

ANALYSIS OF THE STRUCTURAL STATE OF REPAIR, PRESERVATION AND REPAIR OF HISTORIC TIMBER LOADBEARING STRUCTURES

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The preservation and maintenance of historic buildings and structures is taking on ever increasing significance.

This necessitates a complex consideration. Within the scope of a well-bottomed analysis of the structural state of repair, first of all the repair shall be judged and information in terms of statements as to the structural stability and loadbearing capacity of the constructions shall be provided which requires special knowledge with regard to the actual strength of the timber and the historical principles for the structural design and system of the constructions and connections.

One of the most difficult problems surely concerns the determination of reliable initial data for the design and calculation of the construction including the connections.

Within the last years, many studies and investigations concerning the strength of old structural timber and concerning the loadbearing capacity of historical connections have been performed.

### INTRODUCTION

In the territory of the ex-GDR, a lot of constructional types of timber loadbearing structures are available as loadbearing compound units and members in residential, industrial, agricultural or municipal buildings and structures, e.g. as intermediate floor, as roof loadbearing member, as loadbearing skeleton with about 1 million framework buildings and structures or as hall roof frame in industrial buildings and structures.

From the point of view of a careful urban redevelopment and of scarce funds for investments, but also from ecological considerations, the maintenance and preservation of the available stock of buildings and structures should always be studied and considered with care (see the examples of structural damages at residential buildings as shown in Figures 1 and 2).

The examination of the worthiness of buildings and structures in terms of their preservation or maintenance implies a well-bottomed analysis of the structural state of repair preferably at the stage of preliminary planning, if possible.

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EXAMINATION OF THE WORTHINESS IN TERMS OF MAINTENANCE AND REPAIR

Within the scope of the analysis of the structural state of repair, the essential structural damages and the extent and causes of the damages concerned are being determined and ways for an elimination (i.e. repair) of the damages are being established. This is being effected by adopting a methodology which has been scientifically elaborated in the ex-GDR and was being tested in practice since the early 80s and continuously improved and further developed. In the main, said methodology defines 4 working steps or stages of activities as follows (see Figure 3):

- Registration of the structural state of repair
- Determination of the causes of damage
- Evaluation of the structural state of repair
- Definition of construction-engineering measures and activities

Registration of the structural state of repair

Within the scope of the registration of the structural state of repair, the outward physical condition of the timber loadbearing structure concerned is being studied and investigated by adopting well-known and newly developed diagnostic methods and procedures. The simplest approach in terms of this is the visual examination after uncovering the structural components or members concerned.

As a result of this first stage of activities (working step), the technical and structural characteristics and special features (particularities) of the construction concerned, the conditions of utilization of the loadbearing structure, the type, character (appearance) and the extent of damage are being determined and recorded. The stock documentation is being completed or newly prepared, respectively.

The history of the buildings and structures concerned in terms of their construction and utilization is being clarified as completely as possible which includes a construction-historical evaluation as well.

Determination of the causes of damage

Based on the above-mentioned information and data, during the second stage of activities the causes of the occurring failures and damages are being analysed. Their character and their time-related development are being studied and considered in connection with the building chronicle; as a result, their further development is being prognosticated. This estimation contributes to the preparation of static-structural measures and activities in connection with necessary repair work which will ensure the planned residual service life or the durable rehabilitation and maintenance of the loadbearing structures concerned, respectively. By means of a purposeful and subject-minded deduction of measures and activities for a modification of the conditions of utilization, the further development of the damages or their re-appearance after the completion of repair work will be prevented.

Evaluation of the structural state of repair

The third working step or stage of activities includes the evaluation of the structural state of repair based on the mechanical characteristics and parameters of the built-in timber as determined in situ by testing old timber specimens and by taking into consideration the checks and verifications of the loadbearing capacity and usability of the construction concerned as performed on the above-mentioned basis. When estimating the loadbearing capacity and structural stability of an old timber structure, one cannot just revert simply to the applicable design standard specifications since this system of rules and regulations is representing the current level of the building rules for the planning and erection of new constructions and structures.

For the most part, the problems and concerns connected with old timber structures have not been taken into account. This applies first of all to statements and data concerning the reduction of cross-section and stress reduction of the timber due to permanent load, cracks, temperature, biological damages or corrosion of the timber. Historical construction principles or timber fasteners are not included.

The application of the design strengths of the standard specification for new constructions is adapted to a modern system of the classification of the timber in terms of quality and strength which, however, is about 60 years old only.

Thus, the expert or planner of the loadbearing structure needs reliable data (statements) concerning

- 1) the deformations and changes of position,
- 2) the actual strengths of the materials concerned,
- 3) the loadbearing capacity of the connections,
- 4) the modulus of elasticity and shear modulus  $G$ ,
- 5) the moisture of timber,
- 6) the bulk density (apparent specific gravity),
- 7) the essential damages endangering the strength or structural stability.

With a view to determining such characteristics and parameters, test and measuring methods are being applied which will provide reliable data and statements on the very spot, if possible, i.e. in situ.

Figure 4 illustrates the ratio of the bending strength to the modulus of elasticity in bending according to fundamental studies and investigations performed with old timber beams.

The judgement of historical connections raises some difficulties. In this case, the application of X-ray technology and equipment can be very helpful, as shown in Figure 5.

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As a result of this stage of activities, the construction concerned is being classified into one of the grades 1 to 4 of the structural state of repair and the residual loadbearing capacity of the construction concerned is being determined considering the physical condition. Based on a comparison of this parameter with the stresses and strains which the loadbearing structure will be subjected to in future, the necessary technical and structural measures and activities concerning the repair work can be deduced (see the examples as shown in the Figures 6 and 7).

### Definition of construction-engineering measures and activities

The fourth and final stage (working step) within the scope of the scientific methodology comprises the definition of efficient repair measures and activities on the basis and by means of studies and investigations of variants. On the one hand, they must be orientated towards the complete restoration or possibly an increase of the load-carrying capacity and functional safety of the constructions concerned whereas, on the other hand, solutions must be prepared and provided which correspond to the specific character and to the installation conditions of the constructions concerned.

With regard to monuments being valuable in terms of socio-historical aspects, the preservation of the old constructional system and of the traditional detail solutions will make particularly high demands on the static-structural and technological solutions.

The specialist charged to perform the analysis of the structural state of repair should be an expert on timber construction having special knowledge and know-how in the development of this subject, of the structural and engineering-theoretical fundamentals, of the connecting techniques and in the material behaviour.

Nevertheless, subject to the available qualification in this special field he or she must consult other experts in time with a view to solving the issues and problems being under consideration in a complex way. With advancing progress of work, consistently the team must increase (see Figure 8). The close cooperation of all the experts concerned is a prerequisite to the successful solution of the specific problem or task.

Following the submission of such a well-bottomed and complex analysis of the structural state of repair by the expert giving the opinion, the user shall decide on the extent of the necessary construction-engineering measures and activities from the point of view of his user-technological demands and requirements to be made in future and of the economical premises.

### PLANNING OF THE PRESERVATION AND MAINTENANCE MEASURES AND ACTIVITIES

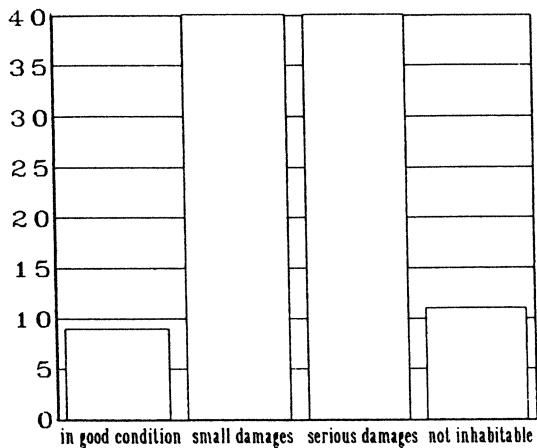
The above-mentioned working steps (stages of activities) are followed by the commencement of the phase of the final planning,

i.e. the preparation and elaboration of the project-related technical solution for a repair, stiffening (reinforcement) or comprehensive reconstruction.

The supervision of the project also by the expert charged to perform the analysis of the structural state of repair is important to the success of the implementation (execution). The probable durability of the measures and activities taken to restore the usability and serviceability can be judged only after a re-examination.

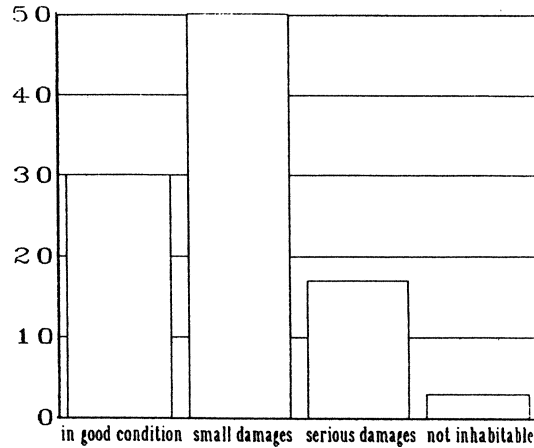
A well-bottomed and comprehensive examination of the worthiness in terms of preservation and maintenance which is being preferred by the authors for years will help in economizing time and money at the stage of planning the preservation and maintenance measures and activities since a comprehensive and detailed survey of the structural defects and of their causes is being provided. In addition, statements (data) concerning the load-bearing capacity and usability of the available construction are being fixed in the expert opinion and investigations into variants of the repair and maintenance (preservation) work and activities are being performed considering the future use and service.

Fig. 1a:  
Structural damages to residential buildings in East Germany  
(per cent)



□ Houses for more families

Fig. 1b:  
Structural damages to residential buildings in East Germany  
(per cent)



□ Houses for one and two families

Fig. 2: Frequency of damages caused by animals and plants to timber structures of residential buildings

*Häufigkeit des Auftretens von Holzschädigungen bei Wohnbauten (in Prozent)*

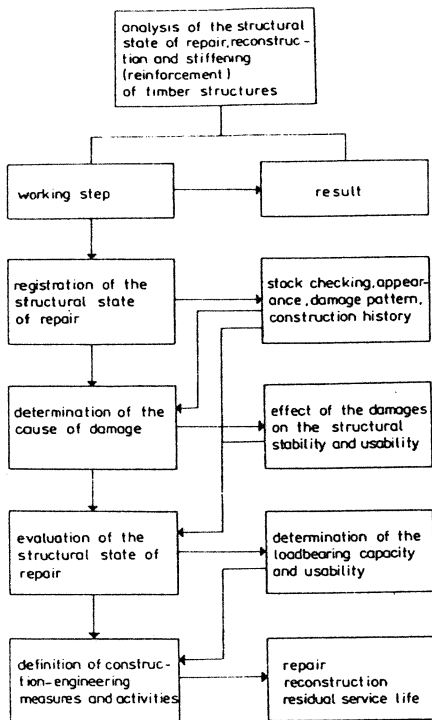
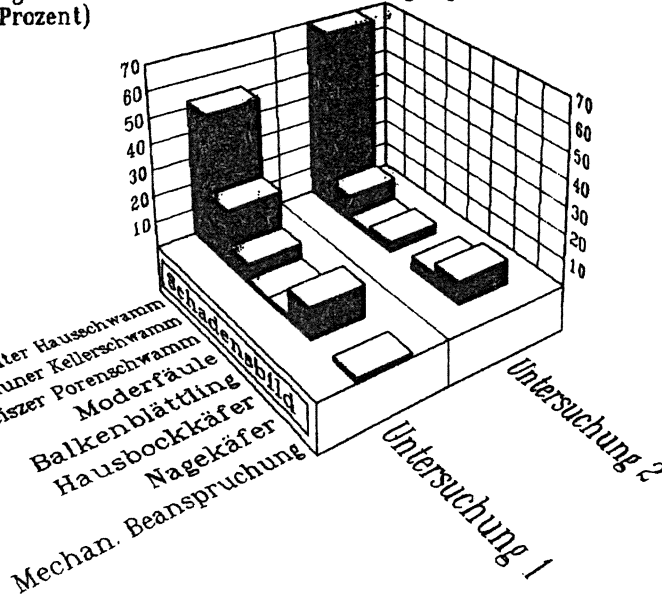


Figure 3: Methodology of the analysis of the structural state of repair

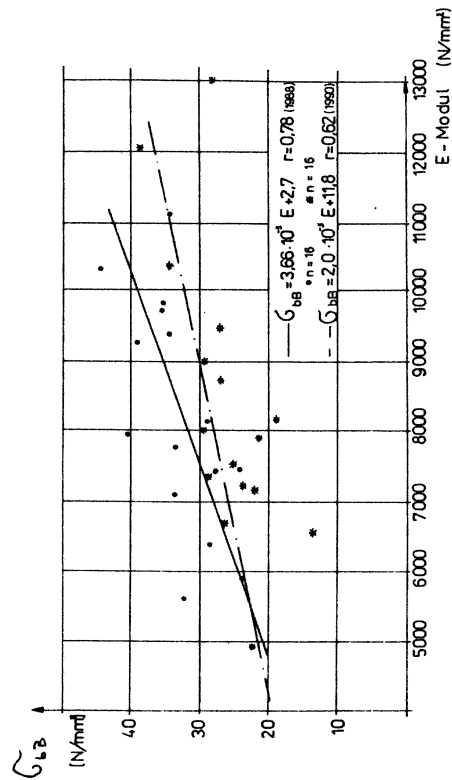


Fig. 4: Correlation between bending strength and modulus of elasticity in bending with old timber, determined by tests on beams for structural timber dimensions.

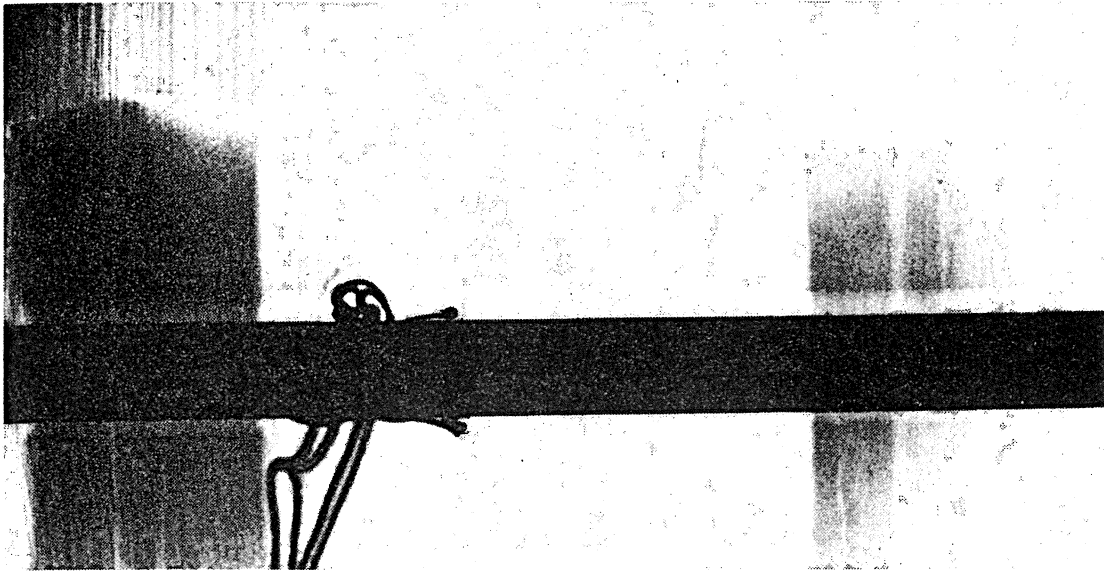


Fig. 5: Radiograph of a historical timber connection (Kübler-type design)

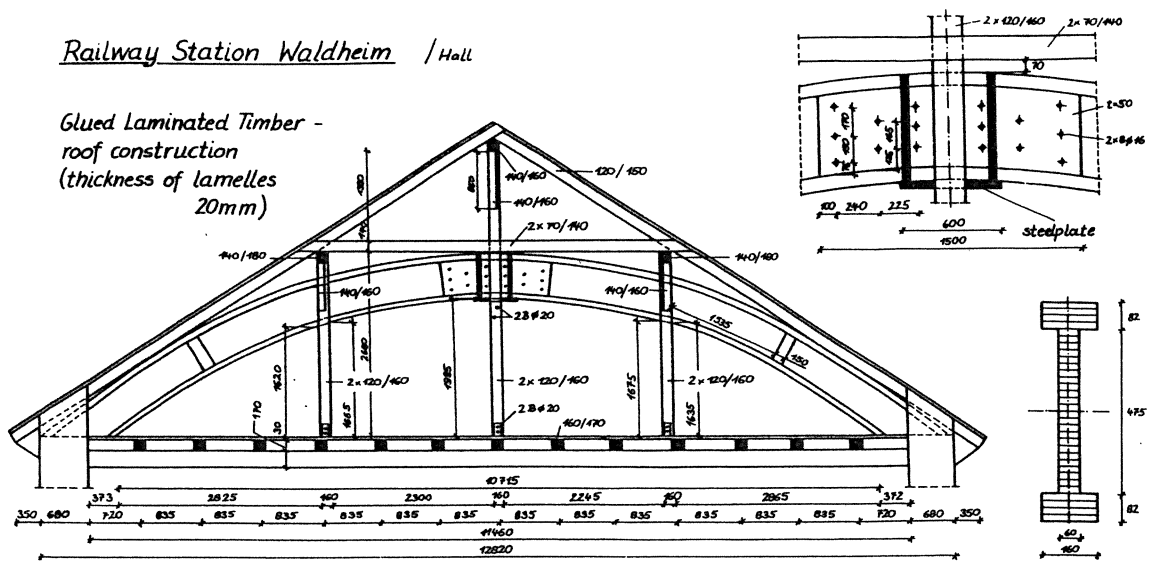


Figure 6  
Roof structure of a railway station (constructional principle: original Hetzer-type design)

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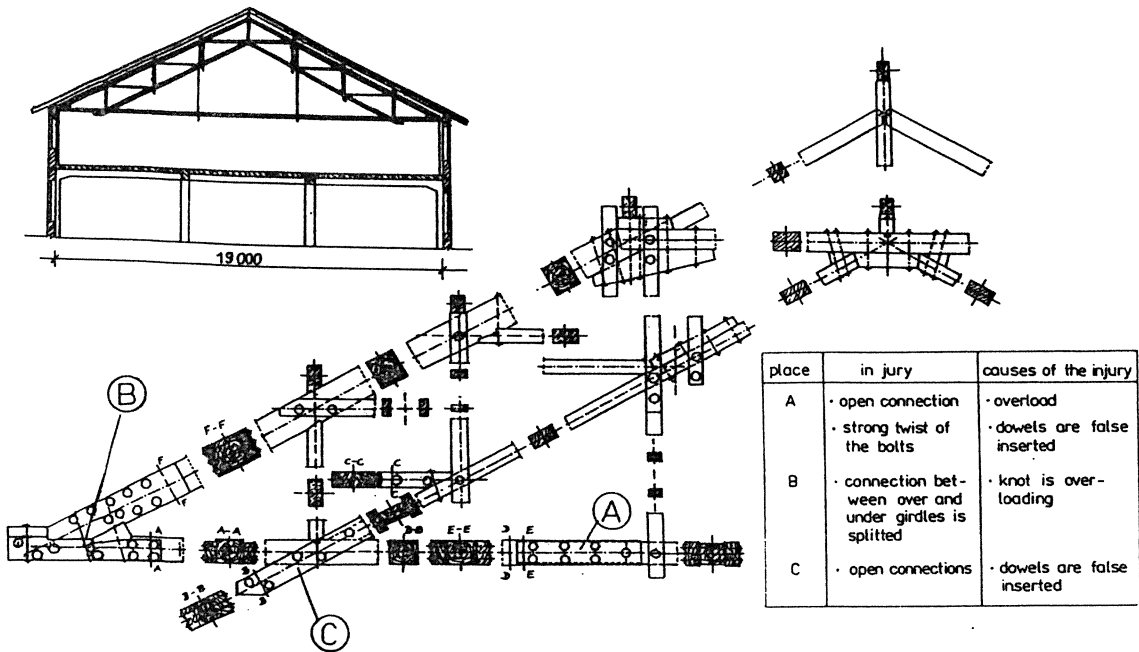
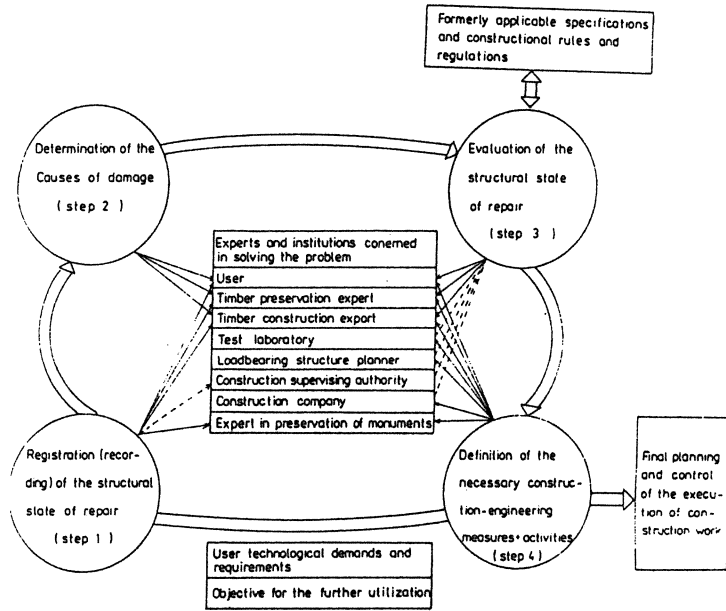


Fig.7: Storage hall having a span of 20 m (year of construction: 1941- constructional principle: Kübler - type design)



Signature: - - - Contribution is not definitely required but possibly expedient, though.      ← Contribution is necessary

Figure 8. Working step (stages) for the analysis of the structural state of repair of old timber structures, including the communication structure between the experts and institutions concerned





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