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Preservation of Historically Important Buildings

Conservation de bâtiments d'importance historique

Erhaltung von historisch wertvollen Bauten

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Fritz Wenzel is a structural engineer. He lectures on structures at the faculty of architecture, Univ. of Karlsruhe. He is concerned with the diagnosis and therapy of old building structures, in research and practice. As a consulting engineer he participated in the restoration of many historic buildings and he has reported on this work in numerous publications, lectures and seminars.

SUMMARY
In the summer of 1985 the Special Research Programme «Preservation of Historically Important Buildings» took up work at the University of Karlsruhe with research projects carried out by the Institute of Bearing Structures, the Departments of Building Material Technology, Timber Construction, Steel Construction, Soil Mechanics and the Institute of Mineralogy together with the Institute of Architectural History and the Provincial Monument Protection Agency. This article gives some information about the programme and describes first results.

RESUME
L'été 1985 l'institution de recherche spéciale «Preservation des Monuments Historiques» a été établie à l'Université de Karlsruhe. Elle consiste de l'institut de statique, l'institut des Matériaux de construction, de l'institut des constructions de bois, l'institut des constructions de fer, l'institut de minéralogie, l'institut d'histoire de l'architecture et de l'autorité de préservation des monuments historiques de l'Etat de Baden-Württemberg. Cette contribution renseigne sur le programme de recherche et représente les premiers résultats.

ZUSAMMENFASSUNG
Im Sommer 1985 nahm der Sonderforschungsbereich «Erhalten historisch bedeutsamer Bauwerke» an der Universität Karlsruhe seine Arbeit auf. Er wird getragen von den Instituten für Tragkonstruktionen, Baustoff-technologie, den Lehrstühlen für Ingenieurholzbau, Stahl und Leichtmetallbau, dem Lehrstuhl für Bodenmechanik und Grundbau, dem Institut für Mineralogie, sowie dem Institut für Baugeschichte und dem Landesdenkmalamt Baden-Württemberg. Dieser Beitrag gibt Auskunft über das Programm und schildert erste Resultate.

1. EXCERPTS OF THE RESEARCH PROGRAMME 1985

The SFB 315 at the University of Karlsruhe "Preservation of historically important buildings" is intended to help revive work with old constructions and building materials. It will focus on the cause of decay and on methods and procedures to preserve and improve the substance. Solutions are to be found that are compatible with the monumental value of old buildings by minimizing both the destruction of the original substance and any addition of technical aids. The costs can be reduced accordingly by carefully-aimed measures. Besides basic and applied research, contributions are to be made to our knowledge of the history of construction and technology.

1.1 PARTICIPATING DISCIPLINES, INSTITUTIONS AND INDIVIDUALS

The SFB 315 concerns the faculties of

- architecture
- civil engineering and surveying
- biology and geology

as well as the

- "Landesdenkmalamt Baden-Württemberg."

It is conducted by the following institutions and invividuals:

- Institut für Tragkonstruktionen
  Prof. Dr.-Ing. Fritz Wenzel (Speaker of the SFB)
- Institut für Baugeschichte
  Prof. Dr.-Ing. Wulf Schirmer
- Institut für Massivbau und Baustofftechnologie,
  Abteilung Baustofftechnologie
  Prof. Dr.-Ing. Hubert Hilsdorf
- Versuchsanstalt für Stahl, Holz und Steine,
  Abteilung Stahl- und Leichtmetallbau
  Prof. Tekn. dr Rolf Baehre
- VersuchsanstaltfürStahl,Holz undSteine,
  Abteilung Ingenieurholzbau und Baukonstruktionen
  Prof. Dr.-Ing. Jürgen Ehlbeck
- Institut für Bodenmechanik und Felsmechanik,
  Abteilung Bodenmechanik und Grundbau
  Prof. Dr.-Ing. Gerd Gudehus
- Mineralogisches Institut
  Prof. Dr. Egon Althaus
- Landesdenkamt Baden-Württemberg
  Prof.Dr. August Gebeßler,Präsident des Landesdenkmalamtes
  Baden-Württemberg

1.2.1 PROJECT FIELD A, BUILDING INVENTORY, HISTORY, MONUMENTAL VALUE

The project field A has been titled "Building Inventory, History, Monumental Value" and is conducted by the "Landesdenkmalamt", the Institute of Architectural History and the Institute of Bearing Structures. As suppliers and recipients of data and information, the three subprojects will be linked especially close to each other and to the other groups in the more technically oriented project fields B and C.
Within subproject A1, the "Landesdenkmalamt" will name those buildings suitable as exemplary research objects for the different areas of interest to the SFB and will make them accessible. It will analyse and determine the monumental value, will accompany the engineer-technical examinations from its history-related point-of-view and analyse the securing measures proposed in respect to their compatibility with the monumental value.
The subproject A2 is intended to contribute to the knowledge of the history of building construction and technique by examining exemplarily selected buildings under the aspect of architectural history. This work deals with general historical questions concerning foundations and mortar composition. The understanding of the particular time, the past ways and means in working with constructions and material should be considered. The architectural historians will be able to compile a sequence of research and examination results by participating in the work done by the other subprojects. By completing and arranging them systematically, an important contribution to technical and constructional history could be achieved.
Within subproject A3, examinations are to be carried out on existing repaired buildings to examine how effective the methods and techniques used to secure old building structures and constructions have been after a number of years or decades have passed. The strong and weak elements in current repair techniques are to be determined to bring about purposeful future improvements.

1.2.2 PROJECT FIELD B BUILDING MATERIAL, CHARACTERISTICS, WAYS OF IMPROVEMENT

The four subprojects of the project field B are summarized by the title "Building Material, Characteristics, Ways of Improvement". These projects are carried out by the Departments of Buildings Material Technology, Timber Construction and Soil Mechanics as well as by the Institute of Mineralogy.
The aim of subproject B1 is to develop effective damp protection methods. First steps will be to work on the physical phenomenon of moisture travel and on the damage caused by dampness. Using data derived from experiments, the moisture protection of porous building material should be characterized mathematically to be able to describe dampening and drying procedures with model calculations.
Within subproject B2, wood-testing methods are to be developed that do little or no damage to the substance. They are to be applied in practice to achieve information on the load-bearing and deformation behaviour of old timber. This subproject will continue, in follow-up work, by systematically examining old timber in buildings and establishing rules for judgement.
The subproject B3 is concerned with those subsoil properties, weaknesses of foundations and environmental effects that to this day cause subsidence and movements of historical buildings with shallow foundations. At the beginning, the continuous settlement of heavily loaded foundations on clayey soil will be of greatest concern as well as

continuing movements and deformation of retaining walls and buildings on clayey slopes. Later, questions will be of interest dealing with the effects of traffic vibration in connection with granular soils and with buildings on expansive soil.
In subproject B4, the Mineralogical Institute, acting as a central laboratory for the whole SFB, is to carry out the experiments needed within the other subprojects dealing with fabric composition and structural properties of materials as far as mineralogical methods can be of any help. It is to be explored which mineral components and processes lead to the observed damages in buildings and which mineralogical and geochemical procedures could help repair them or preserve the repaired condition of the particular building monuments.

1.2.3 PROJECT FIELD C CONSTRUCTIONS, LOAD-BEARING PERFORMANCE, STRENGTHENING TECHNIQUES

The project field C "Constructions, Load-bearing Performance, Strengthening Techniques" covers four subprojects of the Departments of Timber Construction, the Institute of Bearing Structures and the Departments of Steel Construction and Soil Mechanics.
The topic of subproject C1 will be joints and connecting means in old timber constructions. The most important types used in the past are to be recorded. Then, experiments are to be made to determine the bearing and deforming performance. Finally, criteria of judgement are to be derived which allow for the bearing security of old wooden joints and connections to be determined without reference to modern building regulations which apply to new buildings.
The subproject C2, continuing from previous work, is to deal with procedures to determine material strength and deformation values of old masonry that vary greatly. These procedures should be more descriptive than those used when examining stone and mortar samples individually and they should be less destructive than those where complete small pillars are removed. Later on, work should be done using these results and improving the load-bearing and deformation performance of single and multi-shell masonry. The possibilities to stabilize severely torn masonry walls by applying prestressing forces without bonding activity should be investigated now.
Subproject C3 is concerned with iron and steel structures of the 19th century. They date from a time at which the profession of master builder split into those of architect and civil engineer and they therefore represent an important phase in the development of engineering construction. Together with the architectural historians and the conservationists a catalogue of objects worthy of preserving is to be compiled. Material tests and experiments on the load-bearing performance are to help achieve a basis to assess the load-bearing ability, the remaining time for further use, possible alterations in use and suitable securing and repair measures for the structures.
The subproject C4 deals with construction activity within, in the vicinity of and underneath historical buildings. Methods are to be developed to predict the behaviour of the soil and the building in such cases. The investigations give priority not only to achieving or preserving structural stability through such activity but also to preserving the historical building substance as far as possible including the foundations.

1.2.4 PROJECT FIELD D DOCUMENTATION, INFORMATION, ADMINISTRATION

The documentary and transfer office is responsible for the establishment of a commented bibliography, for building documentation and subsequently for the compiling of a register of those valuable constructions dealt with in the selected buildings within the SFB, furthermore for central inventory and archives within the SFB. In addition it is reponsible for the publication series containing the research results of the SFB as well as the recommendations and case studies for practice. Another task will be organizing meetings and workshops and co-ordinating the work of the University Institutes and the "Landesdenkmalamt", especially when buildings are to be examined, and bringing work in the line with the other research groups.

2. FIRST RESULTS

2.1 SUBPROJECT A3: ENGINEERING EXAMINATION OF EXISTING BUILDINGS PREVIOUSLY REPAIRED

FRITZ WENZEL, MICHAEL ULLRICH, HELMUT MAUS:

For decades damaged masonry of historically important buildings has been structurally strengthened by injecting mortar suspension consisting generally of cement mortar, by inserting reinforcement steel and prestressing bars. Reports on these methods exist from as early as the 1920s. These repair techniques are to improve the masonry, handle local tensile stress and re-establish the ability of torn walls to transfer loads.

There are obvious stabilizing effects achieved by grouting and reinforcing old masonry but there are also indications coming from several sources that unsuitable grouting material and corrosion of steel may lead to damages.

Systematic follow-up examinations concerning possible subsequent damages had not been undertaken until recently. Now two groups, in Karlsruhe and Münster, have compiled first results of their work. These were achieved by conducting inspections of old masonry buildings that had been structurally repaired, by exposing reinforcement members, by core-boring and by using an extendable endoscope. There were positive as well as negative results.

On the one hand cavities were found in grouted masonry and old mortar was not entirely surrounded by injection material, additionally steel bars were found lacking sufficient protection against corrosion due to inadequate cement covering. On the other hand the investigations also revealed completely filled cracks and gaps, thoroughly mixed and strengthened old mortar as well as sufficiently covered reinforcement bars without any trace of rust. Measuring the tensile forces in the reinforcement bars, first carried out 11 years ago, was resumed and shows the longterm performance of inserted prestressing members.

Quite different the results of more than 20 buildings in Lower Saxonia. These buildings with walls made of gypseous brick work are in a very bad shape after they were injected with cement mortar 15 to 20 years ago. These injections caused inside the walls a crystallization with volume increase and as a result of this: cracked walls. The flow of injectionmaterial, the position of needles and anchors within the drillholes could be checked in situ after opening walls for repair. Furthermore samples of stones and mortar - decomposed by cristallization - could be collected for laboratory tests. In one building resin-based-mortar was injected 12 years ago, but after opening the wall the material still was liquid and dropped out of the opening.

2.2 SUBPROJEKT B2: LOAD-BEARING AND DEFORMATION BEHAVIOUR OF OLD CARCASSING TIMBER

JÜRGEN EHLBECK, RAINER GÖRLACHER:

The specific density of wood is an important property to assess the quality of wood. This value correlates closely with the wood strength especially with the compressive strength parallel to the fibre. The determination of the specific density is generally conducted according to the DIN 52182 (German Code). For the procedure square or oblong samples are recommended depending on the objective of the examination. The specific density of in-situ building timber (in-situ-measurement) can only be determined by removing samples and therefore material is destroyed if this method is applied. Since it is usually most interesting to examine the properties of highly-strained building members a non-destructive method becomes necessary that will not or at least not substantially damage the members.

Such a non-destructive testing method to determine the specific density of in-situ timber is the Pilodyn technique.
In applying the wood-testing-device PILODYN 6J a steel pin penetrates the wood with a specified amount of energy whereby the depth of penetration is measured. The specific density can then be estimated with the help of regression analysis taking into account the moisture content of the wood and the number of measurement attempts. There was no proof that the angle between the direction of penetration and the course of the annual rings had any influence on the results. First measuring attempts on old timber showed no systematic deviations from measurements on new timber. The number of tests conducted to date is not sufficient to draw any final conclusions. In certain cases, though, this procedure may represent a valuable support in examining the condition of existing timber structures.

2.3. SUBPROJECT C3: IRON AND STEEL STRUCTURES OF THE 19TH CENTURY ROLF BAEHRE, RUDOLF KÄPPLEIN

The cast-iron hollow columns widely used in construction during the second half of the 19th century are expected to reveal considerable irregularities in their form originally not intended. The eccentricities in the cross section occurred during casting in horizontal position when the mould core slipped out of position. There are two techniques at hand to determine the circumferential course of wall thickness of the column shafts - one working with ultrasonics, the other using a mechanical measuring device developed within subproject C3.
These developments from the basis of determining the quantity of eccentricities to consider them when calculating the stability of cast-iron hollow columns.

References: Erhalten historisch bedeutsamer Bauwerke, Forschungsprogramm 1985, Berlin 1987
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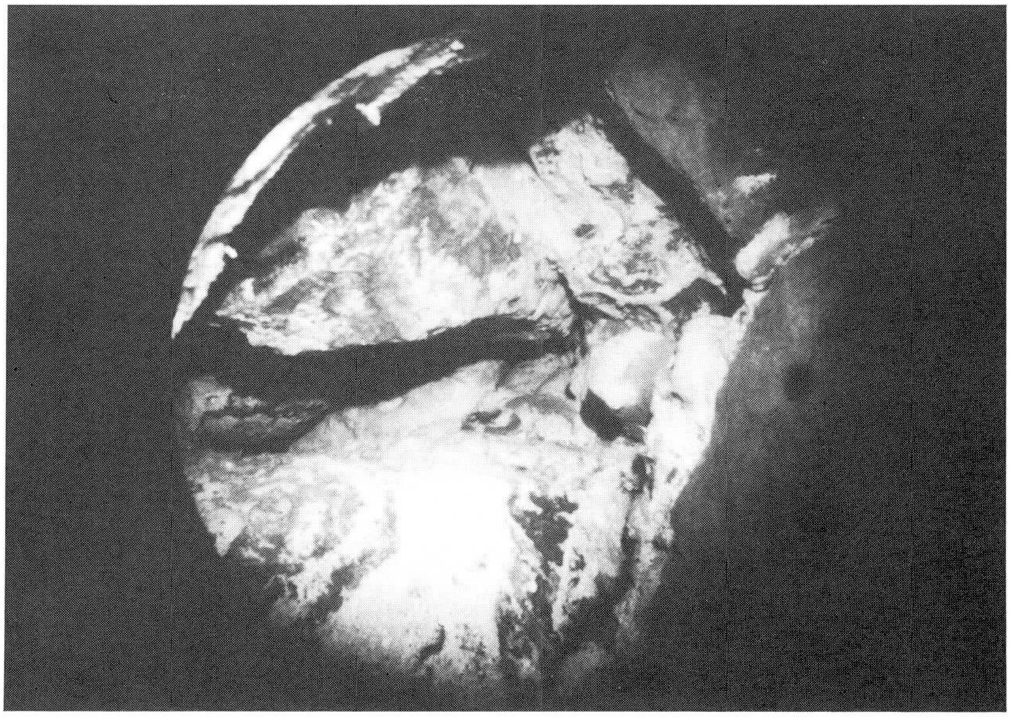
BILDUNTERSCHRIFTEN

fig. 1	Unsuccessful result of grouting. Photograph taken through an endoscope. Cavities are shown that were not reached by grouting mortar. The old mortar had not been stabilized. It was washed away during the survey drilling.
fig. 2	Successful result of grouting. The joint is completely filled. The cement mortar is well interlocked with the porous stone and the lime mortar.
fig. 3	Negative example of protection against corrosion. Reinforcement bar without enough protective cement mortar covering. The diameter of the drill hole was to small.
fig. 4	Good example of protection against corrosion. Photograph taken through an endoscope. A steel reinforcement bar in the middle which has been cut at an angle during survey drilling. Sufficient protective covering with grouting mortar.
fig. 5	The Pilodyn 6J wood tester including loading rod and 3 spare striker pins.
fig. 6	Relationship between density and Pilodyn 6J penetrations in spruce (Piceae abies). + = average of 16 measurements.
fig. 7	Relationship between density and Pilodyn 6J penetrations. Oak, pine and fir from the 18th century.
fig. 8	Cast-iron hollow columns with varying wall thickness due to slipping of the mould core.
fig. 9	Cross sections of cast-iron hollow columns.
fig. 10	Mechanical wall-thickness-measuring-device.



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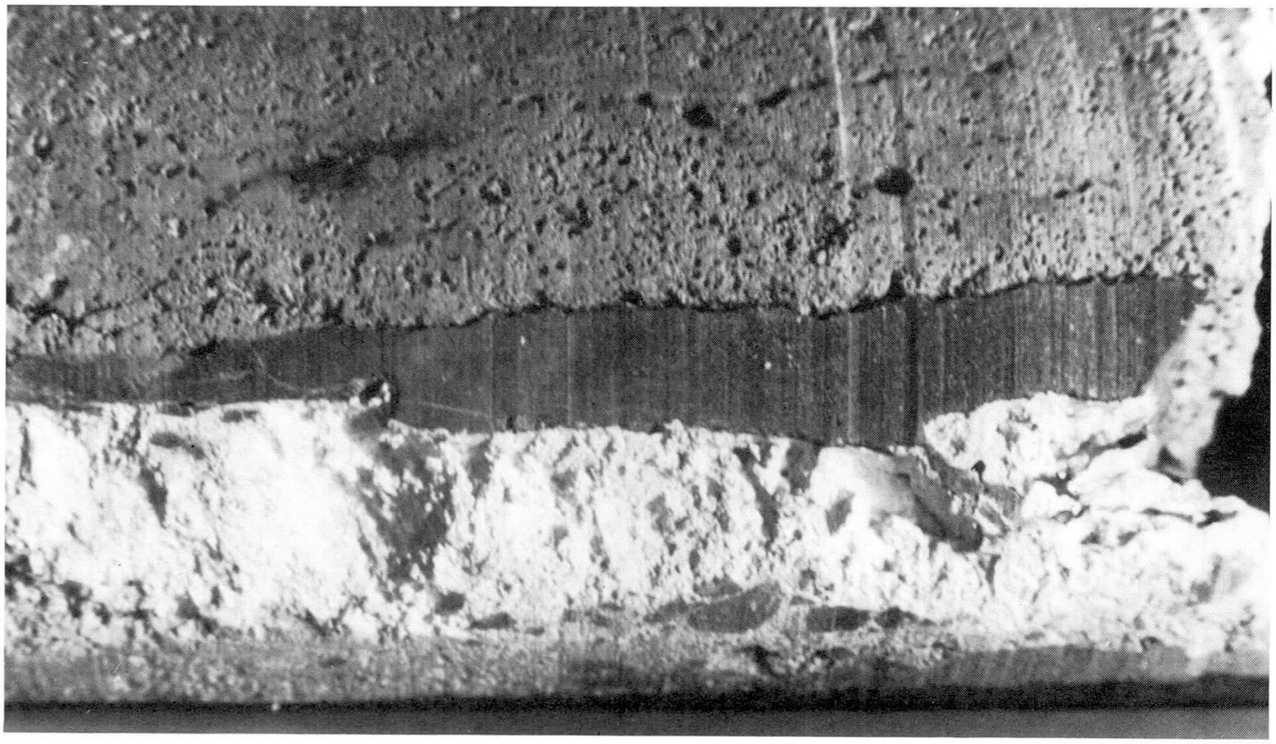

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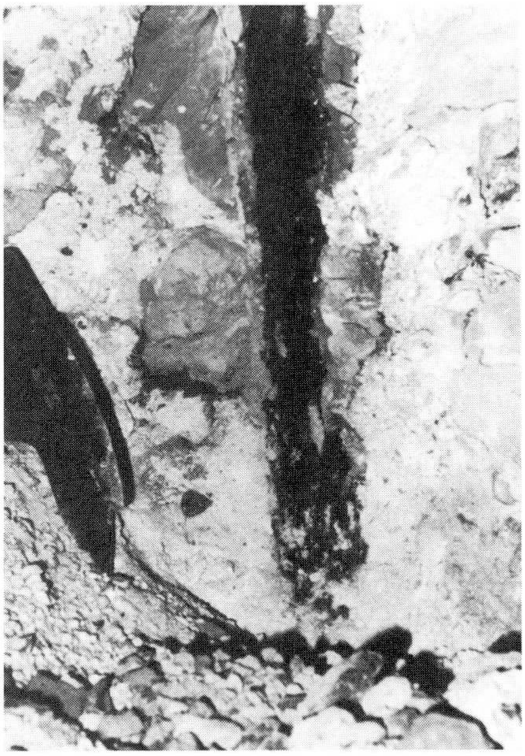

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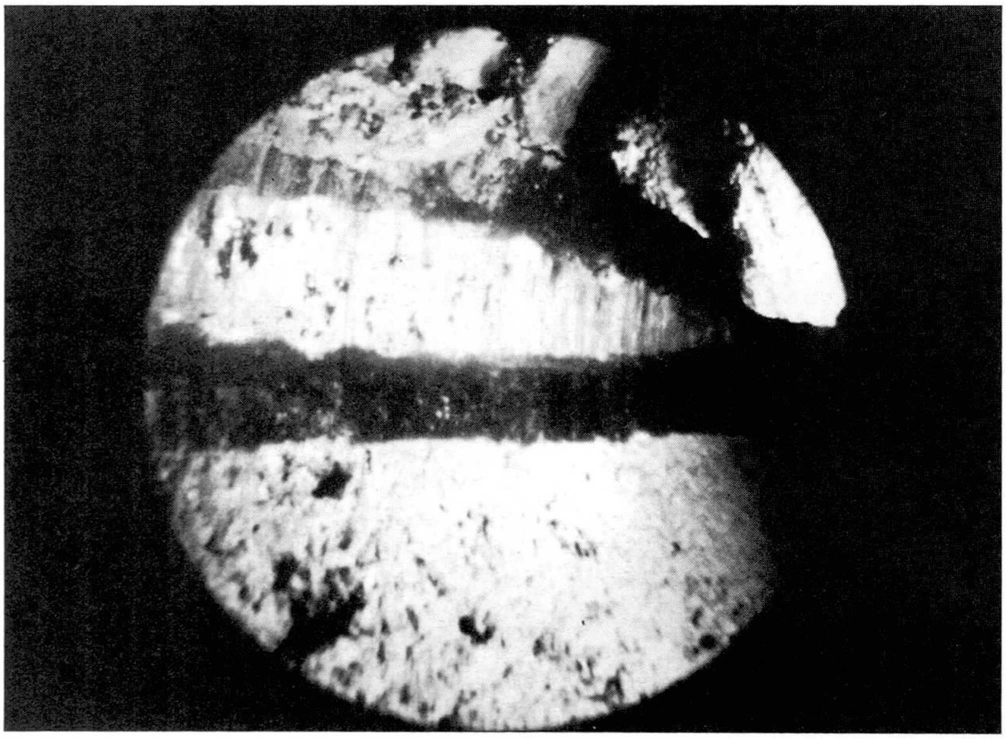

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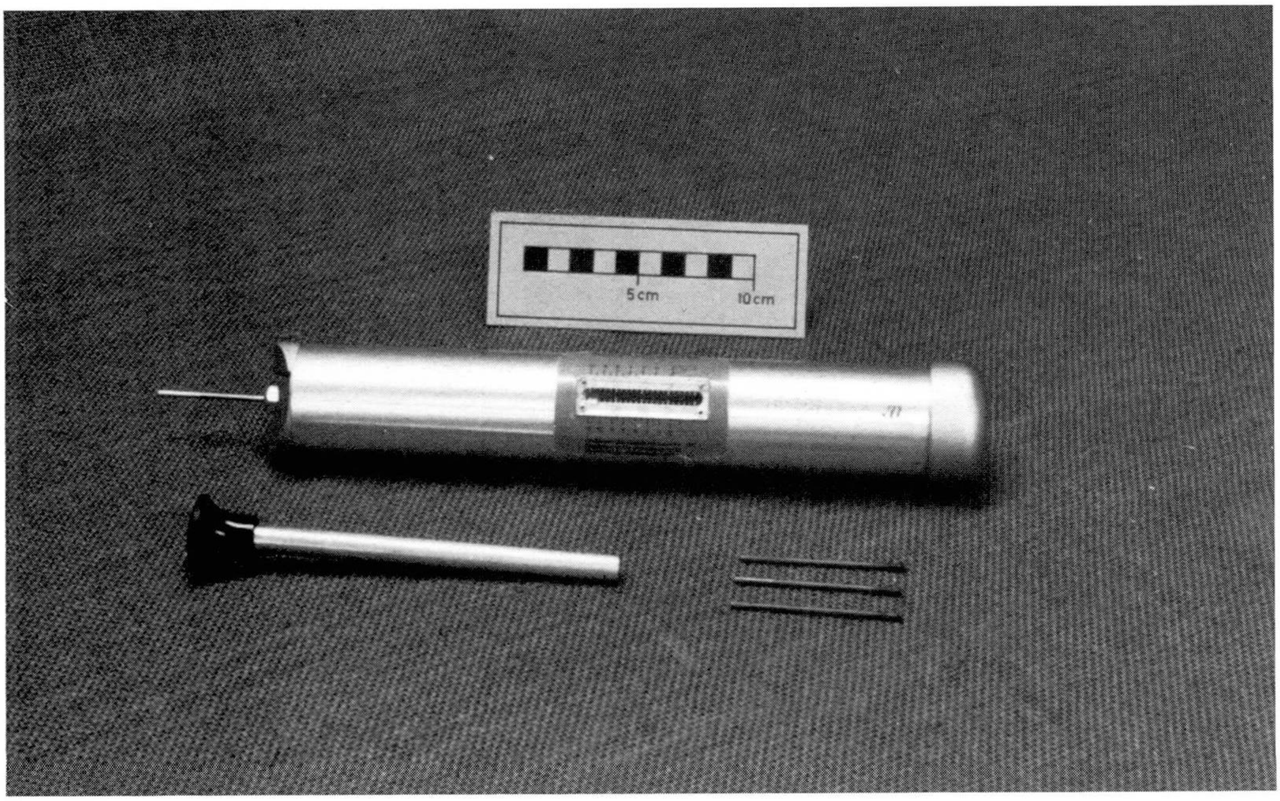


fig. 5 The Pilodyn 6J wood tester including loading rod and 3 spare striker pins.

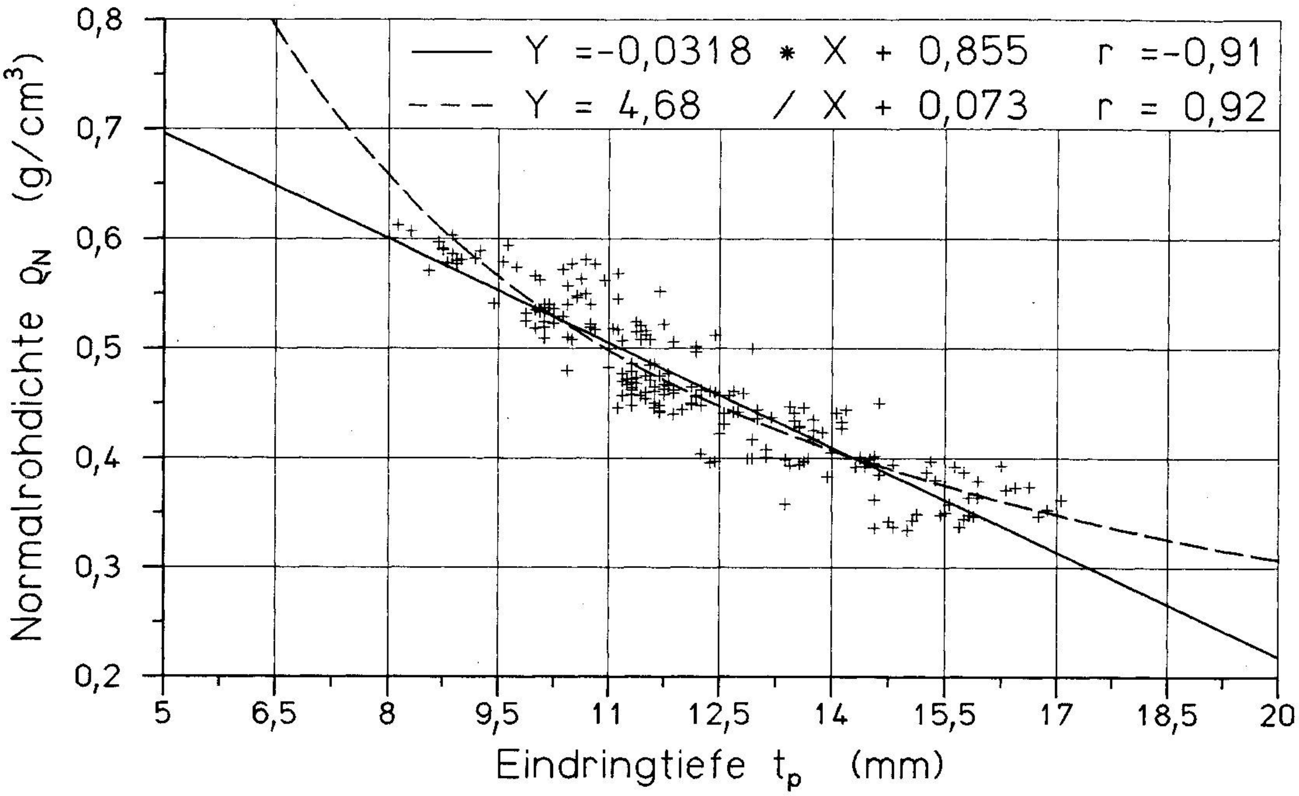
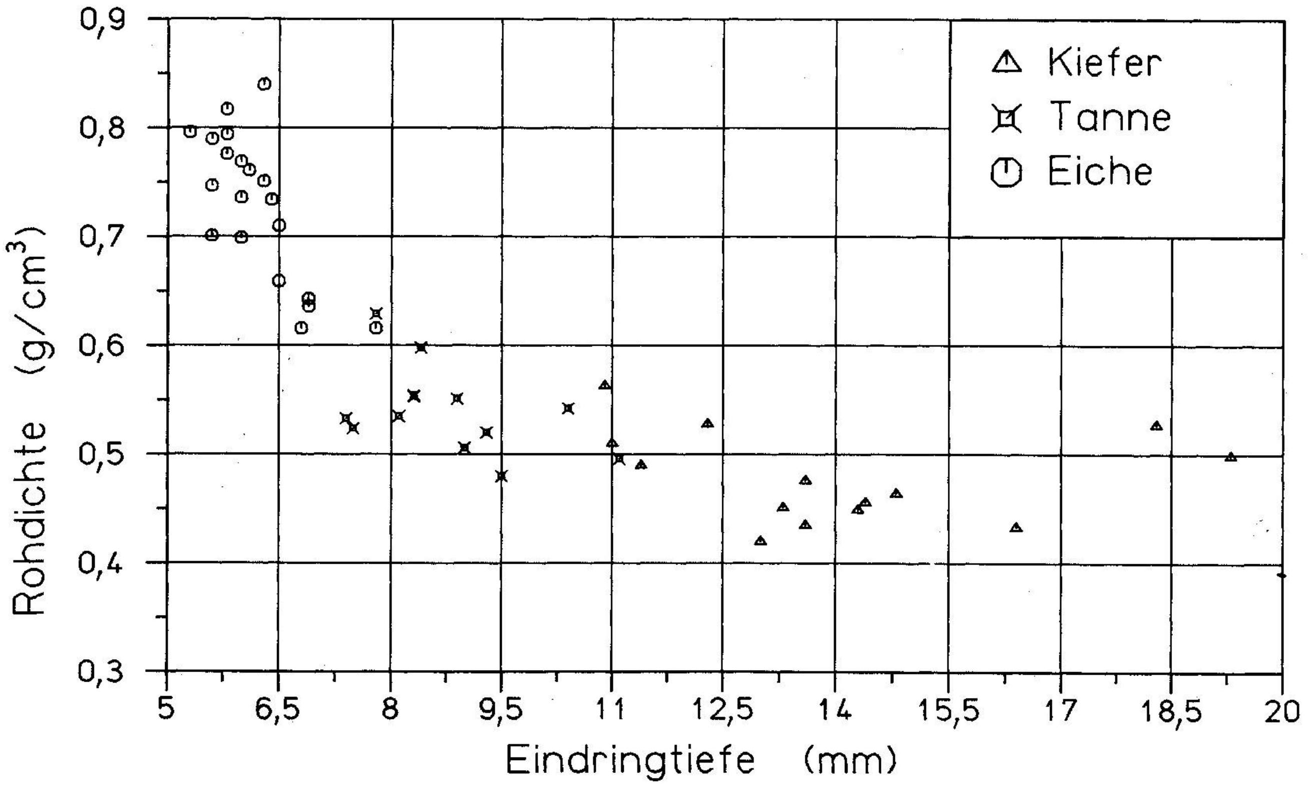


fig. 6 Relationship between density and Pilodyn 6J penetrations in spruce (Piceae abies). + = average of 16 measurements.



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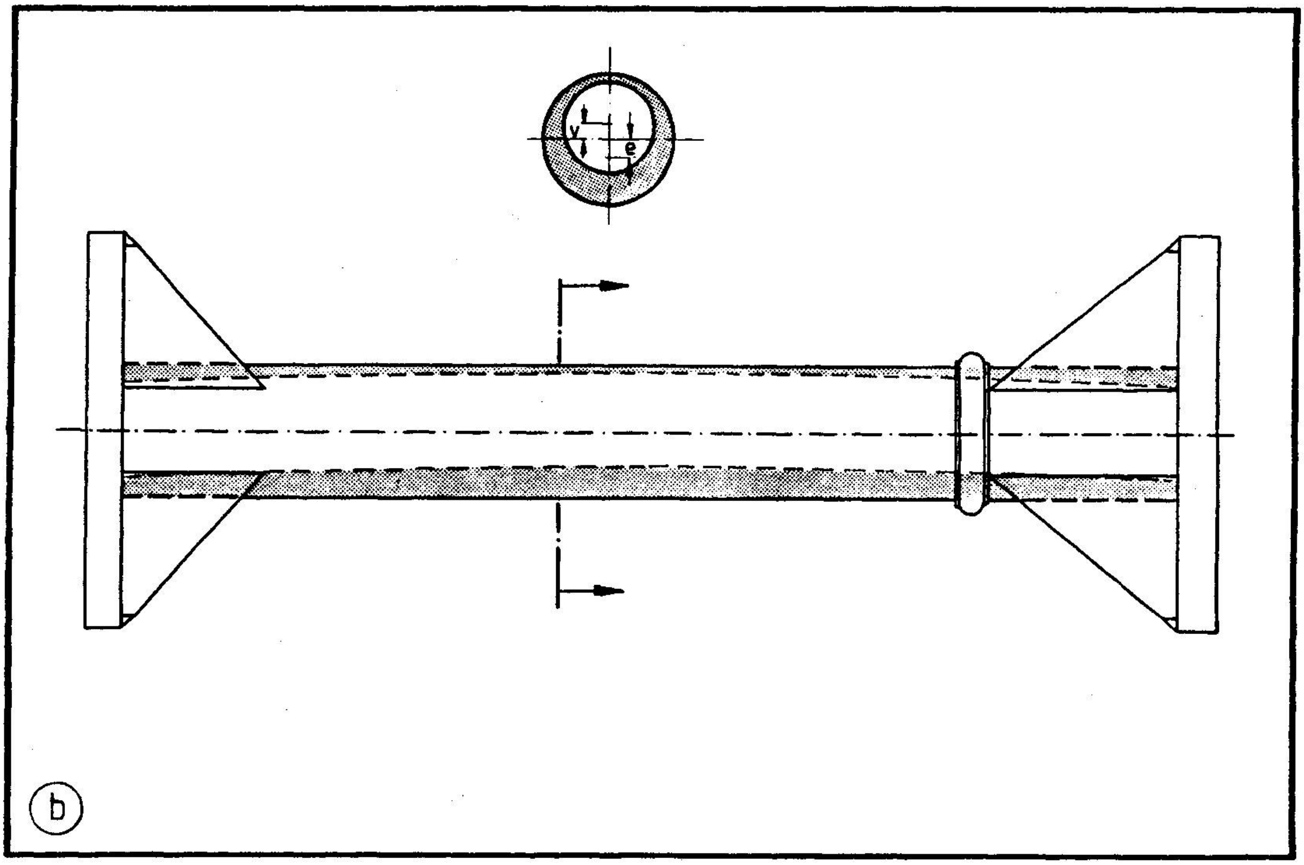

fig. 8 Cast-iron hollow columns with varying wall thickness due to slipping of the mould core.

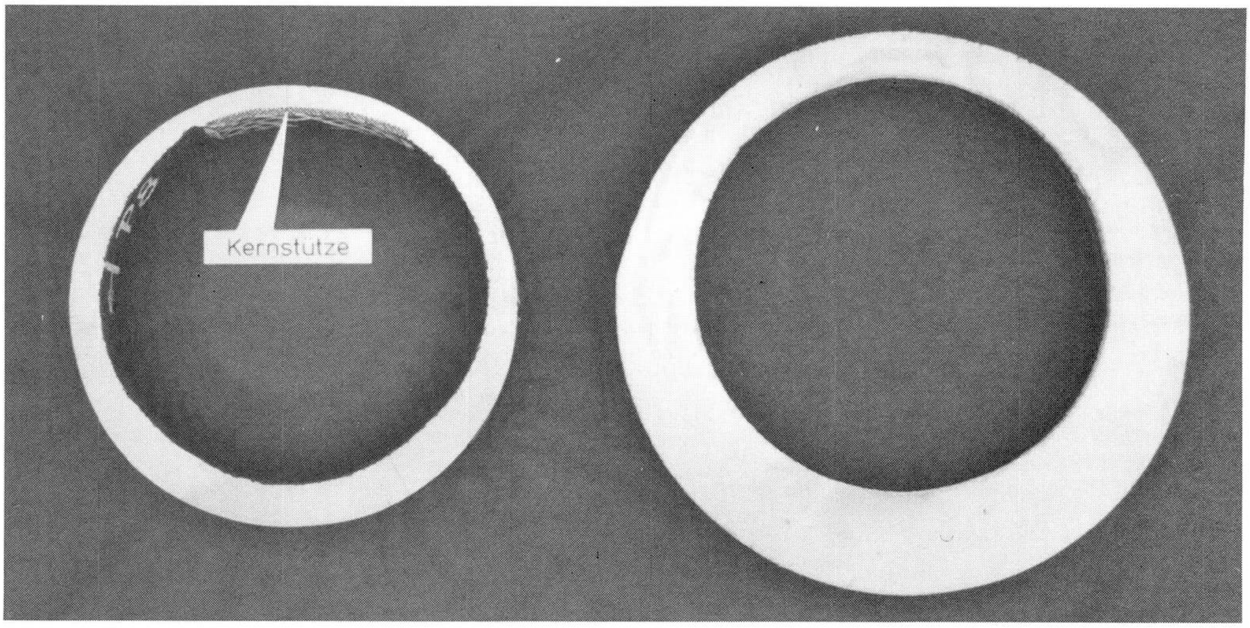

fig. 9 Cross sections of cast-iron hollow columns.

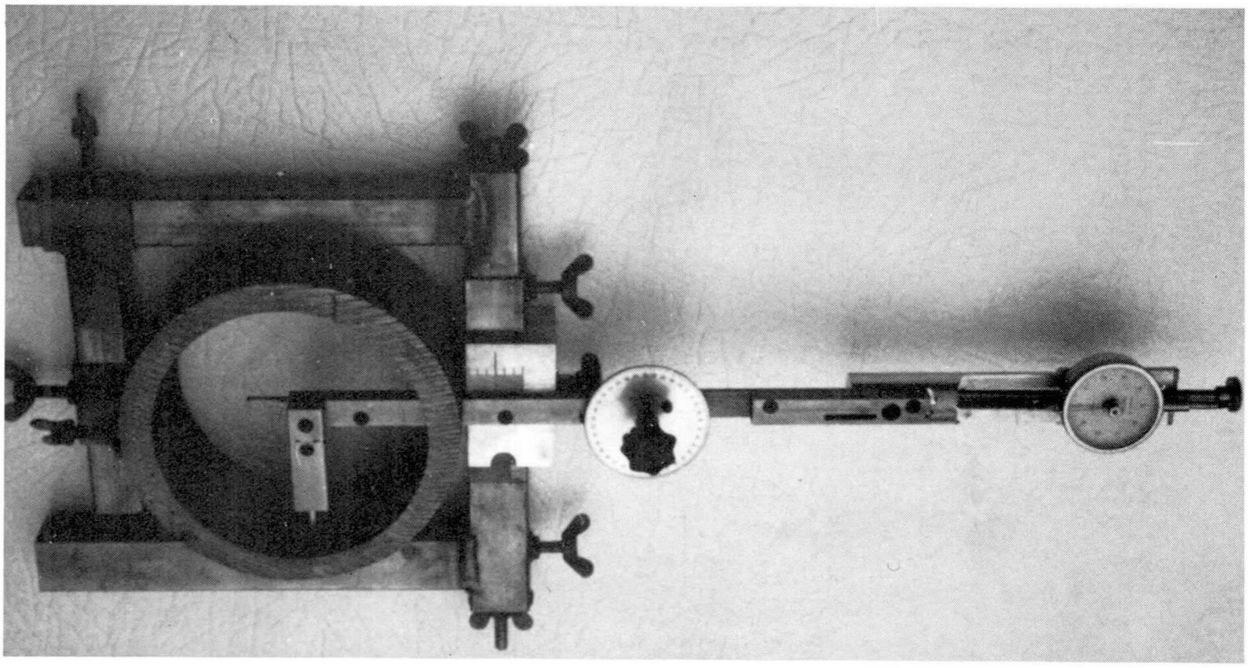

fig. 10 Mechanical wall-thickness-measuring-device.

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