On-Site X-ray Assessment of Density in Timber Structures

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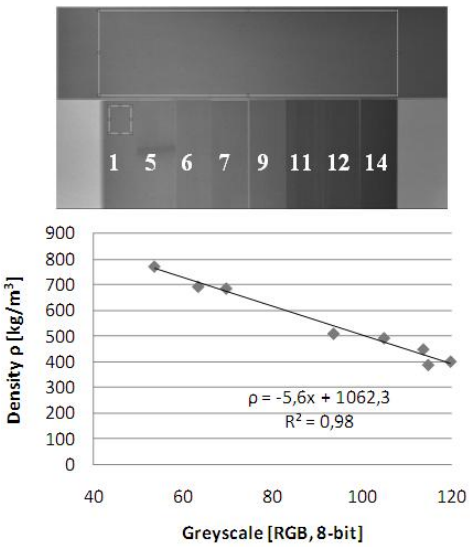
ABSTRACT

Wood density has a strong relationship to several mechanical properties and can therefore be used in the evaluation of timber structures. Several X-ray exist today to determine material properties and to strength grade timber, but those methods are not appropriate for the in-situ assessment of timber. Although, a number of valid techniques to evaluate density properties in timber exist.

The aim of this paper was to create a method that provides local property values from X-ray investigations which can be used to estimate member strength in joints but also for modelling of the structures static behaviour and overall condition. In a second step the influence of moisture and thickness from the X-rayed object were investigated.

To verify density using X-ray equipment, 15 wood specimens of significant density variation were prepared and scanned. Those 15 specimens were also used to correlate the influence of moisture on the X-ray image, and were therefore cut into 6 cubes each and stored in 5 different climate conditions ranging from 35% to 93% relative humidity(RH). The output from the conditioning procedure and the thickness correlation were implemented as correction factors in relation to the thickness of the calibration wedge and a reference moisture level corresponding to air-dried density.



No.	Species Name [SWE - ENG]	Botanical Name [latin]	ρ [kg/m^3]
1	Ceder - cedar	Cedrus brevifolius	389
2	Tall -Southern Pine	Pinus spp (palustris)	394
3	Gran - Norway spruce	Picea abies	395
4	Abachi - African whitewood	Triplochiton scleroxylon	398
5	Gran - Norway spruce	Picea abies	404
6	Gran - Norway spruce	Picea abies	451
7	Al - alder	Alnus glutinosa	495
8	Lind - linden	Tilia (cordata)	501
9	Tall/Furu - pine	Pinus sylvestris	512
10	Rödbok - European beech	Fagus sylvatica	540
11	Valnöt - walnut tree	Juglans regia	689
12	Ek - oak-tree	Quercus (alba/ robur)	696
13	Björk (flammig) - birch	Betula papyrifera	707
14	Ask - ash	Fraxinus excelsior	775
15	Pockenholz - Lignum Vitae	Guaiacum officinale spp, Lignum Guajacum	1301

Figure 1 – Verification of the greyscale density calibration method on a timber specimen (right) using a number of specimens (left) to correlate the density with.

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The result of calibrating the density using X-ray radiation showed strong relationships between the densities of the test specimens and the greyscale of the recorded X-ray image. The relation up to a certain level provides excellent linear correlation up to a density level of 1000 kg/m^3 and correlation values (R^2) between 0.90 and 0.98, see Figure 1.

The influence regarding the moisture content and the surrounding climate is illustrated in Figure 2. There is a clear tendency from the analysis between the mean greyscale and different equilibrium conditions of the specimens expressed in relative humidity (RH) in-between the species. Even though the influence of the moisture on the X-ray images is small, it cannot be neglected, especially when the moisture content lies above 16% and/or below 10% and the calculated mean differences of the max and min greyscale values was 20 RGB (red, green & blue colour model). The influence of the thickness on the X-ray exposure of a specimen is exponation according to Beer's law i.e. that it is of great importance for calibration purposes.

The density calibration method of X-ray images was verified on a timber beam specimen with good agreement and an average accuracy of 97%.

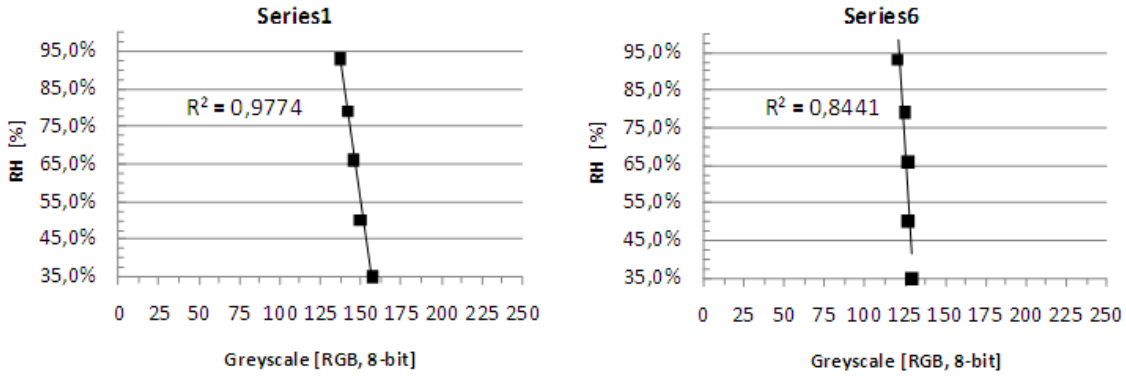

Figure 2 – Examples of results from the differences in of greyscale due to differences in RH

Besides the opportunity of determining mechanical properties of timber, its main advantage over conventional techniques is the detection and quantification of internal damage, defects, disturbances and deterioration that reduce mechanical properties of the structure.

Based on the results from a study the following conclusions can be drawn:

(1) Digital radioscopy is on its way to become a powerful tool for in-situ examination and evaluation of timber structures, and its possibilities are far beyond from being totally explored. It also contributes to detection of failures and deterioration of the material in early stages that in its turn gains the service life and durability of the structure.

(2) It was shown that accurate estimates of the in-situ density of timber using the X-ray procedure in combination with digital image processing were obtained.

(3) The influence of the moisture content can be ignored since it only had little influence on the attenuation of the X-rays; at least for a certain range. Only a tendency of the influence of moisture could be captured, as the scatter between different images was too large to make adequate estimations.

Keywords in-situ assessment, density, timber structures, X-ray, digital radiography, non-destructive testing (NDT), digital image processing;