstärkung solcher Holzdecken durch Verbund der Holzbalken mit einer zusätzlich auf sie betonierten Betonplatte wird vorgestellt. Durch diese Verstärkung verbessert sich die Tragfähigkeit und die Durchbiegung um einen Faktor vier.

1. INTRODUCTION

Wooden ceilings in historical buildings have usually considerable elastic and permanent deflections, so that they are not sufficient for modern demands. A method for increasing the loading capacity and the stiffness of such ceilings is to change the wooden beams by other materials such as steel or reinforced-concrete constructions. It is a pitty that the wooden construction which served for several hundred years has to go lost. The change of ceiling construction is complicated and expensive.

In ČSSR we found a method for strengthening of such wooden ceilings by coupling the wooden beams with additional reinforced-concrete slab made over them. After this strengthening the loading capacity and the stiffness encreases cca 4 x .

2. TYPES OF WOODEN CEILING CONSTRUCTIONS

It is possible to strengthen several types of wooden ceilings. Fig. 1 and Fig. 2. Fig. 3 and 4.

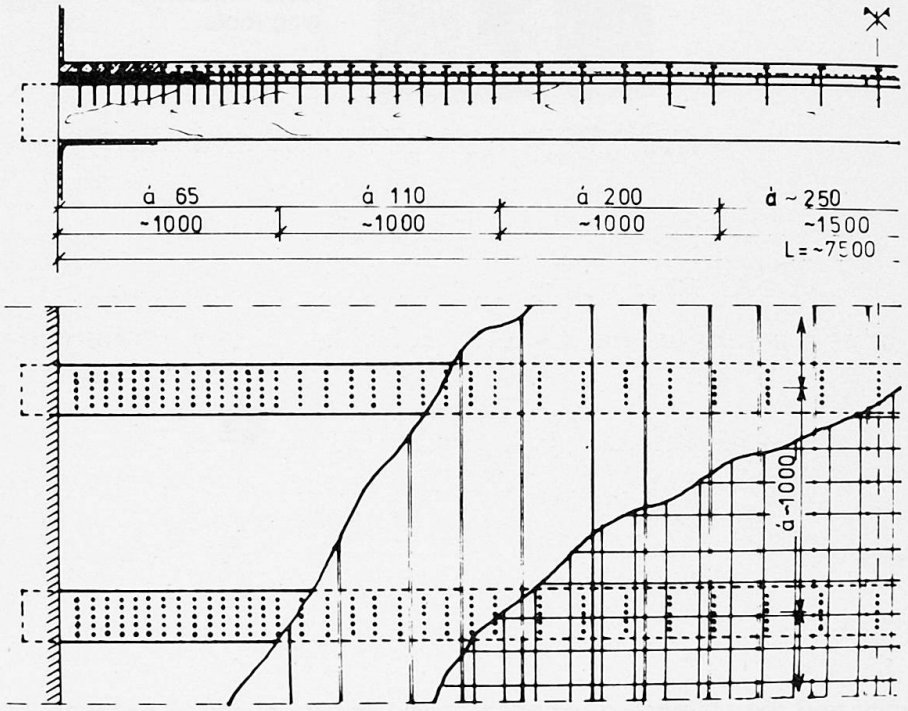

Fig. 1. Wooden beam ceiling construction with the beams in distances.

The figure 1 shows a wooden beam ceiling construction with the beams in distances of cca 1 m. Over the beams there is usually a wooden floor made of boards.

The figure 2 shows the cross section of such ceiling, after the strengthening.

In figure 3 are the wooden beams tightly together, and in figure 4 there is the same ceiling under strengthening operation. The surface of the old wooden ceiling gets coupling elements such as steel nails drived in distances fixed by statical analysis. The nails stick out of the surface cca 40 mm.

3. EXEMPLES OF STRENGTHENED BUILDINGS

The new strengthening method was used the first time for the restruction of a historical building "The good shepherd" in Bratislava, ČSSR in 1960. Since that time this house serves as a watch museum. Fig. 5.

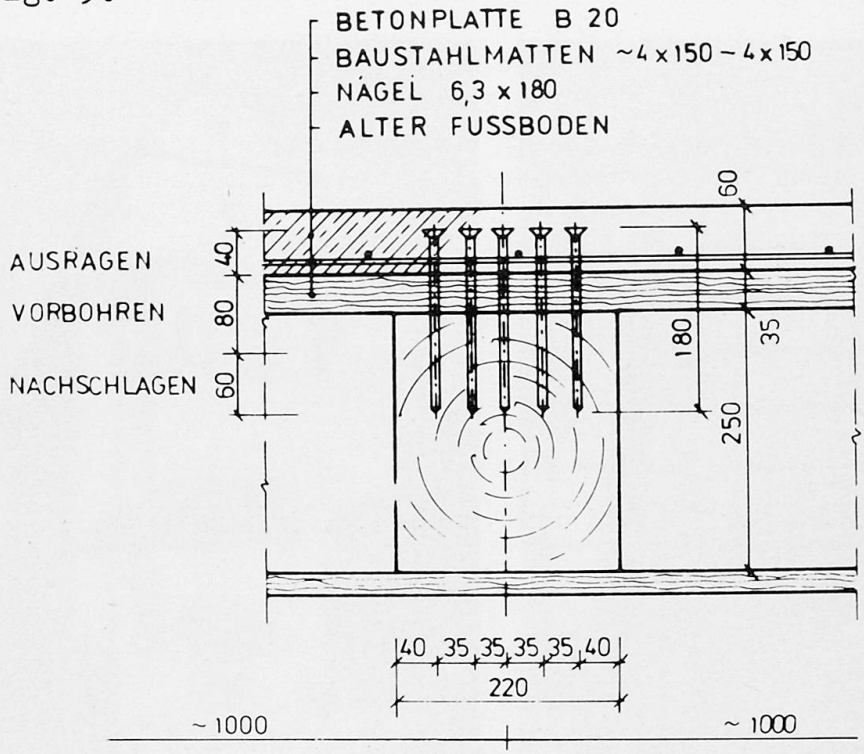

Fig. 2. The cross section of a beam ceiling after strengthening.

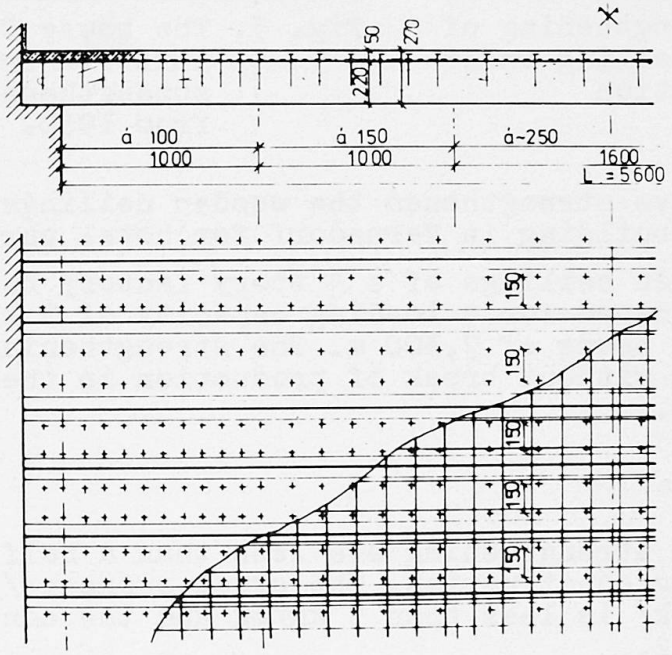

Fig. 3. The wooden beams tightly together - the ground plan.

An other wooden ceiling has been strengthened in 1965 fo the Slovak National Council in Bratislava. The loading capacity of the

old ceilings was not sufficient for assembly rooms with 5 kN/m2. The control measurements after the strengthening has shown that the stiffness and the loading capacity encreased cca 4 x.

Fig. 4. The strengthening of a wooden ceiling under construction

Fig. 5. The house "The GOOD SHEPHERD" in Bratislava with strengthened ceilings from 1960.

In 1968-69 we have strengthened the wooden ceilings of an old 4 story factory building in Varnsdorf for hotel purposes.

In 1972 the wooden ceilings of a 4 story factory building in Krnov were strengthened for a loading capacity of 5 kN/m2 and for a span of wooden beams of 7,300 m. The strengthening was made as a winter work without break of production in the other romms of this building.

4. ECONOMY

The costs of the strengthening are less than a half of the costs for a new ceiling construction. The steel economy /the nails and the steel network/ is less than 5 kg/m2 and the concrete economy is cca 0,06 m3/m2.

In addition to the strengthening we can book an other advantage in the increased protection of the wooden ceiling against fire from the upper surface of the floor.

5. THE STRENGTHENING METHOD

After cleaning of the ceiling surface and after the chemical protection of wood by penetration it is necessary to rough drill the holes for the nails in the upper surface of the wooden ceiling. The depth of the holes has to be more than a half lenght of the nails drived in.

For the rough drilling we use a drilling template made of a thin perforated steel sheet. Fig. 6. The perforation of the template is made in distances ordered by the statical analysis.

Fig. 6. Rough drilling with a drilling template

The nails are drived in by an electric percussion drill with a special inserted tool head in order to let the nails stick out of the surface with 40 mm. Fig. 4. Over the nails we lay down the wire net and the concrete slab can be made.

6. THE LOADING TESTS RESULTS

In order to control the loading capacity and the stiffness of the strengthened wooden ceiling in Krnov there was made a loading test with following results:

The span of the wooden ceiling ..... L = 7,300 m
The calculated load ..... q = 5,00 kN/m2
The maximum testing load ..... q' = 5,69 kN/m2
The tested deflection at q' = 5,69 kN/m2 ..... f' = 18 mm
" " " " q = 5,00 kN/m2 ..... f = 16 mm

$$f = 16 \text{ mm} = \frac{1}{455} L < \frac{1}{350} L$$

The calculated deflection of the wooden beams .. f" = 97 mm !

The stiffnes increased to ..... $n = 97 : 16 = 6{,}1$ x

The permanent deflection after the loading test $f_p = 2$ mm

7. THE LOADING TEST OF THE COUPLING EFFECT

In order to control the coupling effect between wood, nails and concrete slab we have made an other loading test. Fig. 7. The results of this test are in fig. 8 and the deformation of the nails can be seen on fig. 9.

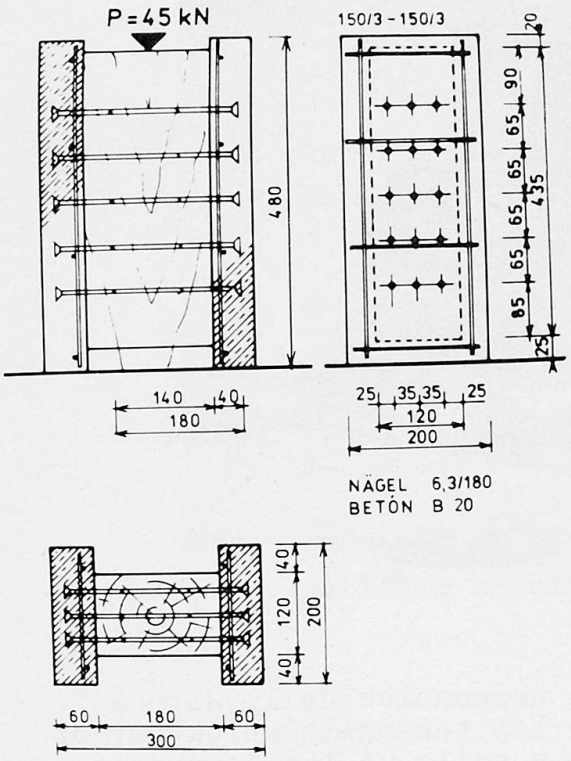

Fig. 7. The testing element for the coupling test

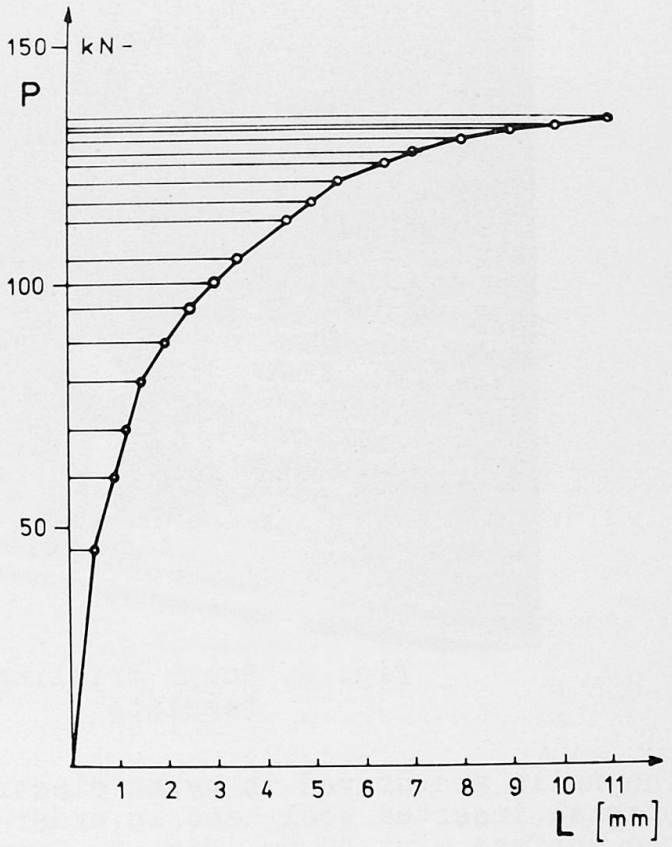

Fig. 8. The results of the coupling test

The calculated testing load of the testing element ... P = 45 kN
The deformation between wood and concrete slab ..... $\Delta L = 0{,}5$ mm
The collapse load ..... $P_{col} = 140$ kN
The safety against collapse : n = 140 : 45 ≐ 3,12 x

8. SAVING OF DAMAGED WOODEN BEAM PARTS

The possibility to help to damaged beam headings is shown in figure 10.

The rotten beams or the rotten parts of them are to be changed by new wood, after chemical conservation of the healthy parts of the wooden ceiling.

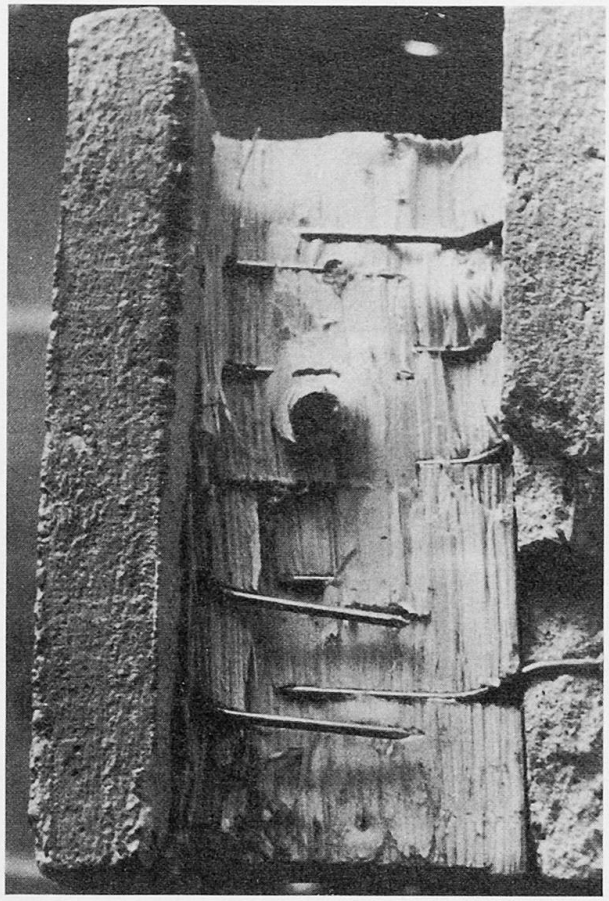

Fig. 9. Deformation of the nails after collapse

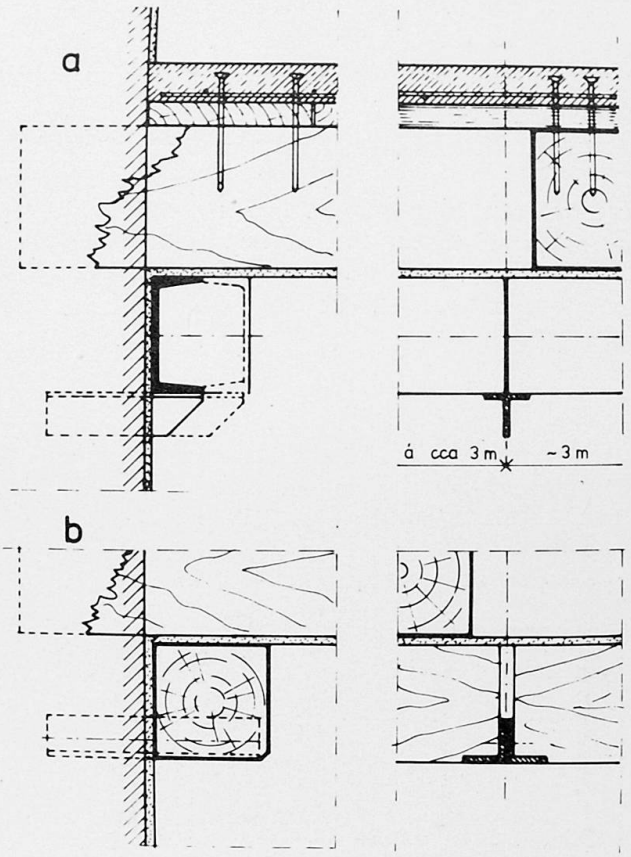

Fig. 10. Saving of damaged beam headings

9. CONCLUSION

There are many historical buildings in the world with wooden ceilings which are to be strengthened. The 23 years experience with our method of strengthening of such ceilings shows that it is a very usefull and economical method. The costs of the strengthening are less than the half of the costs of new ceiling constructions.

This method can be used for new wooden ceilings too.

We can offer our know-how to all people interested in such strengthening.

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