From Damage Maps to Condition Inventories:

A proven concept for documentation of results of inspection of timber bridges and other timber structures

Frank Rinn
President
Rinntech Inc.
Heidleberg, Germany
frank.rinn@rinntech.com

Frank invented the Resistograph™ drilling technique in 1988 and has been refining the tool over the years and has been inspecting numerous timber structures.

Summary

Since 1988 we develop technical devices and corresponding application concepts to inspect trees and timber. The following statements are not the result of theoretical scientific work but show results of practical work of our company, inspecting timber in buildings and bridges in Germany and several other countries.

Keywords: inspection, quasi-non-destructive, drilling, relative density, decay detection

1. Introduction

In Europe, several thousand timber bridges have to be inspected on a regular base. Commonly, results of such inspections had been shown in black and white inventory sketches, showing decayed parts shaded and marked with a number, referring to a list of damage descriptions of each position. This way, reports about timber bridges and other timber structures every now and then ended up being some hundred pages long but still left significant space for question marks: the structural engineer, for example, had no idea about the areas of the structure that were not marked. Have these parts or sections not been inspected (for whatever reason, such as being inaccessible) or are they intact?

One consequence of this situation usually was (and still is in many projects) that engineers assumed more damages being present in the structures than documented and thus, as a precaution, they planned additional repair and reinforcements without knowing if these works are really required.

Another consequence was that carpenters during repair work often found additional decay or they realized that parts were replaced or repaired that did not need to – but afterwards it could not be proven anymore if this additional work was really required because the replaced parts are usually not stored.

Finally, most timber structure and timber bridge repair projects were much more expensive than planned and required.

Based on the success of the application of resistance drilling for inspecting timber starting 1986, we then developed a concept how to document inspection results that provides more precision and reliability but is, at the same time, more easy to understand for both engineers and carpenters.

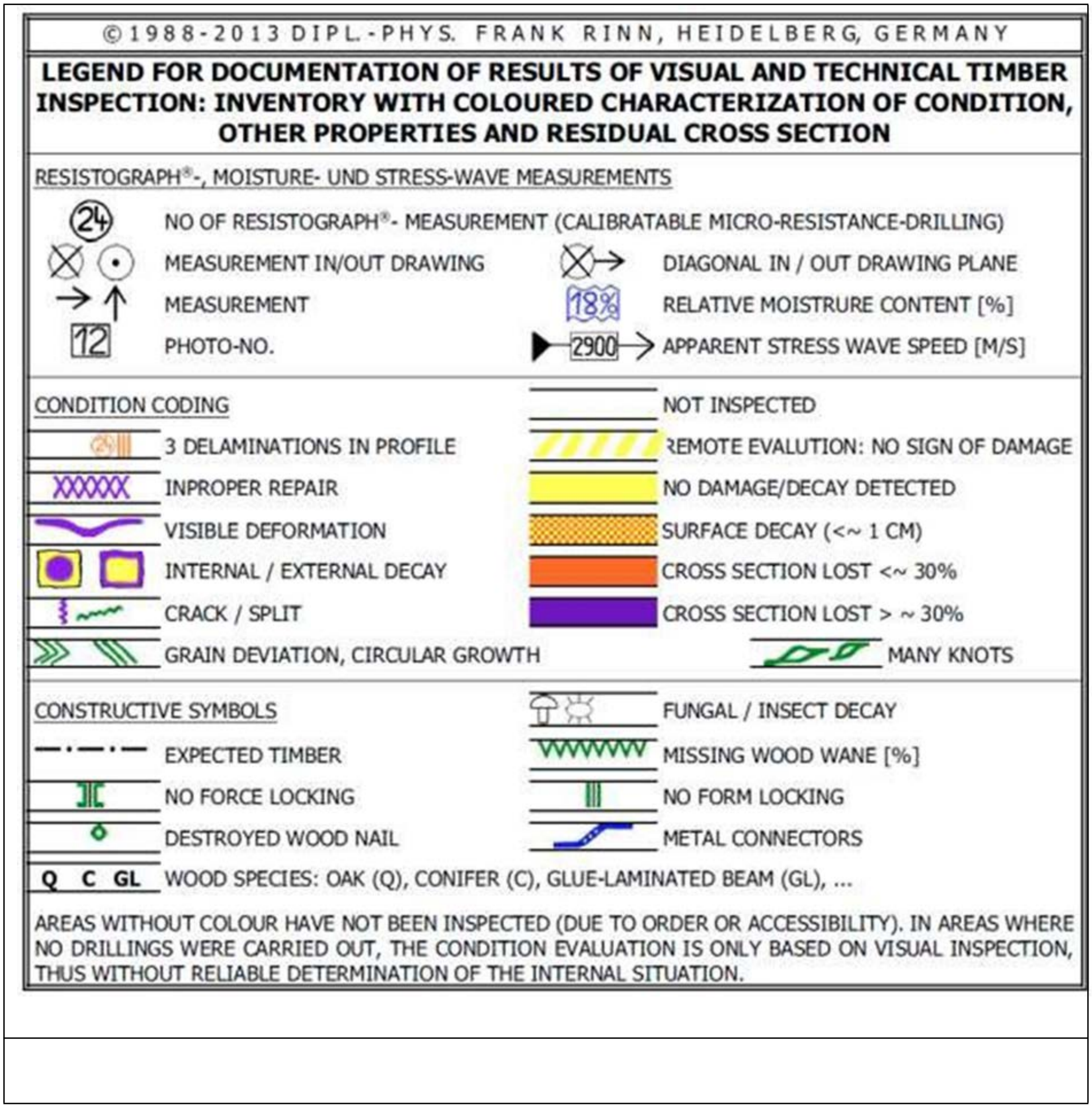

Fig. 1. Legend of colored inventory sketches showing the condition of timber in three major colors and describing additional signs for specific symptoms identified at a beam or structure.

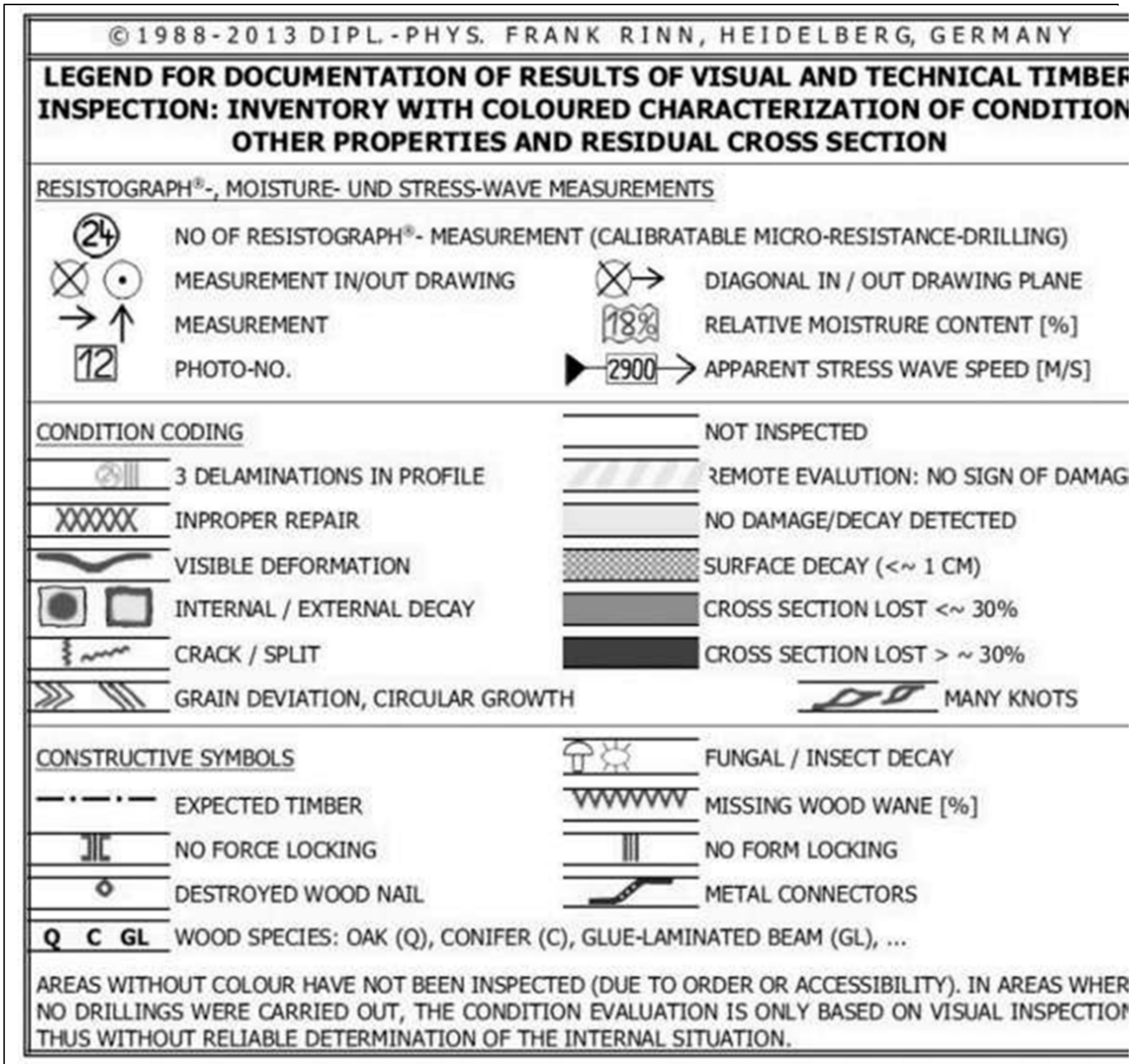

Fig. 2. Black and white copy of the condition legend still providing three major condition markers reliably differentiated by different grey scales.

2. Documentation concept

The first step forward coming from black and white sketches of timber structures with shadings for marking decay was to use colors. But, in order to make the drawings as easy as possible to read, the number of main colors had to be as small as possible, at most three or four.

At the time we developed our concept (late 1980ies / early 1990ies), color copies were still quite expensive, especially if printing in larger than standard letter sizes. The colors thus had to be selected in a way that allows black and white copies still providing the major information about decay and condition (Fig. 1). Consequently, we selected red (extensively decayed), orange (mean decay), and yellow (intact) as the major colors – because they can be differentiated easily on the first view and because black and white copies still show the three colors reliably in differentiated types of grey (Fig.2).

The traffic-light color scheme, green for intact), yellow for partially decayed, and red for strongly decayed parts, was no option because of several reasons: in a black and white copy, green was commonly darker than red, leading to a wrong impression about the condition of the corresponding parts. In addition, structural engineers in Germany commonly used green for marking structurally relevant, local aspects and symptoms, such as cracks.

The biggest step forward was introducing a color for marking parts of timber that were inspected (either visually, by tapping and/or resistance drilling) and where found to be intact and sound. This means, if a beam was tested in whatever kind and no sign of decay was found, this beam is marked with a certain color.

For the first time, this way it was possible to distinguish between the sections of a timber structure that were not inspected (no color) and the parts that were inspected without finding damages (yellow). This may sound as a tiny little aspect but changed a lot because from then on later planning and working steps did know what parts of the structure they can rely on without doubting whether these parts had been checked or not (because there was no decay marked).

Another big step forward was combining as many parts of the usually many individual sketches of a structure as possible into one single overview drawing: this reduced the total number of sketches representing the condition of a structure often from 10 to 1 or 2 – making it much easier for engineers and architects as well as for carpenters getting an overall impression about the condition of the bridge or structure as a whole. In addition, the overview given by a single sketch with a color coded condition inventory allows the identification of connections between sources and reasons of different spots or areas of decay. That means, these overview inventories provide a base for a much deeper understanding of the structure as a whole instead of only working locally on repair of individual parts.

	
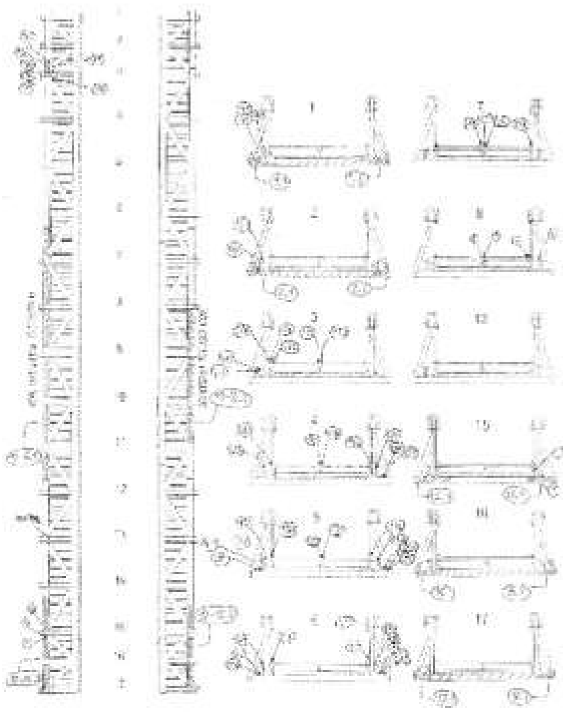	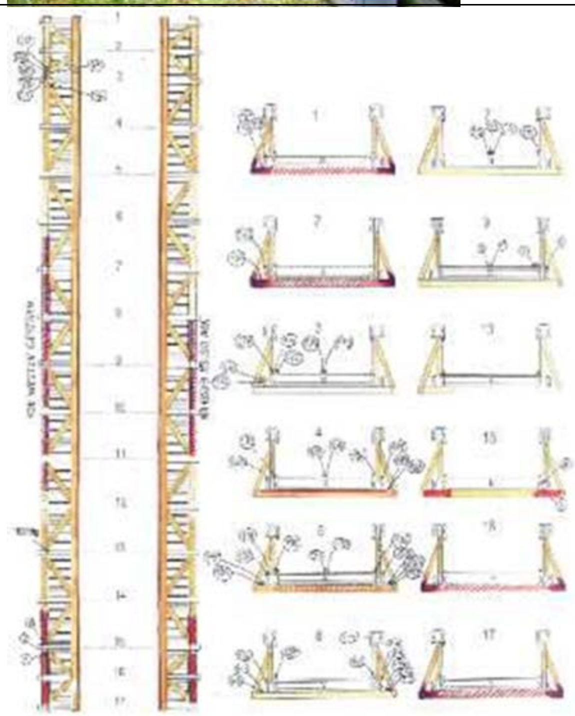
Conventional black and white damage map of a timber bridge. Originally it was common to mark decayed parts with a certain kind of shading and a label that refers to the text list position of the corresponding description of the found damage. Such a drawing consisted usually of 18 individual sketches of each axis and was accompanied by many pages of text within the report.	Colored version of an inventory map showing wood condition in different colors. The colors do not only reveal where decay was found but furthermore show what parts of the structure were found and proven to be intact. Because colors allow the reader to much easier identify damaged areas, such a combined sketch replaces many conventional drawings.

Fig. 3. Typical timber bridge to be inspected because of decay (although made by tropical hardwoods).

3. Practical working steps

Commonly we prepare the basic drawings of structures before the technical inspection starts. Such structural sketches have to show all relevant timber parts that belong to at least one plane of the structure or are connected with this plane. While doing that, we try to avoid showing different beams in one sketch that in reality overlay each other and represent different planes – because it is impossible to show correct colors if these beams have different conditions and thus would have to be characterized by different colors overlaying each other.

Usually, the sketches are prepared in a larger size and scale for enabling the inspector on site to put in all relevant information while inspecting - as one of our major goals was to avoid text notes but reveal all relevant aspects in the sketch. And, all evaluations should be done on the spot without having to go back to office and again work on profile analysis and come to a conclusion that, for example, additional assessments are required. This is time consuming and inefficient. Our goal was to always come to a final conclusion about the condition of timber on site while inspecting because only on site at the structure you can just tap or drill another time at another spot in order to confirm unclear results or suspicious symptoms. The highest (cost and time) efficiency we always achieved when the inspection came to a final conclusion on the site and when all relevant results were documented in the color coded inventory map on site. This drawing has then only to be reproduced in the office and surrounded by a short text note.

The reproduction of the colored on-site drawing is usually done by a reduction factor of 4. These squeezed sketches then represent the most significant part of the report. In addition, the report usually contains some illustrating pictures and a short text summary with recommendations. Even the recommendations for repair work can be partially included in the color coded sketch because lines may be implemented indicating where and how damaged beams should be cut and/or replaced.

All this fits to the traditional German saying: “A good drawing is the language of a good engineer”.

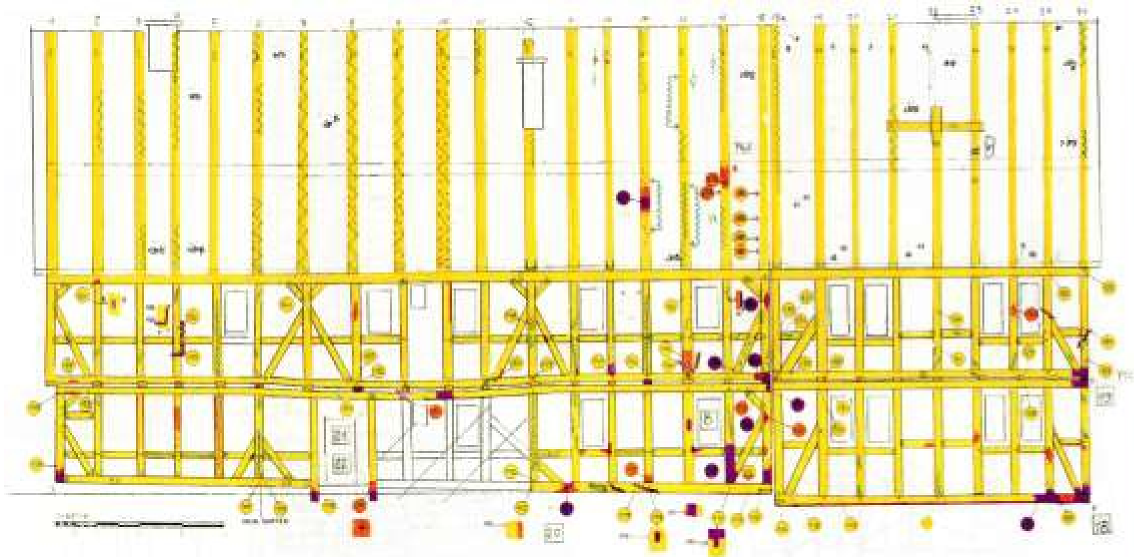

Fig. 4. Overview sketch with color coded condition inventory showing the complete facade of a historical building and all rafter of the roof structure.

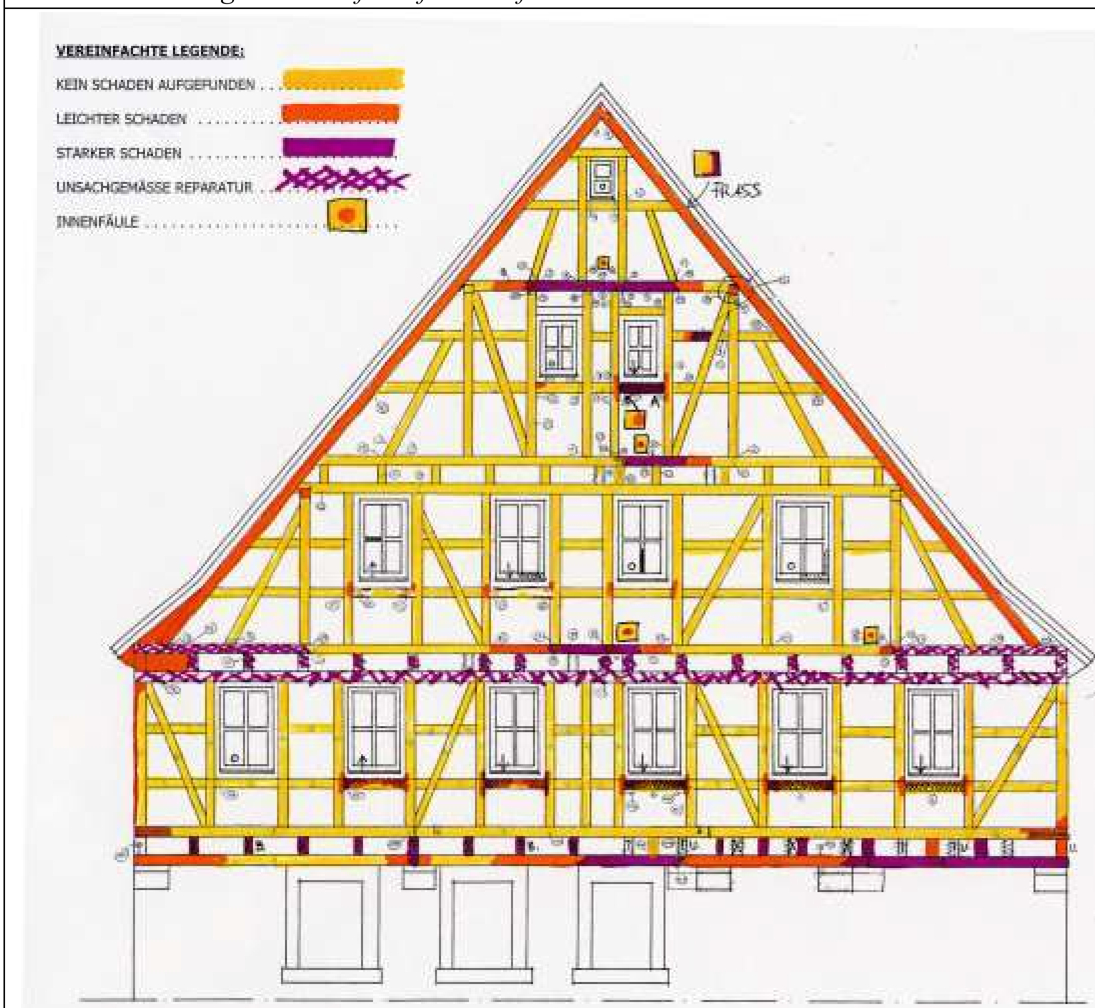

Fig. 5: Overview sketch with a simplified color coded condition inventory. This inspection was carried out by one person on one day including the drawing of the inventory what is usually done on site.

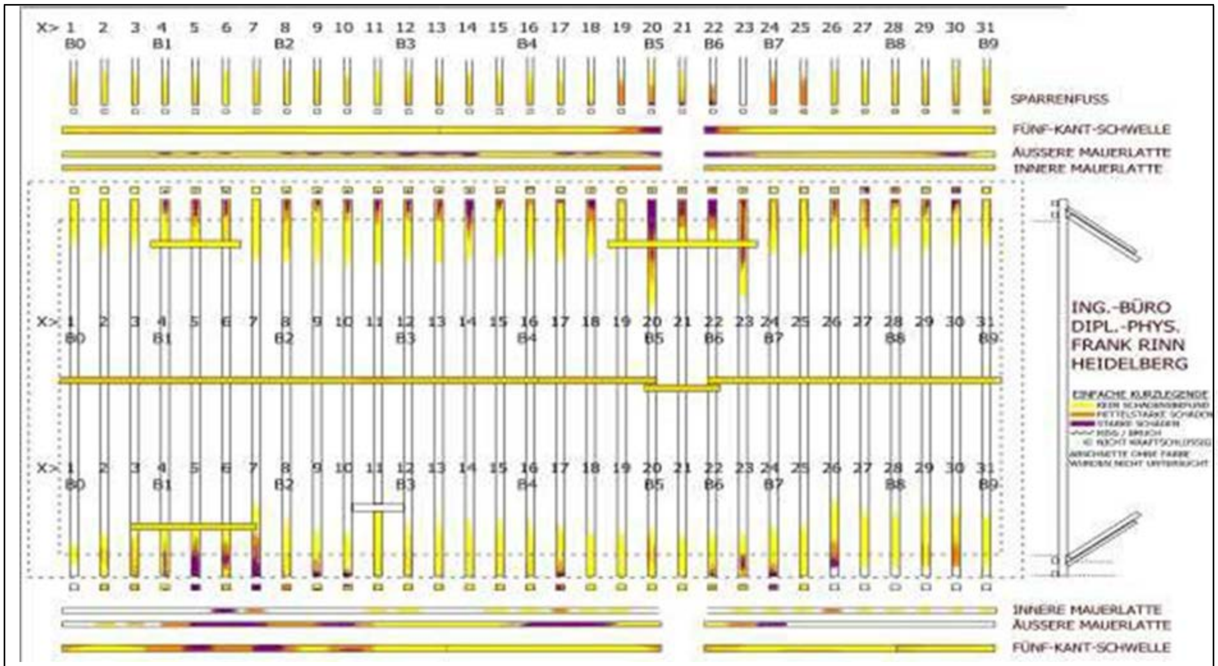

Fig. 6. Ceiling beams of a historic church plus underneath wall beams and the foot parts of looming rafters. This one sketch replaced several dozen sketches of all axes of conventional documentations

4. Consequences

Practical application of this concept in several hundred restoration projects of very different size scales proved its suitability and led to a significant increase of planning safety and furthermore to dramatically reduced total costs.

5. References and further reading

Dackermann, U., K. Crews, B. Kasal, J. Li, M. Riggio, F. Rinn, and T. Tannert. 2013. In situ assessment of structural timber using stress-wave measurements. Materials and Structures. June 2013. DOI
10.1617/s11527-013-0095-4.

Fischer, H.-B., Rinn, F. 1996: Bestandsplan mit farbiger Zustandskartierung der Holzkonstruktion. Bauen mit Holz 11 (1996): 852-858.

Rinn, F. 1988: A new method for measuring tree-ring density parameters. Physics diploma thesis, Institute for Environmental Physics, Heidelberg University, 85pp.

Rinn, F. 1990. Device for material testing, especially wood inspection by drill resistance measurements. German Patent 4122494.

Rinn, F. 1993: Gucken, Klopfen, Bohren. Zerstörungsfreie Bohrwiderstandsmessung als Teil der ingenieurtechnischen Holzuntersuchung. Bausubstanz, 5 (1993): S. 49 - 52.

Rinn, F. 1993: Catalogue of relative density profiles of trees, poles and timber derived from RESISTOGRAPH micro-drillings. Proc. 9th int. meeting non-destructive testing, Madison 1993.

Rinn, F. 1994. Resistographic visualization of tree ring density varia-tions. International Conference Tree Rings and Environment. Tucson, AZ, 1994. Printed in: Radiocarbon 1996, pp. 871-878.

Rinn, F. 1994: One minute pole inspection with RESISTOGRAPH micro drillings. Proc. Int. Conf. on wood poles and piles. Ft. Collins, Colora-do, USA, March 1994.

Rinn, F. 1994: Resistographic inspection of building timber. Proc. Pacific Timber Engineering Conference. Gold Coast, Australia, July 1994.

Rinn, Frank (2006): Konzept für Zustandsanalysen von Holzkonstruk-tionen. bauen mit holz 10/2006. S. 26-33.

Rinn, F. 2012: Basics of micro-resistance drilling for timber inspection. Holztechnologie 53(2012)3. - S. 24 - 29

Tannert, T., R. W. Anthony, B. Kasal, M. Kloiber, M. Piazza, M. Riggio, F. Rinn, R. Widmann, and N. Yamaguchi. 2013. In situ assessment of structural timber using semi-destructive techniques. DOI 10.1617/s11527-013-0095-4.