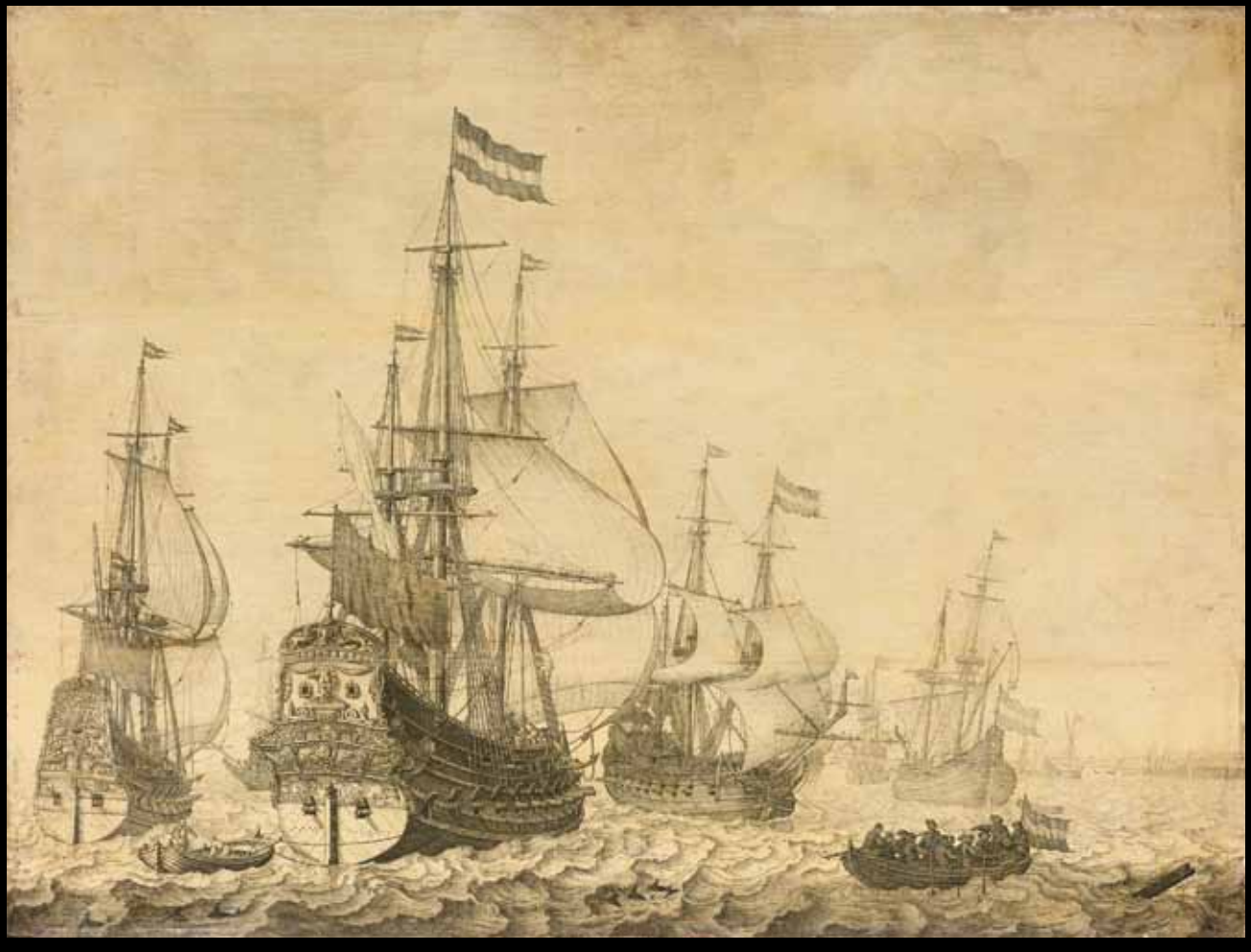
The conservation of panel paintings and related objects

Abstracts of relevant literature



Abstracts of relevant literature

In making this research agenda we have of course used the literature extensively. To facilitate readers who are interested in more background information we present a series of abstracts of relevant literature. This overview is by no means exhaustive. We thank the OPD, Florence for permission to publish abstracts.

Ahola, P., **Adhesion between paints and wooden substrates: effects of pre-treatments and weathering of wood, Materials and structures,** 28, 6, 1995, p. 350 - 356

Abstract: The effects on adhesion between paints and wooden substrates due to pre-weathering (delay in painting), treatments of wood during pre-weathering and the moisture content of substrates were monitored. The adhesion was studied by means of a torque test. Wooden panels were untreated, or treated with unpigmented, penetrating wood preservatives or treated with pigmented strain, and pre-weathered for various periods. The panels were then painted and subjected to further exposure. The adhesion of the paints was determined at two relative humidities. Pre-weathering of 12 weeks impaired the adhesion significantly when emulsion paints were used, and when the wood substrates were untreated or treated with the unpigmented treatments during the pre-weathering. When the substrates were protected with a pigmented stain prior to painting, a longer delay before painting could be accepted. Also, wood substrates with higher moisture contents reduced the adhesion of the emulsion paints.
http://www.springerlink.com/content/02267440476128ur

AHRC/EPSRC, **Science and Heritage Programme Post-Doctoral Research project „Change or Damage? Effect of Climate on Decorative Furniture Surfaces in Historic Properties"**, 2010-2013

Abstract: Change or Damage? (2010-2013) will study the degradation of veneers and marquetry on furniture in historic houses, in collaboration with the project partner, English Heritage. Within conservation, research on wood has focussed on

structural timbers and panel paintings with more recent studies looking at polychrome sculpture and lacquered furniture. However there has been little work to understand the interactions between the complex and often large number of different materials found within marquetry designs, and this project will draw on the results of Woodculther to develop new scientific techniques of monitoring and understanding change.

http://www.ucl.ac.uk/sustainableheritage/changeordamage.htm

Ainsworth M.W., **From Connoisseurship to Technical Art History: The Evolution of the Interdisciplinary Study of Art,** Conservation perspectives, The GCI Newsletter 20.1, Spring 2005

Abstract: Anyone interested in the early development of connoisseurship will find detailed historical accounts in the excellent volume *Historical and Philosophical Issues in the Conservation of Cultural Heritage* (Getty Publications, 1996). In this anthology, one can follow the issues and the chief players in this admittedly subjective field of study that, nonetheless, is the foundation of object-based art history. Yet, it is undeniable that connoisseurship has gotten a bad name over the years. This is partly due to the conflict of interest that can develop in relationships between curators and dealers (the names Bernard Berenson and Joseph Duveen readily come to mind), the undeniable connection of monetary value with attribution, and the inexact science of it all. Perhaps most perplexing is the seeming exclusivity of connoisseurship, fed by the notion that some have "an eye" (often touted as an inborn trait) and others do not.

http://www.getty.edu/conservation/publications_resources/newsletters/20_1/feature.html

Ainsworth M.W., **Special Exhibitions and Panel Paintings: A Curatorial Perspective,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 178 – 189

Abstract: On May 28, 1483, Hugo van der Goes's enormous triptych known as the Portinari Altarpiece, measuring 253 × 304 cm (99.6 × 119.7 in.) when closed, arrived at its destination, the Hospital of Santa Maria Nuova in Florence. The detailed account of its journey from Bruges to Florence would terrify any curator or conservator. Such a journey for a masterpiece of this importance would be unthinkable today; yet if it were deemed absolutely necessary, possible conservation intervention, safe packing, and transport could now be ensured in a way that never could

have been imagined in the late fifteenth century. The issue of the care and transport of panel paintings for special exhibitions has reached a somewhat confusing juncture—where everything is possible and nothing is possible. This paper explores the state of the question from the curator's point of view, in order to consider concerns of risk balanced against guaranteed benefits of sending panel paintings to special exhibitions. Museums have never been better informed about how to treat panels, pack them, and transport them for safe arrival at their destinations, yet attitudes and perceptions about lending panel paintings to exhibitions lag behind these new developments. Case studies are used to evaluate past and present decisions regarding panel paintings and loan shows.
http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Albrecht D., **Diagnostic of the conservation state of antique Italian paintings on panel carried out at the Laboratorio di Restauro dell'Opificio delle Pietre Dure in Florence, Italy with ESPI-based portable instrumentation,** J. Cult. Heritage, 2000, p. 5331 - 5335

Abstract: The aim of this work was to use non-destructive optical measurement techniques to assess the conservation state of ancient Italian paintings and to experiment outside of the laboratory with the most recent ESPI (electronic speckle pattern interferometry) portable instruments developed within the Photonic Technologies and Diagnostic Laboratory of the European Commission Joint Research Centre of Ispra, Italy. The measurements described here took place at the Laboratori di Restauro dei Dipinti dell'Opificio delle Pietre Dure in Florence, Italy. The technique detects hardly visible and invisible defects on paintings on panel during the restoration phase and allowed the production of both qualitative and quantitative data, owing to its high resolution and sensitivity to thermal deformation. The system used allowed the inspection of a larger area (400_300 mm) in comparison to that reported in literature concerning continuous wave portable ESPI systems applied in the conservation field.
http://www.ingentaconnect.com/content/els/12962074/2000/00000001/90000001/art00146

Allegretti O. and Raffaelli F., **Barrier effect to water vapour of early European painting materials on wood panels,** Studies in conservation 53, 3, 2008, p. 187 - 197

Abstract: Reports results of experimental measurements of diffusive water vapor flux through spruce wood specimens coated with 16 combinations of paint layers replicated according to materials and techniques used from the late Middle Ages to the Renaissance period. Layers represented two base preparations (ground), four polychrome paint layers, and presence or absence of varnish. The flux of water vapour was measured from sorption tests in unsteady-state conditions. The internal resistance to the transport of water in wood and the external resistance due to the coating layers was calculated with a numerical method. The results show that all paint layers reduce the flux and that there are significant differences among paint layer combinations. The calculated mass transfer coefficient is an important physical characteristic of the material, and it allows improved models for the understanding and prediction of the influence of coatings and paint layers on the hygroscopic and deformative behavior of wooden objects subjected to changes in environmental climatic conditions.

http://www.iiconservation.org/node/1175

Altamura M.L., Bellucci R., Castelli C., Ciatti M., Frosinini C., Nieri P., Parri M., Rossi E., Santacesaria A., **La pittura a Pisa nel Duecento: osservazioni sulla tecnica artistica**, OPD restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze 17, 2005, p. 239 - 264

Abstract: Technical art history is now considered to be an essential part of the entire approach to understanding and planning conservation interventions. The theoretical tradition in the Italian school of conservation and restoration is based upon understanding and interpreting the work before undertaking technical operations. Experience over the years on a number of 13th-century paintings in the Tuscan area has stimulated an attempt to make some comparative observations about panel paintings in and around Pisa in the 1200s. In a comprehensive introductory section, the article traces theoretical approaches and technical traditions in documentary sources. Compelling questions are raised about the presence of both traditional local construction techniques and a broad, varied influence of Byzantine typologies. Pisa was historically one of Italy's most important seaports and trade centers, and similar to Venice, it was in constant contact with Byzantine culture and goods. This fact raises the plausible suggestion that during this period there may have been Eastern artists working alongside the local Pisan artisans and

masters. The authors analyze and hypothesize about the change from the use of chestnut for panel supports in the 1100s to the use of poplar during the subsequent century. Comparisons are made of construction and assembly techniques used in Pisan painted crosses and those found in other Tuscan areas, especially Florence and Siena. Painting and gilding techniques are also compared, and a number of painted works of the period are cited. Although no hard conclusions can be drawn at this time, the article contributes to a catalog of data from individual Pisan works.

Ambrosini D. and Paoletti D., **Holographic and speckle methods for the analysis of panel paintings. Developments since the early 1970s**, Reviews in Conservation, 2004, p. 38 - 48

Abstract: Of the methods of scientific investigation that are currently finding their place beside traditional art historical research, holographic and speckle methods are among those that can greatly contribute to the care and conservation of paintings on wooden panel. This paper aims to describe the state-of-the-art and the evolution of optical non-destructive analytical techniques, including holographic interferometry, electronic speckle pattern interferometry (ESPI) and speckle decorrelation. The various features of each technique are outlined.
http://www.iiconservation.org/fr/node/2240

Anderson L.W. and Krathwohl D.R. eds., **A taxonomy for learning, teaching and assessing: a revision of Bloom's taxonomy of educational objectives,** Complete edition, New York: Longman, 2001

Abstract: This revision of Blooms taxonomy is designed to help teachers understand and implement standards-based curriculums. Key topics: Cognitive psychologists, curriculum specialists, teacher educators, and researchers have developed a two-dimensional framework, focusing on knowledge and cognitive processes. In combination, these two define what students are expected to learn in school. Like no other text, it explores curriculums from three unique perspectives-cognitive psychologists (learning emphasis), curriculum specialists and teacher educators (C&I emphasis), and measurement and assessment experts (assessment emphasis). This "revisited" framework allows you to connect learning in all areas of curriculum.
http://www.transitionmathproject.org/partners/wcp/doc/bloom.pdf

Andres B. and Gierasimiuk E., **Wyniki wstepnych badan nad wpływem grzybów plesniowych na pigmenty stosowane w XV w. w małopolskim malarstwie tablicowym (Results of preliminary research on the influence of mould fungi on pigments used in the 15th century panel painting in Lesser Poland)**, Ochrona zabytków 2, 2009, p. 91 - 95

Abstract: Discusses issues related to the influence of mold on tempera paintings on wood panels. Samples of linden wood were covered with a glue and chalk ground, painted with egg tempera of a specific color, and then exposed to mold. After an incubation period, the paint layer was submitted to computer image analysis. The results of analyses demonstrated no correlation between the degree of growth of the test fungi on the sample and change of color.

http://www.nid.pl/UserFiles/File/Publikacje/Ochrona%20Zabytk%C3%B3w/OZ%202009/Andres.pdf

Ashley-Smith J., **Risk Assessment for Objects Conservation**, London, Butterworth Heinemann, 1999

Abstract: This book explains the mechanisms of deterioration of museum artifacts, quantifying the probability that damages will occur and estimating the rate of progress when it does. The principles outlined and the comprehensive explanations of scientific or mathematical material to take into consideration the readers who have no background in these areas, alongside a basic introduction. The structure of the book provides a logical progression through tools concepts information and examples. (BCIN) This book is about the effect of use and environment on objects in museum collections. It offers guidance on reduction of risk to exhibits of movable objects, defined as “anything smaller than a cathedral.” The author makes a point of distinguishing objects from living beings who have needs, desires, and rights. The museum makes use of external resources and provides benefits beyond its walls; risks should only be taken if the benefits warrant it. The author’s fundamental philosophy is that accepting risk is the same as accepting damage. (AATA)

http://www.getty.edu/conservation/publications_resources/teaching/case/olita/resources/docs/Assessments.pdf

ASHRAE **Applications Handbook Atlanta,** GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 2003

Abstract: The 2003 ASHRAE Handbook-HVAC Applications describes heating, ventilating and air-conditioning in a broad range of applications. It is divided into five sections: Comfort Applications, Industrial Applications, Energy-Related Applications, Building Operations and Management, and General Applications. The Handbook has been completely revised and updated from the 1999 version, and includes new chapters on HVAC applications in justice facilities (prisons, courthouses, etc.) and on electrical considerations in HVAC applications. Significant revisions have also been made to chapters such as Health Care Facilities, Laboratories, Sound and Vibration Control, Kitchen Ventilation, and Thermal Storage. This book provides background information to designers new to the application as well as those needing a refresher on the topic.
http://books.google.nl/books/about/ASHRAE_handbook.html?id=j0ZSAAAAMAAJ&redir_esc=y

Bardage S.L. and Bjurman J., **Adhesion of waterborne paints to wood,** Journal of Coatings Technology, Volume 70, 878, 1998, p. 39 - 47

Abstract: Using a modified torque technique, statistically significant differences in adhesion values were detected for waterborne model paints on wood as a function of moisture content, waterborne preservative, and after fungal inoculation. Change in a paint constituent sometimes resulted in a significant change in the adhesion value. The adhesion values of the alkyd emulsion paints tested decreased after inoculation with a blue stain fungus. On the contrary, the adhesion values of the acrylic dispersion paints tested became significantly higher after inoculation.
http://www.lw20.com/2011042924115187.html

Bauermeister J., Struchtrup M., **Zur Abnahme von Parkettierungen,** Restauro 8, 2011, p. 18 - 26

Abstract: Lange wurden Holztafelgemälde parkettiert, um den Bildträger plan zu halten. So auch ein Gemäldezyklus von Jan Baegert. Während einer umfassenden Restaurierungskampagne im Stadtmuseum Münster entschieden sich die Beteiligten für eine im deutschsprachigen Raum selten praktizierte Lösung im Umgang mit Parkettierungen.
http://www.baufachinformation.de/zeitschriftenartikel.jsp?z=2011129015554

Beardsley B.H., **A Flexible Balsa Back for the Stabilization of a Botticelli Panel Painting,** Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 153 - 156

Abstract: A flexible balsa back has been used to stabilize a panel painting that is exposed to wide and unpredictable temperature and relative humidity changes. A tondo by Sandro Botticelli from the Baltimore Museum of Art which had been treated for structural instability previously without success, is used as an example of the treatment. After cleaning the surface of the reverse, a bulking bonding material, a "moisture retardant/bonding layer" made with PVA (two grades), kaolin, and calcium carbonate was squeegeed onto the tondo and a piece of open weave fiberglass embedded into it. Balsa wood blocks were arranged on the reverse and adhered with a mixture of Multiwax W-445, Zonarez B-85, kaolin, and calcium carbonate. This mixture was more alkaline than the original support.
http://www.iiconservation.org/node/1701

Bellucci R., Boddi R., Castelli C., Ciatti M., Frosinini C., **Anticipazioni sul restauro del Ritratto di ignoto di Antonello da Messina, Antonello da Messina: Analisi scientifiche, restauri e prevenzione sulle opere di Antonello da Messina in occasione della mostra alle Scuderie del Quirinale,** ed. Gianluca Poldi and Giovanni Carlo Federico Villa. Milan, Silvana Editoriale, 2006, p. 76 – 87

Bergeon S., Emile-Male G., Huot C., Bay O., **The Restoration of Wooden Painting Supports Two Hundred Years of History in France,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 264 - 288

Abstract: Traces the lineage and technical traditions of restorers in the main Parisian studios serving the Louvre from the 18th century on. Transfer of paint layers from one wooden support to another or to canvas was widely practiced until 1938. Cradling of panel paintings was performed from 1740 on, with the sliding cradle that could accommodate some dimensional instability devised around 1770. Besides providing support, the cradle took on importance as an aesthetic accessory. Backing, a strategy whose date of origin is uncertain, involved the addition of

support to an older, thinned support. In 1965 a specialist in wooden supports was installed at the Louvre, and the ethic of minimal intervention came to the fore. Transfer of paintings ceased. Supports were designed to remove stress and minimize friction on distorted panels. The preservation of existing material became a guiding principle for restoration in France.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

Bergman R., Cai Z., Carll C.G., Clausen C.A., Dietenberger M.A., Falk R.H., Frihart C.R., Glass S.V., Hunt C.G., Ibach R.E., Kretschmann D.E., Rammer D.R., Ross R.J., Stark N.M., Wacker J.P., Wang X., White R.H., Wiedenhoeft A., Wiemann M.C., Zelinka S.L., **Wood Handbook, Wood as an Engineering Material,** General Technical Report FPL-GTR-190, Madison, WI, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2010

Abstract: Summarizes information on wood as an engineering material. Presents properties of wood and wood-based products of particular concern to the architect and engineer. Includes discussion of designing with wood and wood-based products along with some pertinent uses.

http://www.fpl.fs.fed.us/products/publications/specific_pub.php?posting_id=18102&header_id=p

Bernabei M. and Bontadi J., **Determining the resonance wood provenance of stringed instruments from the Cherubini Conservatory Collection in Florence,** Italy, Journal of Cultural Heritage, 2011, p. 196 - 204

Abstract:The wood provenance of what is considered today's most important collection of stringed instruments by Tuscan violin-makers, the Collection of the "Luigi Cherubini" Conservatory, at the Accademia Gallery in Florence, was analyzed dendrochronologically. On the basis of 95 geographically very widely distributed master chronologies, the most likely areas of origin of the Norway spruce wood used for the construction of 32 from a total of 37 instruments were determined. Consequently, the most important centres of wood supply were established. Finally, a location in the Tuscan-Emilian Apennines was identified as the likely provenance of a considerable quantity of timber used in the construction of these instruments. The results provide a new prospect in studying the geographical origins of the wood from which stringed instruments were made in the past, by using dendrochronological analysis.

http://www.citeulike.org/article/8751827

Bernabei M., Bontadi J. and Rognoni G.R., **A dendrochronological investigation of stringed instruments from the collection of the Cherubini Conservatory in Florence,** Italy, Journal of Archaeological Science, 2010, p. 192 - 200

Abstract: A total of forty-nine stringed instruments of the Conservatory Cherubini collection, at the Musical Instruments Department of the Accademia Gallery in Florence, were submitted to a dendrochronological investigation in order to date them, check the validity of their attribution and to find out more about their construction characteristics. Thirty-seven instruments were successfully dated, thereby determining the terminus post quem date of manufacture. The correlation values of the statistical cross-dating tests were generally very high. The dendrochronological analyses determined which instruments had been made from wood of the same provenance and, in some cases, from the same tree trunk. The mean chronology built from the musical instrument series, named ''Accademia Master Chronology'', is 558 years long and dates from 1396 to 1953AD. The interval between the youngest ring dated dendrochronologically and the given date of manufacture increased constantly in the course of the centuries, from a mean value of just over eleven years for instruments built in the eighteenth century, to nearly 74 years in the twentieth century, when the use of old wood from other artefacts became more frequent. Furthermore, in the Cherubini Collection, the average tree rings on violins are smaller than those of other stringed instruments; in fact, they increase in proportion to instrument size and are widest in cello and double bass.
http://www.researchgate.net/publication/223904005_A_dendrochronological_investigation_of_stringed_instruments_from_the_collection_of_the_Cherubini_Conservatory_in_Florence_Italy

Bernikola E., Nevin A. and Tornari V., **Rapid initial dimensional changes in wooden panel paintings due to simulated climate-induced alterations monitored by digital coherent out-of-plane interferometry**, Appl Phys A, 2009, p. 387 - 399

Abstract: Climate and environmental change may provoke constant microscopic dimensional alterations to organically composed works of art. The complexity of alterations obstructs the classification of destructive effects and sustainable strategies for preservation, and systematic investigation of change requires safe inspection tools, repeatable procedures and non-perturbing approaches. In this paper, a state-o-the-art description on the dimensional monitoring tools for the assessment of the effects of climate fluctuations in paintings is given. Rapid initial

start-up reactions of alteration processes that may simulate endangered conditions, which may be encountered during transportation of works of art, are studied. The case of wooden panel paintings is considered here as panels are representative models of inhomogeneous organic construction. The effect of the surface movement of panel painting surfaces due to simulated changes in temperature and relative humidity is characteristic of structural deterioration and as such these effects are primarily monitored in the start-up of the reaction process. The environmentally-provoked spatial alteration is recorded in full-field surface coordinates using optical coherent out-of-plane digital interferometry in a geometry utilizing holographic speckle patterns. Results demonstrate the suitability of the method to follow the start-up simulated process in real time directly from the work of art and to follow the rate of reaction towards equilibrium. The effectiveness of the full surface assessment provided in real time is presented and provides significant advantages compared to alternative techniques which are based on fragmented solutions. http://connection.ebscohost.com/c/articles/36810211/rapid-initial-dimensional-changes-wooden-panel-paintings-due-simulated-climate-induced-alterations-monitored-by-digital-coherent-out-of-plane-interferometry

Bisacca G. and Fuente Martinez J. de la, **The Treatment of Dürer's Adam and Eve Panels at the Prado Museum,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 10 – 24

Abstract: Albrecht Dürer's Adam and Eve were painted in 1507 on two separate panels, but they are to be considered a single work of art. Scant documentary evidence indicates that the panels have always been together and received conservation treatments in 1853, 1937, and 1972. The two panels appear to have undergone near-identical treatments until 1972, when it seems that the Adam panel alone was thinned and heavily cradled. The Eve panel, by contrast, retains its original thickness, including a porphyry imitation on the reverse. While each panel had two or three major splits, which were already visible in nineteenth-century photographs, the Adam panel has developed at least fifty new splits since having been cradled. The treatment of the two panels was undertaken at the Prado Museum between October 2008 and May 2009. There was a relatively minor intervention on the Eve panel, including the removal of three later crosspieces and the repair of a few splits. The treatment of the Adam panel entailed the removal of the cradle and the repair of several dozen splits by the insertion of narrow wedges. A curved secondary support strainer was then constructed and attached with new spring mechanisms that were developed during the course of the past year.
http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Blanchette R.A., Haight J.E., Koestler R.J., Hatchfield P.B. and Arnold D., **Assessment of Deterioration in Archaeological Wood from Ancient Egypt,** JAIC 33, 1994, p. 55 - 70

Abstract: Archaeological wood from many different ancient Egyptian tombs and diverse areas along the Nile Valley was examined to identify the type of deterioration present and to evaluate the current condition of the wood. Three different forms of degradation were identified and appear frequently among wooden cultural properties excavated from these ancient tombs; soft rot and brown rot fungal decay and a nonbiological form of deterioration. Decay by soft rot and brown rot fungi was prevalent in wood with extensive areas of degradation. Soft rot was characterized by cavities formed within the secondary cell walls. Cells with advanced stages of soft rot had numerous coalescing cavities that caused remaining cell wall layers to collapse. Ultrastructural observations of wood decayed by species of brown rot in the class Basidiomycetes revealed swollen, porous cell walls that were disrupted, leaving a granular mass of residual wall material. Many objects also suffered from a nonbiological type of deterioration. Cracks and fissures were evident within secondary walls, and cells delaminated at middle lamellae regions. Chemical deterioration from interactions among wood surfaces, limestone, gypsum, sodium chloride, and moisture are proposed as a cause of this degradation. The types of deterioration identified are common among objects that have survived in these unique physicochemical environments. Knowledge of these different degradation processes and the resulting condition of the wood provide important information that can now be used for developing appropriate conservation and restoration procedures.

http://www.jstor.org/discover/10.2307/3179670?uid=3738032&uid=2&uid=4&sid=47698919088337

Blanchette R.A., **A Guide to Wood Deterioration Caused by Microorganisms and Insects,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 55 - 68

Abstract: Describes the conditions that encourage biodeterioration of wood, the organisms responsible, and the macroscopic and microscopic decay patterns generated by various organisms. The author discusses the conditions hospitable to specific decay organisms and the biological processes occurring as they invade and degrade wood. He covers fungi (brown rot, soft rot, white rot, mold, and stain

fungi), bacteria, and wood-degrading insects in various life stages. He emphasizes that a clean, pest-free environment with relative humidity maintained below 60% is most effective against biodeterioration, and that correct identification of decay organisms is essential for remedial control.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings1.pdf

Blessley K., et al, **The Feasibility of Flash Thermography for the Examination and Conservation of Works of Art,** Studies in Conservation, 2010.

Abstract: This study investigates the feasibility of flash thermography for the examination and conservation of works of art: paintings, works on paper and sculpture. Thermography is a non-destructive technique for the identification of subsurface defects in materials. It is based on the propagation of surface-deposited heat through into the material. Differences in propagation between defect and defect-free areas result in a difference in the surface temperature of the material. The surface temperature is mapped over time by imaging with a mid-infrared digital camera. A xenon arc lamp is used to provide the initial source of radiation, and signal processing is typically applied to the collected data to reduce noise and to enhance key signal characteristics. This technique offers the possibility of investigating the structure of paintings and paper, particularly in cases where other non-destructive examination techniques do not provide sufficient information, for example subsurface delamination and layer structure. The results indicate that thermography is a good technique for detection of paint delamination and the degree of adhesion between layers, particularly in canvas paintings. It also successfully detected wood grain in situations where X-rays did not, although it was not effective for detecting voids or defects in wood.

http://www.courtauld.ac.uk/people/young-christina/PDF%202%20Studies%202010.pdf

Bobak S., **A Flexible Unattached Auxiliary Support,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 371 - 381

Abstract: When the distortion of a panel is due to forces applied by the cradle, such as a washboard effect produced by raising of wood between fixed battens, it may be best to remove the cradle. Depending on the condition of the panel--including

both evident damage and limitations imposed by prior repairs--an auxiliary unattached support structure may be able to substitute for the cradle. The flexibility of this construction must be greater than that of the panel so that the support yields to the panel. The author describes a construction consisting of a hardwood tray sized to accommodate the edges of the deformed panel and a flexible Sitka spruce batten and back spring to be placed behind it to support the panel while allowing limited movement in response to changes in ambient humidity. Design of moveable parts of the spring must allow for clearance of all members during maximum deformation. A stable backboard holds panel and support to the tray, which is inserted in the original frame. Use of this device is limited to panels with sufficient strength and frames with enough depth to hold the new support.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=175115

Bonsanti G. and Ciatti M., eds, **Ulisse Forni, Manuale del pittore restauratore. Studi per una nuova edizione,** Florence, Edifir, 2004

Bratasz L. and Kozlowski R., **Laser Sensors for Continuous In-Situ Monitoring of the Dimensional Response of Wooden Objects,** Studies in Conservation, 2005, p. 307 - 315

Abstract: The application of triangulation laser displacement sensors to the continuous in situ monitoring of the response of wooden cultural objects to variations in temperature and relative humidity in their environment is reported. The sensors are robust, fast and precise, provide non-contact measurements, and are capable of operating in the field. They have been applied to monitor the response of the altarpiece in the church of Santa Maria Maddalena in Rocca Pietore, Italy, to fluctuations in temperature and relative humidity caused by the use of the heating system. Complex short-, medium- and long-term responses of a variety of carved wooden elements have been recorded.
http://www.iiconservation.org/fr/node/1118

Bratasz L., Camuffo D., Kozlowski R., **Target Microclimate for Preservation Derived from Past Indoor Conditions,** Museum microclimates: contributions to the Copenhagen conference 19-23 November 2007(b), National Museum of Denmark, Copenhagen, Denmark, 2007, p. 129 - 134

Abstract: Proposes a new approach for establishing target indoor microclimates suitable for preserving organic materials susceptible to fracture and deformation, including wood and paints. Since mixed collections containing organic materials have adapted to individual indoor environments over many decades, the new approach argues that it is impossible to establish a priori the best RH level for the conservation of all such collections. Instead, the proposed strategy focuses on replicating the past average levels of RH and specifies bands of tolerable short-term fluctuations that may be superimposed over these average levels. The goal is to eliminate the upper 16% of fluctuations, which are considered the most risky; these correspond to one standard deviation in the distribution of the fluctuation amplitudes. The approach further proposes reducing the width of the target band of tolerable fluctuations by taking into account how much the fluctuations depart from the average seasonal RH level. Three case studies of historic churches illustrate the approach, representing different geographical locations, construction materials, and use patterns: the wooden church of S. Michael Archangel in Debno, Poland; the basilica of S. Maria Maggiore, Rome; and the stone church of S. Maria Maddalena, Rocca Pietore, Italian Alps. The approach is designed to be applicable also for temperature variations.

http://natmus.dk/fileadmin/user_upload/natmus/bevaringsafdelingen/billeder/far/Museum_Microclimate/Proceedings/musmic150.pdf

Bratasz L., Jakiela S. and Kozlowski R., **Allowable Thresholds in Dynamic Changes of Microclimate for Wooden Cultural Objects: Monitoring In-Situ and Modelling,** ICOM Committee for Conservation 14th Triennial Meeting, The Hague, 2, 2005, p. 582 - 589

Abstract: Triangulation laser displacement sensors have allowed for precise in situ measurements of short-, medium-, and long-term dimensional responses of sculpted wooden elements to variations of temperature and relative humidity. They show that massive wooden elements are endangered by mechanical damage. Most numerical modeling of the phenomenon quantified gradients of moisture contents and related stress distributions for a cylindrical object, imitating a wooden sculpture, subjected to a range of microclimatic fluctuations reflecting real-world situations. The obtained stress levels permit the determination of

allowable thresholds in the magnitude and rate of the air parameter fluctuations which the wooden objects may ultimately endure without irreversible deformation or damage.

http://eprints.sparaochbevara.se/67/

Bratasz L., Kozlowski R. and Kozlowska A., **Conservation of the Mazarin Chest: Structural Response of Japanese Lacquer to Variations in Relative Humidity,** ICOM Committee for Conservation 15th Triennial Meeting, 22 to 26 September 2008, New Delhi, India, 2, 2008, p. 1086 - 1093

Abstract: Moisture absorption and diffusion, dimensional response, as well as the related stress field in materials constituting lacquer furniture were investigated to support the conservation treatment of the Mazarin Chest, renowned as one of the finest pieces of Japanese export lacquer from around 1640 preserved at the Victoria and Albert Museum in London. The measurements demonstrated that both the wood support and the lacquer adsorb considerable amounts of moisture and undergo dimensional changes which, when restrained, lead to mechanical damage. The domains of tolerable fluctuations of relative humidity (RH) are quite considerable in the mid-RH region: variations in RH in the current display environment of the chest at V&A are much smaller. The domains become narrower, however, at high RH levels. The lacquer layer, though retarding the water vapor diffusion into the wood, cannot mitigate the stress development in the object if the variations in RH become significant.

http://www.cyf-kr.edu.pl/~ncbratas/aboutus/Kozlowski_Wood_2008.pdf

Bratasz L., Kozlowski R., Camuffo D., Pagan E., **Impact of indoor heating on painted wood: monitoring the altarpiece in the church of Santa Maria Maddalena in Rocca Pietore, Italy,** Studies in conservation 52, 3, 2007, p. 199 - 210

Abstract: Triangulation laser displacement sensors were applied to the continuous in situ monitoring of the dimensional response of the wooden altarpiece in the church of S. Maria Maddalena in Rocca Pietore,(Veneto, Italy), to variations in indoor temperature and relative humidity (RH) between December 2002 and March 2005. Further, a small inductive sensor was used to monitor the width of a crack in one of the elements. The measurements demonstrated that only the external layer of wood, several millimetres thick, continually absorbs and releases water vapor following external variations in RH. For massive elements, this leads to gradients in

the moisture content through the wood, a restraint of the dimensional change, and a development of stress, which is the main threat to the integrity of the wood and the decorative layer. Particularly strong RH variations and related high stress levels were produced by the intermittent heating system based on the inflow of warm air. To incorporate requirements for preservation, heating systems must provide a localized comfortable temperature in the area occupied by people without changing the natural climate of the church as a whole.

http://www.cyf-kr.edu.pl/~ncbratas/aboutus/LBCamuffo_2007.pdf

Bratasz L., Kozlowski R., Kozlowska A., Rachwal B., **Sorption of Moisture and Dimensional Change of Wood Species Used in Historical Objects,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage, 5-7 November, Braga 2008. Firenze University Press, 2010, p. 11 - 16

Abstract: 'General' moisture sorption and swelling/shrinkage patterns which would apply as a first approximation to any wood species constituting cultural objects were proposed. They were obtained from the experimental data measured for 21 historically important wood species used in the past for panel paintings and woodcarving. Information on further wood species of interest to the wood conservation community can be added to the Database and used to constantly improve the general relationships.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Bratasz Ł., Harris I., Lasyk Ł., Łukomski M., Kozlowski R., **Future climate-induced pressures on painted wood,** Journal of Cultural Heritage, volume 13, No. 4, October-December 2012, p. 365 - 370

Abstract: A broad category of cultural heritage objects are multilayer structures composed of organic, humidity-sensitive materials – wood, animal glue, paper, leather, bone or paints. They respond to variations in relative humidity (RH) in their environment by cyclically gaining and losing moisture, and consequently swelling and shrinking. Differences in the moisture response of the materials induce internal stresses in the individual layers of the structures, which cause objects to deform and crack. Polychrome wood is examined in detail. The cumulative physical damage of the design layer on wood due to repeated RH variations is quantified in terms of their magnitude and number of times they occur. The climatological risk index for accumulated, 'fatigue' damage is established, using a procedure to reduce irregular real-world climate histories into simple RH cycles of

known damage impact. Using output from the Hadley Model (HadCM3) and simple transfer functions predicting indoor temperature and RH from outdoor climate, changes in the indoor climate through to 2100 were forecast for unheated buildings. European maps highlighting the areas in which painted wood may be significantly affected by climate change are presented.
http://dx.doi.org/10.1016/j.culher.2012.01.013

Brémand F., et al, **Relief analysis of the Mona Lisa's wooden pane**l, Proceedings of the XIth International Congress and Exposition 2008, Society for Experimental Mechanics Inc., Orlando, Florida USA, 2008

Abstract: An original application of the use of optical methods for the study of the famous painting, Mona Lisa, is presented. Mona Lisa is painted on a poplar support, so the aim of our study is to obtain a 3D whole field profile of the panel on front and back face of Mona Lisa. Furthermore, these values allow us to understand the mechanical impact by the frame in which the panel is maintained attached. They are used to describe the hygromechanical behaviour of the wooden painting by comparing measurements made several times during a day. These experimental data have been used to realize a numerical model of the panel, and also used to validate the numerical simulations of the mechanical behavior of the panel. Shadow moiré technique and fringe pattern profilometry technique are presented. Two campaigns of tests have been realized and their results are compared.
http://sem-proceedings.com/08s/sem.org-SEM-XI-Int-Cong-s017p01-Relief-Analysis-Mona-Lisas-Wooden-Panel.pdf

Bret J., Jaunard D., Mandron P., **The Conservation-Restoration of Wooden Painting Supports Evolution of Methods and Current Research in the Service de Restauration des Musées de France,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 252 - 263

Abstract: The Service de Restauration des Musées de France bases its treatment of panels on results of research directed to specific problems of wooden supports. Accelerated aging of simulated treatments is combined with observation of actual treatments performed over the last 25 years to evaluate the effectiveness and consequences of procedures. The primary ethic of preventive conservation dictates minimal intervention and reversibility of treatments to preserve the integrity of the

work. One investigation looked at response of panels to variable relative humidity and determined that panels painted on both sides showed superior stability. Another study investigated the repair of splits and fractures, finding that gluing and the insertion of triangular inlays when necessary were least likely to cause secondary problems in a repaired panel. A third study compared methods of backing panels that had been severely thinned in earlier interventions to straighten warped wood. Two layers of honeycombed balsa pieces applied to the back of the panel proved resistant to distortion and effective at strengthening the panel. Disinfection and consolidation are also being studied to determine optimum procedures.
http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

Brewer A. and Forno C., **Moiré fringe analysis of cradled panel paintings,** Studies in Conservation, 1997, p. 211 - 230

Abstract: Cradle-related effects such as "washboarding" and tented flaking were investigated by computer-aided moiré fringe analysis of panel models subjected to cycled changes in relative humidity. In-plane and out-of-plane displacements were recorded and compared for cradled and unreinforced panel models. These results were related to the behavior of actual cradled panel paintings. Results indicate that restraint of warping increases in-plane strain due to swelling, and the strain distribution is in close correspondence with cradle restraint. Compressive strain, recorded over the fixed battens, and out-of-plane distortions in the exposed panel areas are discussed in relation to deformations and damages in cradled panel paintings.
http://www.iiconservation.org/it/node/921

Brewer A., **Effects of batten reinforcements on paintings on wood panel,** 12th triennial meeting, Lyon, 29 August - 3 September 1999, preprints (ICOM Committee for Conservation), Bridgland Janet (Editor), Earthscan Ltd., London, 1999, p. 276 - 281

Abstract: Effects of battens on panel paintings were first examined using observations, interviews with specialists, and information from conservation records. Battens were then classified into three groups based on degree of restraint: rigid and fixed, rigid and sliding, flexible and sliding. To examine behavior under changing relative humidity (RH), an example of each type was applied to mock-ups of thinned panel paintings which were conditioned to a moderate RH of 60%,

followed by three repeated cycles of low (40%) and high (80%) levels, and finally returned to 60%, all at constant temperature. Surface deformations were measured using digital photogrammetry and illustrated as wire-frame diagrams and raking-light photographs. Deformations were more apparent as restraint was increased, with twist overall and buckling in the less restrained areas. Less restraint in and out of plane allowed movement more like unrestrained panels. Sliding battens caused seizure of panel movement under extremely high RH conditions. Deformations near retainers were caused by wood movement during RH cycling.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=182193

Brewer A., **Effect of selected coatings on moisture sorption of selected wood tests panels with regard to common panel painting supports,** Studies in conservation 36, 1, 1991, p. 9 - 23

Abstract: The effect on moisture sorption of six types of coating (heat-infused and noninfused beeswax, Acryloid B-72, Saran F-310, commercial polyurethane and uncoated) applied to blocks of four different species of wood (mahogany, oak, basswood (linden), poplar) was examined after exposure to repeated cycles of relative humidity (RH). Each coating covered the entire sample. Plots of moisture sorption versus time for three RH-cycles showed characteristic curve patterns for each wood/coating combination. Sorption rate was calculated for each wood/coating combination. Analysis of variance showed that sorption was influenced by coating type and wood species.
http://www.iiconservation.org/node/740

Brough J., Dunkerton J., **The Construction of Panel Trays for Two Paintings by the Master of Cappenberg,** National Gallery Technical Bulletin 8, 1984, p. 63 – 70

Abstract: Following conservation of Christ before Pilate and The Coronation of the Virgin by the Master of Cappenberg, it was decided that the thinned panels were too weak and flexible to be reframed. The article gives details of the panel trays constructed to hold the painting against a cushioned auxiliary support.
http://www.nationalgallery.org.uk/technical-bulletin/brough_dunkerton1984

Browne F.L., **Wood Properties and Paint Durability,** 1962
http://books.google.nl/books?id=3ysuAAAAYAAJ&printsec=frontcover&hl=nl#v=onepage&q&f=false

Buck R.D., **Some Applications of Rheology to the Treatment of Panel Paintings,** Studies in Conservation, 17, 1972, p. 1 - 11

Abstract: A survey is given of some properties of wood related to dimensional stability. Warping, bending, elasticity, plasticity, moisture, and rheological behavior are briefly discussed. The treatment of two warped panel paintings with reference to the theoretical aspects is described.

http://www.jstor.org/discover/10.2307/1505557?uid=3738736&uid=2129&uid=2&uid=70&uid=4&sid=21100996553273

Buck S.L., **Shaker Painted Furniture Provocative Insights into Shaker Paints and Painting Techniques,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 143 - 154

Abstract: Analysis of Shaker painted wooden furniture to determine paints used and technique used. Almost all wooden objects were sized with a gum priming layer before the paint layer was applied to seal the wood fibers so that the paint would form a more consistent, intensely-coloured layer and a smaller amount of expensive pigment could be used to produce an even paint layer. Paint layers tended to penetrate the wood despite the size, probably due to a low ratio of pigment to binder.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood2.pdf

Buzzegoli E., Castelli C., Di Lorenzo A., I**l 'Compianto sul Cristo morto' del Botticelli dal Museo Poldi Pezzoli di Milano: Note di minimo intervento e indagini diagnostiche non invasive**, O.P.D. Restauro 16, 2004, p. 15 – 30

Castelli C., Ciatti M., Parri M. and Santacesaria A., **Considerazioni e novita sulla costruzione dei supporti lignei nel quattrocento,** OPD restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze, 9, 1997, p. 162 - 174

Abstract: Changes in the construction of wooden supports in central Italian painting of the 15th century reflect the increasing use of a new rectangular format influenced by the forms of classical architecture, a rethinking of the function of wooden supports and of the relationship between their construction and the painting itself. Instead of the Medieval system of rigid control obtained by nailed transverse bars, there were various experimental attempts to introduce a lighter and more mobile arrangement. Examples include works by Fra Angelico and other Florentine painters such as Neri di Bicci, Filippo Lippi, and the anonymous master of the panel in the parish church at Romena. The contribution of the Sienese school is also considered and a comparison made with the problems posed by the new format adopted by Bernardo Rossellino for the altarpieces in the Cathedral of Pienza. The response to these problems by painters at the court of Urbino is covered, using earlier studies on the constructions used in works by Joos van Gent, the construction of the Montefeltro Altarpiece by Piero della Francesca, and the comparative studies of two allegorical figures, probably from the studiolo in Gubbio.

Castelli C., **Metodo di Riduzione dei Movimenti dei Supporti Lignei Dipinti,** OPD restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze, 10, 1998, p. 87 - 94

Abstract: A new system of protecting and stabilizing panel paintings has been developed as part of a wider restoration campaign to improve the conservation of wooden supports. Deformations in the wood can be checked and improved stability acquired by the application of a material with the same characteristics as the original support; the increased thickness of the panel allows it to absorb atmospheric changes more easily. The system uses non-invasive materials which are easily removable.

Castelli C., **Proposta per un nuovo tipo di traversa per dipinti su tavola,** OPD Restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze, 2, 1987, p. 78 - 80

Abstract: The construction of a new type of cradle is explained with diagram and photographs of the tryptch by giovanni del biondo in the church of s. Croce in florence.

Cassar M., **Environmental Management Guidelines for Museums and Galleries.** London, Routledge.
http://www.tandfonline.com/doi/abs/10.1080/09647779409515385

Ciatti M., Castelli C., Santacesaria A., eds, **Panel painting: Technique and Conservation of Wood Supports**, Florence, Edifir 2006

Ciatti M., Frosinini C., Rossi Scarzanella C., eds, **Angeli, santi e demoni:Otto capolavori restaurati. Santa Croce quaranta anni dopo** (1966–2006), Florence, Edifir 2006

Ciatti M., Frosinini C., Bellucci R., eds, **La Croce dipinta dell'abbazia di Rosano. Visibile e invisibile. Studio e restauro per la comprensione**, Florence, Edifir 2007

Ciatti M., Natali A., Ritano P., eds, Raffaello: **La rivelazione del colore. Il restauro della Madonna del Cardellino della Galleria degli Uffizi,** Florence, Edifir 2008

Ciatti M., Meccio S., Rossi S. and Filippo Lippi C., **Le esequie di San Girolamo (Filippo Lippi: The funeral of St. Jerome)**, OPD restauro: rivista dell'Opificio delle pietre dure e laboratorio di restauro di Firenze 22, 2010, p. 243 - 252

Abstract: Describes the condition and treatment of a large (292 x 173 cm) 15th-century painting on wood panel by Filippo Lippi from the cathedral in Prato, Italy. The most precarious aspect of the panel was the lifting and separation of the ground and paint layers. Cross-section analysis showed that the outermost ground layer was flaking, thereby affecting the stability of the paint film. The authors describe the composition and construction of the panel, ground, and paint layers. Chemical action from prior restoration treatments was most likely the cause of the weakened bonds in the surface layers, resulting in the lifting and flaking. The main goal of treatment at this time was to stabilize the paint and ground layers. Sturgeon glue was used at different strengths (1:10 and 1:20 in water) to consolidate the layers. One phase of consolidation took place in a vacuum bag to assist in the penetration of the glue throughout the layers. The pictorial integration was completed using tempera and/or watercolors, applied with the selezione cromatica technique. The panel surface was protected with mastic varnish.

Ciatti M. and Castelli C., **The Conservation of Panel Painting Supports at the Opificio delle Pietre Dure: Experiences and Methodologies**, Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui. Los Angeles, Getty Conservation Institute, 2011, p. 25 – 35

Abstract: This paper presents the work done in the Florentine Opificio delle Pietre Dure for the improvement of the conservation of paintings on wooden supports, starting in the beginning of the 1980s. The introduction summarizes the main guidelines and the technical methods carried out in the recent past. The paper then presents case studies of important paintings that have undergone restoration in recent years. They are:

- Bronzino, Descent of Christ into Limbo, Santa Croce Museum, Florence: A new type of batten was proposed, with the same shape as the ancient ones, and inserted in a dovetail channel.
- Botticelli, Mourning of the Dead Christ, Poldi Pezzoli Museum, Milan: A new stretcher control system was applied without the original support being touched.
- Masaccio, a predella, Storia di San Giuliano, Horne Museum, Florence: The stretcher control system was applied with very few connection points, and the rear was closed with loose wooden elements.

· Antonello da Messina, Portrait of a Man, Palazzo Madama Museum, Turin: The flexible control system was not applied on the panel but was connected to the frame, modified to close the back of the painting.
· The Rosano Crucifix, Abbey of Santa Maria di Rosano, Rignano sull'Arno: The original construction system was reestablished, with a less invasive and more functional conservation treatment.
· Raphael, Madonna of the Goldfinch, Uffizi Gallery, Florence: Because of the ancient damage, a low-invasive technique was performed on the old cracks.

In the conclusion the paper points to the authors' planned research for the future.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Colmars J., Nakano T., Yano H., Gril J., **Creep Properties of Heat Treated Wood in Radial Direction,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage, Braga 2008, Firenze University Press, 2010, p. 24 - 29

Abstract: This paper discuss about ageing-like process of heating wood in completely dry conditions and the effects on creep properties for poplar wood (Populus alba). Creep tests have been performed in the radial direction, for heat treated and untreated samples over 10 hours. Beforehand some samples were heat treated at 150°C during a few days. Differences in creep phenomenon between new and aged samples are discussed with the help of graphical methods such as the approximated complex plane.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Conte S. Le, Moyne S. Le, Ollivier F., Vaiedelich S., **Using mechanical modelling and experimentation for the conservation of musical instruments**, Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September, ed. Gril, J., p. 161 - 164

Abstract: The Musée de la musique in Paris keeps a collection of more than 4500 musical instruments. Many of them are subject to investigations aiming at improving their conservation conditions. The approach to study these cultural heritage objects is pluridisciplinary, combining material analysis, research of historical context, and mechanical aspects. This paper focuses on the application of dynamical mechanics to a case study, the restoration to playable state of a historical harpsichord. The mechanical model supported the decision for the "best" restoration and conservation conditions

http://dx.doi.org/10.1016/j.culher.2012.04.004

Cronyn J. M. and Horie C.V., **St. Cuthbert's coffin, the history, technology and conservation,** Durham, Dean and Chapter, Durham Cathedral, 1985

Abstract: The seventh century (698 AD) oak coffin has been the subject of veneration and study for 1,200 years. The book describes recent conservation. An historical summary of the treatment and survival of the coffin is amplified by findings from technological, dendrochronological, and chemical analyses. Reversal of past conservation treatments (pine resin, glue, PVAC, plaster, and cellulose nitrate consolidants and adhesives) was followed by strengthening and readhering to a plywood backing with a poly(vinyl butyral) adhesive.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=85882

Deacon J., **Fungal Biology**, 4th ed., Chichester, Wiley-Blackwell, 2005

Abstract: Provides insights into many topical areas such as fungal ultrastructure and the mechanisms of fungal growth, important fungal metabolites and the molecular techniques used to study fungal populations. Focuses on the interactions of fungi that form the basis for developing biological control agents, with several commercial examples of the control of insect pests and plant diseases. Emphasises the functional biology of fungi, with examples from recent research. Includes a clear illustrative account of the features and significance of the main fungal groups.

http://www.scribd.com/doc/49072252/Fungal-Biology

Dinh A.T., Pilate G., Assor C., Perre P., **Measurement of the Elastic Properties of Minute Samples of Wood Along the Three Material Grain Directions,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage, 5-7 November 2008, Braga, Firenze University Press, 2010, p. 30 - 35

Abstract: Reaction wood is an important trait of secondary growth in trees, which allows the mechanical structure to be adapted to its environment. It is well-known that reaction wood is different from normal wood, in terms of anatomical and ultrastructural features. Among the important differences between reaction and normal wood, we can list: thicker cell walls, chemical composition, microfibril orientation... A complete characterisation of the mechanical properties at the tissue level remains however seldom, especially in the three material directions. This work proposed a complete characterisation of the stiffness of poplar, at the

tissue level, for normal wood, reaction wood, opposite wood. The material comes from a poplar tree artificially bent for several years to oblige the stem to produce reaction wood. This procedure allows large zones of tension, normal and opposite wood to be easily obtained for sample preparation. Two different micro-testing machines were designed and built in our laboratory: A tensile testing device with determination of the strain field using an optical microscope and image correlation (Radial and Tangential directions), with specimens about: 20 × 4.5 × 1.8 mm3; a 4-point bending device to determine the Longitudinal Young modulus on very small samples with determination of the deflection using a laser micrometer, with specimens about 30 × 2 × 0.7 mm^3. As most significant results, one may note the low transverse stiffness of tension wood in spite of its high density and the very high longitudinal stiffness of tension wood. Indeed, the specific longitudinal Young Modulus of tension wood reaches 70% that of crystalline cellulose.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Dinwoodie J.M., **Timber It's Nature and Behaviour**, E & FN Spon, London, 2000

http://www.crcnetbase.com/doi/abs/10.4324/9780203477878.fmatt

Dionisi-Vici P., Mazzanti P. and Uzielli L., **Mechanical response of wooden boards subjected to humidity step variations: climatic chamber measurements and fitted mathematical models,** Journal of cultural heritage 7, 1, 2006, p. 37 - 48

Abstract: Describes selected results from research focused on the behavior of wooden boards, simulating the supports of panel paintings, subjected to cyclic humidity variations. The article describes the mechanical response of two boards made of poplar (Populus alba) wood, 400 ◇ 400 ◇ 40 mm (length ◇ width ◇ thickness), assumed to behave as "structural replicas" of true panel paintings, subjected to step variations of air humidity under controlled conditions. One of the two boards was free to deform, and its cupping was monitored; the other was prevented from deforming, and the forces it exerted against its constraints were also monitored by means of an expressly developed measuring apparatus called monitoring cross beam (MCB). Free deformations of a third "dummy" board, smaller in size, were also monitored. Instantaneous values of forces and deformations, together with temperature and relative humidity of the controlled microenvironment, were monitored at 15 min intervals and stored in a datalogging system. Several adsorption-desorption cycles were carried out in a climatic chamber,

keeping T = 30×C and imposing RH step variations between approximately 35 and 50 and 65%. During some cycles, both faces of the boards were free to exchange moisture with the environment; during other cycles, one face was waterproofed to simulate paint layers. Each cycle lasted approximately three months in order to achieve constant equilibrium moisture content throughout the whole thickness of the boards; in total, the tests lasted over two years. In response to each step variation of RH, both forces and deformations showed the same kind of response: 1) with both faces free, response was asymptotic, reaching final state after approximately two to three months; 2) with one face waterproofed, the asymmetrical moisture gradients produced--in addition to asymptotic ones--transient responses as well, culminating in about 15 days and fading out after about six months. Descriptive models of the board's mechanical behavior were developed by fitting experimental data to the following general exponential equation, made by the sum of a "short period" and a "long period" component: Parameters p1 to p6 were computed for all cycles. Although the time required to reach equilibrium to the new steady humidity conditions in the reported tests was approximately three months, very fast responses to hygrometric disturbances were also detected, lasting hours, or even minutes. Further analysis of the collected data needs to be performed, based on the constitutive equations of the involved phenomena, namely moisture diffusion and mechano-sorptive behavior of wood. The main objective of this research is to develop an interpretative model featuring both descriptive and quantitative characteristics in order to predict the behavior of panel paintings under environmental variations; this predictive ability should then open the way to evaluating appropriate measures to improve their conservation.
http://www.sciencedirect.com/science/journal/12962074/7/1

Dionisi-Vici P., et al, **Monitoring Climate and Deformation of Panel Paintings in San Marco (Florence) and other Museums,** Wood Science for Conservation of Cultural Heritage, Florence 2007: Proceedings of the International Conference held by COST Action IE0601, L. Uzielli (editor), Florence, University Press, 2009

Abstract: This paper briefly describes selected past and ongoing researches carried out by the Authors at DEISTAF - University of Florence, in the field of monitoring deformations of Panel Paintings exhibited in important Museums and Historical Buildings – mostly in Florence –, related to the variations of microclimatic conditions. From actual deformations, behavior and sensitivity of wooden supports may be studied, mathematical models can be calibrated, and stresses can be evaluated. A self-powered concept-apparatus named "Deformometric Kit" is also described,

which was developed at DEISTAF in order to log during long periods the climate and the deformative behavior of the panels, or the forces acting on them, as in the Mona Lisa case. Some initial data and results from Deformometric Kits installed on two mock-panels placed in a room of the San Marco Museum are also described.
http://ottimari.agr.unifi.it/~uzielli/Alcune_Pubblicazioni/2009%20COST%20Florence%20Monitoring%20San%20Marco%20Museum.pdf

Duin, P. van, **Panels in Furniture: Observations and Conservation Issues, Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training,** Proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 92-103

Abstract: This paper is intended as an introduction to furniture and its conservation issues for professionals dealing with panel paintings. It discusses the construction of oak doors of cabinets in the Netherlands in the sixteenth and seventeenth centuries, and by systematic observation, it explores their relation to damage caused by changes in humidity. In particular, the influence of wooden boards attached cross-grain onto panels is considered. This issue relates to the construction and condition of a poplar panel of the Tabernacolo di Linaioli by Fra Angelico, created in Florence in 1433. Clearly, cross-grain supports may cause damage when panels shrink, but there is also evidence that when wooden auxiliary supports cover a substantial area of the panel and are well glued, the panel can absorb the tensions that would lead to shrinkage. Further research on old panels is required, to which a collaborative project by the Rijksmuseum, the Instituut Collectie Nederland (ICN), and University of Amsterdam will contribute. The second part of the article is devoted to the conservation treatment of two doors of a cabinet with floral marquetry, dated to 1690, by the Dutch master cabinetmaker Jan van Mekeren. A plea is made for preserving instead of trying to improve original constructions, because their quality should not be underestimated, and the authenticity of panels as well as of furniture is of paramount importance.
http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Duin, P.H.J.C. van, **The construction of flat decorated doors of Dutch seventeenth-century cabinets, Report of a master class, Restoring joints, conserving structures,** Tenth International Symposium on Wood and Furniture Conservation, Amsterdam, 8-9 October 2010, Vasques-Dias Miko (Editor), Stichting Ebenist, Amsterdam, 2011, p. 121-143.

Abstract: Some of the most challenging furniture conservation treatments that have been carried out in recent years in the Rijksmuseum were related to cabinets on stands decorated with marquetry. These cabinets on stands, with large flat doors and simple mouldings were very popular in Holland during the late seventeenth century. The cabinets were specifically designed to provide ample space for decorative surfaces. Decorations were made in different materials and with varied techniques: floral, geometrical and architectural marquetry, japanning, lacquer panels, textile coverings and paintings. The construction of the cabinets and specifically of the doors must have been a challenging task. The large flat surfaces made it difficult to use the tried and tested method of panels set into frames. The risk of shrinkage cracks or warping caused by movement of the wooden support had to be kept to a minimum. The article is a report of a masterclass in which the construction and condition of 16 pairs of doors were studied by the participants. This resulted in much information about the working methods of cabinetmakers in the past. A great variety of construction methods was found. Cleated ends are most common, but differ greatly in width, from 1.5 to 17 cm. Some cabinetmakers used more elaborate and also more labour-intensive construction methods. They made hollow doors and doors with panels made of different layers of wood. No construction method was successful in preventing shrinkage cracks, and the amount of shrinkage of the support did not seem to differ significantly between the various doors. An important finding was that nearly all cracks were actually failing joints between the wooden members. This failure was obviously caused by shrinkage but indicates that at some point in the 300 years life-span of the cabinets the glue became weaker than the wood.

Dulieu-Barton J.M., et al, **Deformation and strain measurement techniques for the inspection of damage in works of art,** Reviews in Conservation, 2005, p. 63 - 73

Abstract: The engineering techniques used for inspecting structural damage are not widely known in the conservation sector. Techniques are available based on deformation or strain measurement that have the ability to provide quantitative data. This paper reviews currently available techniques, covering point-strain

measurements using resistance strain gauges and fibre-optic sensors, as well as full-field optical measurement approaches such as holography, electronic speckle pattern interferometry, photoelastic stress analysis and photogrammetry. The underlying technology of each of the techniques is described for the non-specialist. The relevance of each technique is established from a conservation perspective through accounts of usage. The application of the techniques to a wide range of artwork, including panel paintings, statues, murals and mosaics is described and the results critically reviewed. The paper also provides an insight into possible future applications of the techniques and identifies areas for further investigation.
http://ae.metu.edu.tr/~melin/PDFs/OtherWork/REVIEWS_CONSERVATION.pdf

Dureisseix D., et al, **Follow-up of a panel restoration procedure through image correlation and finite element modeling,** International Journal of Solids and Structures, 2011, p. 1024 - 1033

Abstract: Residual stress estimation is an important question for structural integrity. Since residual stresses are self-balanced stress fields, a classical way to obtain information on them is to remove a part of the structure, and observe the structure displacement field arising from the stress redistribution. The hole-drilling method is such an approach. In some cases, as for the present one concerning a painted panel of cultural heritage, the hole-drilling method is not suited (a structure with a complex geometry, few tests allowed) but one can take advantage of structural modications if they are monitored (here, a restoration act). We therefore describe in this article a model updating approach, focusing on the residual stress estimation and not on the material parameter identication. This study couples an optical non-invasive shape measurement (digital image correlation, using a projected speckle pattern on the painted panel, with luminance compensation) and a numerical approach (3D finite elements) for the model updating. The 3D stereo-correlation is used to measure a partial displacement field between three different states of the structure (at three different times of the restoration act). The numerical part concerns stress evaluation, once the model and the experiments are compared using a geometric mapping and a spatial projection of discrete fields. Using modeling and identication, the simulation is used to obtain the residual stresses in the panel, before and after the restoration.
http://hal.archives-ouvertes.fr/docs/00/56/04/37/PDF/DDJCABFMHM.pdf

Dureisseix D. and Marcon B., **A partitioning strategy for the coupled hygromechanical analysis with application to wood structures of cultural heritage,** International Journal for Numerical Methods in Engineering, 2011, volume 88, issue 3, p. 228 - 256

Abstract: One of the main causes for damage of panel paintings of cultural heritage is due to the environmental micro-climatic variations. Wood science and numerical modeling may help to analyze and calibrate restoration interventions, to predict the behavior of the artwork, taking into account the individual painted panels and the conservation environment. In this article, a partitioning numerical strategy is proposed to predict by simulation the behavior of such artworks. It is based on a multiphysics partition focusing on the interactions between the different physics that are described in a thermodynamical framework. It is applied to the case study of Mona Lisa, modeled as a strongly coupled hygromechanical structure. The strategy is designed to couple two different modelings: a plate model for the mechanical behavior of the panel and 1D transverse diffusion for the moisture evolution. © 2011 John Wiley & Sons, Ltd.

http://onlinelibrary.wiley.com/doi/10.1002/nme.3173/abstract;jsessionid=A27AB093AC326546354A9225F1F7B0CD.d02t03?deniedAccessCustomisedMessage=&userIsAuthenticated=false

ECCO, **Framework of Competences for Access to the Profession of Conservation-Restoration,** ECCO General Assembly, Brussels, 13th June 2010

Abstract: The work detailed in this document arises from a mandate given by the E.C.C.O. committee at the General Assembly held in March 2008 to propose entry level competences and the proficiency of a person qualifying to use the title of Conservator-Restorer. This corresponds to the Descriptors given in the European Qualifications Framework (EQF) Level 7, which equates to a post graduate academic Master degree in accordance with E.C.C.O./ENCoRE guidelines. The work supports the delivery of the professional Conservator-Restorer qualification through an academic route but it is acknowledged that there are other routes into the profession that provide a similar level of skills, knowledge and competence. In addition to the central piece of work that is reported herein, the proposed competencies for access to the Conservation-Restoration profession, the proficiency levels at Bachelor degree and PhD are also suggested. These have been proposed in order to complete the typical range of academic qualifications encountered within the field of Conservation-Restoration and are equivalent to European Qualification Framework Levels 6 and 8. They represent the intermediate goals of an education pro-

gramme and the extended goals of life-long learning that a Conservator-Restorer should aspire to.

http://www.skr.ch/fileadmin/skr/pdfs/Grundlagentexte/ECCO/Competences_for_access_to_the_profession_ECCO.pdf

Elias M., Masa N., Cotteb P., **Review of several optical non-destructive analyses of an easel painting,** Complementarity and crosschecking of the results, Journal of Cultural Heritage, 2011, p. 335 - 345

Abstract: Five optical analyses of a given work of art are presented, using multispectral imaging, optical coherence tomography, goniophometry, UV-fluorescence emission spectroscopy and diffuse reflectance spectroscopy. All these methods are non-destructive, contactless, and implementable in situ. They all lead to results in quasi-real time. The multispectral camera allows imaging of the whole painting with very high definition and recording of 240 millions of spectra. Optical coherence tomography allows local 2D and 3D imaging with in-face and in depth stratigraphies inside the painting with a micrometric accuracy. It allows the evaluation of the pigment volume concentration inside a layer, the measurement of the thickness of one or two varnish layers, the detection and measurements of gaps inside the paint layer, the depth of varnish micro-cracks. Goniophotometry allows the measurement of the upper surface state of the painting in different locations, by quantifying the mean slope of the facets making up the surface. UV-fluorescence emission spectroscopy allows the identification of the resin, the binder and the ageing state of varnishes by use of databases of reference varnishes. Diffuse reflectance spectroscopy leads to pigment, pigment mixture anddye identifications again by use of databases. The three last methods are implemented with the same portable multi-function instrument. It allows time saving, locations on request in front of the artwork and easy use by non-scientists. Each instrument is described with its protocol and accuracy. The studied painting is a portrait of a lady painted by the Austrian artist Franz Strotszberg, chosen for its several restorations. The five kinds of results are successively detailed, analysed and compared between themselves. It is shown that the different results are complementary and their crosschecking brings thorough information. For example, the shape of the network of varnish microcracks detected on the surface with the multispectral camera is added to the measurement of their depth with optical coherence tomography. Another example allows connecting two different surface states of the upper varnished surface measured by goniophotometry with the identification of these varnish with UV-fluorescence and with their thicknesses measured with optical coherence tomography.

http://www.octnews.org/articles/2930673/review-of-several-optical-non-destructive-analyses/

Ellis L. and Heginbotham A., **An Evaluation of four Barrier-Coating And Epoxy Combinations in The Structural Repair of Wooden Objects,** JAIC, 2004, 1, p. 23 - 37

Abstract: Barrier coatings are widely used in conservation to add a measure of reversibility to an otherwise irreversible adhesive bond. Barrier materials are applied as thin films to mating surfaces prior to application of a primary (irreversible) adhesive. Subsequently, if reversal is required, the barrier layer can be softened or dissolved, releasing the bonded joint. This investigation was undertaken to determine the suitability of two synthetic resins for use as barrier layers in the bonding of wood with epoxy. The two materials in question, Paraloid B- 72 and Paraloid B-67, were chosen because of their potential to be practically reversible in low-polarity solvents. The two polymers were compared, as barrier materials, to two proven barrier coatings, hide glue and Butvar B-98, by measuring their strength in shear according to ASTM D905-98. Investigations were also undertaken to determine the amount of time necessary for barrier layers to dry prior to application of epoxy. Finally the practical reversibility of the barrier coatings was empirically evaluated. Paraloid B-72 was found to be a suitable barrier material in all respects, while Paraloid B -67 failed both strength and reversibility tests.
http://cool.conservation-us.org/coolaic/sg/wag/2002/WAG_02_ellis.pdf

ENCoRE, **Clarification of Conservation/Restoration Education at University level or Recognised Equivalent,** 3rd General Assembly, Munich, 19–22nd June 2001

Abstract: Fundamentally, the conservation/restoration of cultural heritage artifacts is a humanistic academic discipline within the global conservation discipline of all cultural heritage. The political and philosophical basis for all its activities was defined in 1996 in the report of the UNESCO World Commission on Culture and Development "Our Creative Diversity" as a right belonging to all humankind.5 The necessary existence, access, and protection of cultural heritage as a right to all humankind make great demands on the quality as well as democratic control of and public insight into all aspects of cultural heritage activities and management, including education. The quality, democratic control of and public insight into conservation/restoration education can only be guaranteed by governmentally validated academic education at university level leading to protected and internationally recognised academic titles. Educational institutions which are not called universities, but which offer programmes of study which in length, content and quality are regarded by the respective governmental validating bodies (such as

Ministries of Education) to be equivalent and/or compatible to university degree provision should be recognised as being the same level.
http://www.encore-edu.org/ENCoRE-documents/cp.pdf

Erhardt D., Mecklenburg M., Tumosa C., Olstad T., **New Versus Old Woods; Differences and Similarities in Physical, Mechanical and Chemical Properties,** ICOM Committee for Conservation 11th Triennial meeting, Edinburgh, Scotland, 1996, p. 903 - 910

Abstract: Physical, mechanical, and chemical properties of specimens of new and old (17th-century) wood (Pinus sylvestris L.) from the same locale in Norway were examined. Only slight changes resulted from more than 300 years in an uncontrolled environment. No significant differences were seen in mechanical and physical properties including stress-strain behavior and dimensional moisture isotherms. Chemical changes found in the resin and cellulose were minor. Analysis indicated some hydrolysis of xylan. These results confirm previous work showing that wooden objects of all constructions, including furniture, safely tolerate moderate fluctuations in temperature and relative humidity. Cycling experiments on the present specimens confirmed this. Intact wood is chemically stable over a wide range of environments. The deterioration of furniture and wooden objects is due primarily to other factors, including abuse, extreme changes in temperature or relative humidity (such as hot, dry conditions caused by central heating), biological attack, or liquid water.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=169573

Erhardt D., Tumosa C.S. and Mecklenburg M.F., **Applying Science to the Question of Museum Climate,** Museum Microclimates, Contributions to the Copenhagen Conference, Copenhagen, National Museum of Denmark, 2007, p. 11 – 18

Abstract: An examination of the history and development of recommendations for the climate in museums reveals that there was minimal scientific support for the values and ranges that were selected. The small basis of research that existed was often extended to materials or objects to which it did not apply; decisions that were merely best guesses based on minimal evidence became set in stone; and the rationale for many decisions seems to have been forgotten or twisted around. Many recommendations were based on considerations other than permanence of the objects, such as mechanical limitations of HVAC systems, constraints imposed

by the exterior climate or historic building regulations, or costs of implementation and maintenance. It is only relatively recently that research has provided a general scientific basis for determining appropriate values for the museum climate, especially the range in which temperature and relative humidity can be safely allowed to vary. Because the results of this research differed from what had become climatic dogma, it was criticized by some in the field. However, the results have stood up, with no substantive challenge to the data or conclusions, and are increasingly widely accepted.

http://www.conservationphysics.org/mm/index.html

Falciai R., et al, **Continuous monitoring of wooden works of art using fiber Bragg grating sensors**, Journal of Cultural Heritage, 2003, p. 285 - 290

Abstract: In recent years the control and monitoring of works of art has gained more and more importance. In particular, works partially or totally realized with wood, such as polychrome sculptures, painted panels or Crucifixes, are highly sensitive and delicate and thus need a particular attention. The wooden support is, in fact, an essential element for the stability of pictorial layers: the color lies on a preparation, which in turn, is anchored to the wood. Wrong conservation methods, i.e. in an environmental climate that is not controlled, or intrinsic mechanical stresses, can warp such structures, and the effects can be irreversible and destructive to the painted layer. The use of fiber Bragg grating (FBG) sensors for the quasi-distributed, in situ measurement and continuous monitoring of deformations in painted wood panel is proposed. In order to demonstrate the applicability of FBG sensors to painted wood panels, a wooden support, made using the same 15th–16th century techniques, was prepared in the Opificio laboratories. A number of Bragg grating sensors were affixed in several critical points, on the back and front sides and on the strengthening cross-beams, in order to detect deformations in the panel dependent on the variations in the environmental relative humidity (RH). Measurements during the removal of the cross-beams are also reported. The results of measurements have shown the applicability of FBG sensors for the continuous in situ monitoring of valuable wooden objects and works of art.

http://www.citeulike.org/article/36222

Fontana R., et al, **Integrating 2D and 3D data for diagnostics of panel paintings,** Optical Metrology for Arts and Multimedia, SPIE, 2003

Abstact: Imaging techniques are widely used for the diagnostics of paintings. The results, collected by applying various imaging techniques are generally compared by the art historian who studies the object. These 2D data can be effectively integrated to form a multi-dimensional dataset, and added to a 3D digital model of the painting, thus creating a complete package of information about the opera. In this work we present some examples of applications of data integration with measurements performed on some important panel paintings. The imaging analysis was carried out by applying techniques such as infrared reflectography, colour and false colour imaging and ultraviolet fluorescence. The IR reflectogram, the false colour and the colour image are simultaneously acquired with a scanning device characterized by a high resolution (16 dots/mm2), a high tonal dynamic and point-to-point correspondence between these three images. A multi-spectral device, based on a high resolution CCD camera, is used for UV fluorescence. The 3D relief was obtained by means of scanning microprofilometry with a quota resolution of about 1 micron. The integration of the 3D model with the results given by several imaging techniques greatly increases the information and it eases the analysis of the painting under investigation.

http://adsabs.harvard.edu/abs/2003SPIE.5146...88F

Francis D., Tatam R.P. and Groves R.M., **Recent developments in shearography,** (review), Meas. Sci. Technol., 2010, 21, 102001.

Abstract: Shearography is a full-field speckle interferometric technique used to determine surface displacement derivatives. For an interferometric technique, shearography is particularly resilient to environmental disturbances and has hence become an invaluable measurement tool outside of the optics laboratory. Furthermore, the inclusion of additional measurement channels has turned shearography from a qualitative inspection tool into a system suitable for quantitative surface strain measurement. In this review article we present a comprehensive overview of the technique, describing the principle of operation, optical configurations, image processing algorithms and applications, with a focus on more recent technological advances.

http://repository.tudelft.nl/view/ir/uuid%3A4045f126-6b59-49b6-968e-8d21cef5c859/

Frihart C.R., **Adhesive Groups and How They Relate to the Durability of Bonded Wood,** Journal of Adhesion Science and Technology 23, 4, 2009, p. 601 - 617

Abstract: There is a need to develop models that evaluate the interaction of wood adhesives at the macroscopic level to explain observations on the durability of bonded wood laminate products with changing moisture conditions. This paper emphasizes a model that relates durability to strain on the bondline caused by wood swelling. The effect of this strain is discussed in relation to two groups of adhesives with different chemistry, structure-property and adhesive-wood interaction relationship models. The in situ polymerized adhesive group involves highly cross-linked polymers with a rigid backbone that need to limit the swelling of the wood surface to provide a durable bond. The pre-polymerized adhesive group includes polymers with backbone flexibility and limited cross-linking so that they can thus distribute the swelling strain within the adhesive. These models emphasize the importance of the adhesive-wood interactions and end-use application for establishing the performance criteria.

http://treesearch.fs.fed.us/pubs/32702

Frihart C. R. and Hunt C.G., **Adhesives with Wood Materials, Bond Formation and Performance**, Wood handbook: wood as an engineering material General technical report FPL ; GTR-190, ed. Robert J. Ross, Madison, WI, U.S, Dept. of Agriculture, Forest Service, Forest Products Laboratory, 2010

Abstract: Adhesive bonding of wood plays an increasing role in the forest products industry and is a key factor for efficiently utilizing our timber resource. The main use of adhesives is in the manufacture of building materials, including plywood, oriented strandboard, particleboard, fiberboard, structural composite lumber, doors, windows and frames, and factory-laminated wood products. Adhesives are also used in the assembly of furniture and cabinets, manufacture of engineered wood products, and construction of residential and commercial structures. Adhesives transfer and distribute loads between components, thereby increasing the strength and stiffness of wood products. Effective transfer of stress from one member to another depends on the strength of the links in an imaginary chain across the adhesive-bonded joint. Thus, the performance of a bonded joint depends on how well the complex factors that contribute to the properties of the individual links (wood, adhesive, and interphase regions of wood and adhesive) are controlled during product assembly, which ultimately determines the strength of the chain.

http://www.fpl.fs.fed.us/products/publications/specific_pub.php?posting_id=17970&header_id=p

Frihart C.R., Charles R., **Wood adhesion and adhesives,** Handbook of wood chemistry and wood composites, Boca Raton, Fla: CRC Press, 2005

Abstract: An appreciation of rheology, material science, organic chemistry, polymer science, and mechanics leads to better understanding of the factors controlling the performance of the bonded assemblies. Given the complexity of wood as a substrate, it is hard to understand why some wood adhesives work better than other wood adhesives, especially when under the more severe durability tests. In general, wood is easy to bond to compared to most substrates, but it is harder to make a truly durable wood bond. A main trend in the wood industry is increased bonding of wood products as a result of the use of smaller diameter trees and more engineered wood products

http://www.treesearch.fs.fed.us/pubs/22048

Fuesers O., Krieg V., Kühnen R., **Studie zum hygroskopischen Verhalten von Holz: Dehnungsmessstreifen zur Dokumentation von Materialeigenschaften,** Zeitschrift für Kunsttechnologie und Konservierung 19, 1, 2005, p. 129 - 136

Abstract: Reports the results of an experiment concerning the hygroscopic behaviour of oak in different climatic conditions. The dimensional changes of the wood were measured with strain gages. Three oak wood panels were placed in hermetically sealed boxes with different air volumes, which were exposed to temperature changes. Humidity was not regulated, and no other hygroscopic material was present. The results of the experiment show that the movement of the wood can be reduced by minimizing the surrounding air volume. Already with a ratio of 1 kilogram wood to 100 litres air a stabilizing effect can be measured. Besides the ratio of wood to air volume and relative humidity, a constant temperature plays an important role for the dimensional stabilization of wood, especially when only a small air volume is available for humidity exchange.

http://www.baufachinformation.de/zeitschriftenartikel.jsp?z=2005079011300

Garcia M., S**tructural Interventions on Sixteenth-Century Monumental Oak Panels in Tomar, Portugal,** Poster in Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix, Alan (Editor) and Chui, Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 200 - 201

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing4.pdf

Gavrilov D., et al, **Infrared Methods in Noninvasive Inspection of Artwork,** 9th International Conference on NDT of Art, Jerusalem, Israel, 2008

Abstract: The problem of attribution and forgery in artwork is quickly becoming more acute with the advance of both the technology and experience of painting forgers. Sometimes even an experienced expert is not able to detect counterfeits that have been made with almost the same materials and technique as the original. Further, even the substitution of the signature of a famous artist on a painting can dramatically increase its value. Another problem of interest is the examination process of a painting preceding its restoration. This procedure can show the restorer the most affected regions of a canvas and/or its delimitations, separating particular regions by the extent of their damage. For these reasons, the role of professional scientific examination is of great importance. Thus, scientific procedures based on modern high-technological devices and methods must be developed to enable both restoration preexamination and complex forgery-detection. In this article the three infrared methods suitable for the inspection of art inspection are discussed. These include near infrared vision, thermography, and pulse phase thermography, a method never before used in art field. Through the use of several original masterpieces, these techniques are shown to be effective instruments for art inspection and restoration alike. They permit the detection of hidden underdrawings that were done before the painting was finished, concealed and altered signatures, and restored regions of pictures. These methods may also be used to locate delaminations between the paint layers and areas of varying paint thickness.

http://www.ndt.net/article/art2008/papers/040Gavrilov.pdf

Glatigny J.A., **Backings of Painted Panels,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 364 - 370

Abstract: The Institut Royal du Patrimoine Artistique in Brussels has occasionally used balsa block backing on panel paintings that were severely thinned or distorted. This article recounts the process of stabilizing a 17th-century panel painting of the Adoration of the Magi attributed to the Francken family with this method. The panel was flattened in a microclimate box in which relative humidity (RH) was gradually raised to 75%. Two staggered layers of end-grain balsa wood blocks were placed diagonally with respect to the grain of the panel and affixed with adhesive consisting of seven parts beeswax, two parts dammar resin. The RH was gradually

reduced to 50%, the surface was cleaned and retouched, and the panel was re-framed. No distortion was observed over the following year in spite of fluctuating RH in the panel's environment.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Goli G., Fioravanti M., Busoni S., Carlson B., Mazzanti P., **Measurement and modelling of mass and dimensional variations of historic violins subjected to thermo-hygrometric variations: The case study of the Guarneri "del Gesú" violin (1743) known as the "Cannone",** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September, ed. Gril J., p. 154 - 161

Abstract: This paper presents a study regarding the hygro-thermal conditions to which the violin Guarneri "del Gesù" (1743), known as the "Cannone", is subjected during its conservation and occasional use in concerts with special attention on its mass and dimensional variations. Several environmental measurement campaigns were planned and carried out using relative humidity and temperature probes. The violin mass variation was measured continuously inside the display case where it is conserved, and before and after concerts by means of a special exhibition frame integrating a precision balance. These measurements enabled reproducing the thermal and hygrometric variations to which the violin is normally subjected using a purposely-developed portable climatic chamber, and also enabled measuring the consequent hygroscopic and thermal deformations in selected points by means of a purposely-developed measuring frame. An empirical model for computing the mass variations according to the variation of environmental conditions was implemented and verified and the typical mass variation consequent to the use of the violin during concerts was also determined. The violin's thermal and hygroscopic deformations were measured in selected points for given temperature and relative humidity steps. The paper includes a discussion about the possible impact of hygro-thermal variations on violin conservation.

http://dx.doi.org/10.1016/j.culher.2012.04.007

Goto D.T. and Groves R.M., **A combined experimental with simulation approach to calibrated 3D strain measurement using shearography,** Proc. SPIE 2010, 7387, 73871J

Abstract: This paper is concerned with the development of a calibrated 3D shearography strain measurement instrument, calibrated iteratively, using a combined mechanical-optical model and specially designed test objects. The test objects are a cylinder loaded by internal pressure and a flat plate under axial load. Finite element models of the samples, combined with optical models of the shearography system, allow phase maps to be simulated for subsequent comparison with experimental phase maps from the shearography instrument. The algorithm to extract the strain maps from the phase maps includes an error compensation for in-plane strains on curved surfaces, measurement channel redundancy, variations in the shear magnitude due to object shape and the optical characteristics of the imaging system. The improvement introduced by the error compensation techniques is verified by the opto-mechanical simulation and its effect is demonstrated experimentally on maps of displacement gradient.

http://repository.tudelft.nl/view/ir/uuid%3A73658655-2114-4fa4-81a6-aa50d0eab600/

Grabner M., Kotlinova M., **Ageing of Wood – Described by the Analysis of Old Beams,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage 5-7 November, Braga. Firenze University Press, 2010, p. 42 - 46

Abstract: Wood underlies ageing processes which means that the properties of old wood have been changed. Wood density shows very close relationships to the amount of latewood (for softwoods only). There are no changes of the wood anatomy due to ageing; except due to destruction by insects or fungi. Interior beams of two buildings (felling of the trees 1720 AD and 1854 AD) were sampled. To understand the effect of ageing on wood density, x-ray densitometric analyses of 10 beams from pith to bark were done. Plotting radial profiles of percentage of latewood and wood density sometimes showed an increasing divergence of these trends with increasing cambial age.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Grattan D. and Michalski S., **Environmental Guidelines for Museums - Temperature and Relative Humidity** (RH), Canadian Conservation Institute, October 2010

Abstract: This general introduction to the current approach to controlling ambient RH and temperature in museums is intended for all museum professionals. It is based on the "Museums, Galleries, Archives and Libraries" chapter in the American Society of Heating, Refrigeration, and Air Conditioning Engineers Inc. (ASHRAE) Handbook, a rather technical document intended primarily for engineers designing, maintaining, or operating HVAC systems in buildings that house heritage collections. The approach taken in the chapter represents a departure from earlier more traditional thinking about museum environments, which called for stringent control of RH and temperature. In the current approach, RH fluctuation is linked to measurable damage in artifacts. Certain types of artifacts are much more sensitive to RH fluctuation than others, and it is neither economical nor environmentally acceptable to have very tightly controlled conditions if they are not necessary.

http://www.cci-icc.gc.ca/caringfor-prendresoindes/articles/enviro/index-eng.aspx

Griesbach M., **A Hybrid Approach to the Structural Treatment of Panel Paintings: Case Studies from American Collections,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 82 - 91

This paper presents case studies exemplifying how varied structural conservation techniques from different regional traditions proved to be very useful in the design of the treatments shown. Four treatments are described. The first two represent well-established traditions in the treatment of panels, one of Italian origin and the other British. The third and fourth treatments are departures from these systems and show how adaptations were made to meet the particular needs of each painting. The mechanics of each treatment are not the primary focus here. Instead, the reasoning behind the choice of structural systems for a particular issue or problem is addressed.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Gril J., Ravaud E., Uzielli L., Dupré J. C., Perré P., Dureisseix D., Arnould O., Dionisi Vici P., Jaunard D., Mandron P., **Mona Lisa saved by the Griffith theory: Assessing the crack propagation risk in the wooden support of a panel painting.** In International Conference on Integrated Approach to Wood Structure, Behavior and Applications, ESWM and COST Action E35, 2006

Abstract: A 2D finite elements model of the wooden support of Mona Lisa painting was developed to estimate the risk of propagation of the existing crack due to the restraining action of the frame, using observations on the wood structire and panel geometry and measurements of the forces exerted by the crossbars on the panel. A good agreement was obtained with shadow Moiré data of the displacement field. According to the simulations, the frame applies a small tearing and a slight opening of the crack lips; the calculated release energy rate is far below the critical values, suggesting practically no propagation risk, even accounting for the effet of hygrothermal fluctuations.

http://www.citeulike.org/user/dureisse/article/5518143

Groves R.M., Pradarutti B., Kouloumpi E., Osten W. and Notni G., **2D and 3D non-destructive evaluation of a wooden panel painting using shearography and terahertz imaging,** Non-destructive Testing and Evaluation International, 42 (6), 2009, p. 543 - 549

Abstract: Structural diagnostics information about artwork is commonly obtained by adapting and applying non-destructive testing techniques from engineering. Shearography is a technique well known for type inspection, and for structural analysis in automotive, aerospace and industrial applications. In art conservation, a limited number of shearography sensors are in use at museums and research institutes throughout the world for detecting surface and sub-surface defects. Terahertz imaging is a new and rapidly developing non-destructive testing technique that has so far found application mainly for security. The aim of this study is to measure a complex object, a wooden panel painting using both techniques and to determine the capability of a combined sensor for cultural heritage applications.

http://publica.fraunhofer.de/documents/N-96995.html

Groves R.M., Liu X., Li A., Hackney S., Osten W. and Peng X., **Virtual reality visualization of strain data from shearography,** Proc. Lacona VIII, Sibiu, Romania, 2009, p. 29

Abstract: The development of virtual reality algorithms for the display of shearography strain data from a canvas painting in a Virtual Reality Modelling Language (VRML) compatible interface provides a new powerful tool for the cultural heritage community. Shearography is an optical non-destructive testing technique providing non-contact full-field displacement gradient data on surface and sub-surface defects in the form of phase maps, which are usually colour-coded for display. Since for artwork, the colour variation of the painting composition is an important reference for locating defects, strain expressed as a deviation in height of the surface (false height) can be implemented. The effect is rather like a raked light photograph. Using a freely downloadable VRML viewer the object can be rotated in virtual space, allowing the user to view the painting surface at a small angle, making small defects more easily identifiable. As this is performed virtually, it can be performed on a remote PC.

http://www.lacona8.ro/pagini/home.html

Guidi G., et al, **Painting Survey by 3D Optical Scanning, The Case of the Adoration of the Magi by Leonardo da Vinci,** Studies in Conservation, 2004, p. 1 - 12

Abstract: Optical scanning has been applied to generate a complete 3D model of the famous Adoration of the Magi by Leonardo da Vinci (Uffizi Gallery, Florence). Front and rear surfaces and the sides of the great painting on 10 vertical planks of wood were scanned with a lateral resolution around 0.3 mm, so as to obtain a high quality three-dimensional digital representation. The main goal was to highlight and measure a map of deviations from planarity due to the curving and warping of the wood, leading to the possibility of planning an intervention in order to prevent further deterioration. Some parts of the painting, exhibiting visible local defects, were acquired with 90 µm of resolution. Application of 3D optical scanning has been proved to be of unique value for documenting spatial deformation suffered by panel paintings and can represent a reference tool for periodic monitoring of their state of conservation.

http://www.iiconservation.org/hr/node/1076

Hagan E., Quasney E. and Mecklenburg M., **A parametric analysis of relative humidity effects on traditional panel paintings,** Materials issues in art and archaeology VII, symposium held November 30-December 3, 2004, Boston, Massachusetts, U.S.A., Materials Research Society symposium proceedings, 852, Vandiver Pamela B., Mass Jennifer L. and Murray Alison (Editors), Materials Research Society, 2005, p. 3 - 11 [ISBN 1-558-99800-4]

Abstract: A finite element analysis was performed on panel painting structures subjected to changes in relative humidity. Measured Young's modulus values and humidity expansion coefficients were used to define the properties of materials characteristic to northern and southern European panels. Models of northern panels simulated white oak and two layers of oil paint, while models of southern panels simulated cottonwood with gesso and two oil paint layers. In both cases, the properties of the oil paints were input for lead white and Naples yellow, respectively. Influence of radial/tangential grain orientation, panel thickness, and structural support were investigated through various humidity changes. Results are presented in the form of stress in the wood, gesso, and paint layers as well as curvature of the painted surfaces. The authors discuss methods of reducing panel curvature with structural support, which involve applying a frictionless cradle, wood battens, or verso gesso layer. Verification of the model was performed with a derivation of general stress equations for a cradled painting with no friction between the slider bars and the panel. A comparison of derived and parametric results confirms accurate behavior of the model.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=241302

Hansen E. F., **The effects of solvent quality on some properties of thermoplastic amorphous polymers used in conservation,** Materials Issues in Art and Archaeology IV, edited by Pamela B. Vandiver, James R. Druzik, Jose Luis Galvan Madrid, Ian C. Freestone and George Segan Wheeler, Material Research Society, 1995, p. 807 - 812

Abstract: Reviews the effects of solvent quality on the physical properties of "amorphous" polymers applied from solution, with a focus on recent testing of materials used in the conservation of art objects. Because the solvent composition or quality affects the shape and orientation of polymer molecules in solution, the nature of the partly crystalline dry film can also be affected. Thus, the physical and optical properties of a number of polymers have been shown to vary when deposited from solutions of different quality. This phenomenon is specifically related to the desired performance of a coating, adhesive, or consolidant used for the

conservation of an art object. The effects of "good" or "poor" quality solvents on the physical properties of solution-cast films of poly(vinyl) acetate and Acryloid B-72 are discussed. In addition to polymer specific variations due to solvent quality on the glass transition temperature and the tensile properties (strength and elongation), the effects of quantitative amounts of retained solvent on these properties are considered. – AATA

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=165835

Hansen E.F. and Bishop M.H., **Factors Affecting the Re-Treatment of Previously Consolidated Matte Painted Wooden Objects,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 484 - 497

Abstract: Consolidating porous, fragile matte paint without affecting the appearance of an object is considered by ethnographic conservators to be one of the most challenging conservation treatments. Today, due to a greater knowledge of preventive conservation and an increasing consideration of ethical issues, consolidation treatments are not so readily or routinely attempted as in the past. But many objects have been treated in the past, and conservators are often required to re-treat them. This chapter considers some factors affecting the choice of procedures and materials for re-treatment of painted wood objects in which a previous consolidation treatment produced an undesirable change in appearance or insufficiently strong consolidation. This discussion is based on the authors' previous reviews and evaluations of treatment methods and materials. One major difficulty encountered is ascertaining what materials and methods have been used in prior conservation treatments, due in a large part to a lack of documentation. Therefore, another purpose of this chapter is to emphasize the need for a comprehensive history of the materials used in the consolidation of painted objects.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood6.pdf

Hastings Lynne D. and Bigelow D., **Collaborations Past and Present: A Classical Success Story,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 437 - 453

Abstract: This article addresses two collaborations that created and conserved an important suite of Baltimore painted furniture for past and future enjoyment. These critical dialogues—between artist and client, curator and conservator—have spanned almost two centuries.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood5.pdf

Helfen L., et al, **High-resolution three-dimensional imaging of flat objects by synchrotron-radiation computed laminography,** Applied Physics Letters, 2005, p. 071915-1 – 071915-3

Abstract: Computed laminography with synchrotron radiation is developed and carried out for threedimensional imaging of flat, laterally extended objects with high spatial resolution. Particular experimental conditions of a stationary synchrotron source have been taken into account by a scanning geometry different from that employed with movable conventional laboratory xray sources. Depending on the mechanical precision of the sample manipulation system, high spatial resolution down to the scale of 1 mm can be attained nondestructively, even for objects of large lateral size. Furthermore, high beam intensity and the parallel-beam geometry enables easy use of monochromatic radiation for optimizing contrast and reducing imaging artifacts. Simulations and experiments on a test object demonstrate the feasibility of the method. Application to the inspection of solder joints in a flip-chip bonded device shows the potential for quality assurance of microsystem devices.

http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4893647&abstractAccess=no&userType=inst

Hoadley R.B., **The Dimensional Response of Wood to Variation in Relative Humidity,** Conservation of Wood, Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 1 - 6

Abstract: Seasonal variation of relative humidity in heated buildings may produce perpendicular-to-grain dimensional change in wood of up to several per cent. However, the elastic strain limit is generally, less than 1%. Therefore if free swelling or shrinkage is restrained, compression set or tension failure may result. Common problems involving restrained wood are analyzed and recommendations for dimensional control are discussed.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=11443

Hoadley R.B., **Wood as a Physical Surface for Paint Application,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 2 - 16

Abstract: Wood has always been a vital factor in human existence and has provided an array of blessings, from basic needs to fanciful luxuries. It is not surprising that as we survey our heritage, we find deep involvement with artifacts of wood, both utilitarian and decorative. In the study of decorative arts, attention is easily focused on design and aesthetics, as is so often the case with painted wood, while the wood itself may well receive the least consideration. To explore wood is to realize its complexity, its diversity, and its variability. That a material with such a simple designation as wood could in fact be so complicated is part of its fascination. On the one hand, wood is a straightforward and simple material, a delightful bounty of nature, to be used at will. On the other hand, wood has its ability to remain enigmatic and troublesome. The union of wood and paint is as old as the human desire to protect an object, or simply to decorate a surface. The link between paint and wood is therefore at the heart of any approach to conservation of these objects. To the conservator, the analysis of conditions and problems involves a familiarity with the physical structure of the wood as a material and with its surface interaction with the applied paint, as well as with the behavior of the wood after paint application. Evaluating a wood surface begins by exploring the wood itself, with the realization that every surface is different from the next and cannot be predicted in detail. This article will therefore focus on the basic anatomical structure of wood tissue to provide an understanding of potential surfaces generated by cutting through it. In addition, pertinent physical properties will be summarized, with particular attention given to the wood's response to variation in atmospheric humidity and resulting dimensional changes.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood1.pdf

Hoadley R.B., **Identification of wood in painting panels,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 21 - 38

Abstract: Proper treatment of wooden artifacts begins with proper identification of the wood. Occasionally woods can be identified by visual features, though variations in samples and changes over time can be deceptive. A hand lens used to examine end-grain surfaces of wood cuts is the next step. The most sure method of examination is microscopic study of thin sections of transverse, radial, and tangential planes and comparison of these with written descriptions and reference sets of micrographs of wood samples. A table showing the most common panel woods refers to figures illustrating micrographic features of each.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings1.pdf

Hoadley R.B., **Chemical and Physical Properties of Wood,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 2 - 20

Abstract: A primer on the physical structure and chemical properties of wood, with an emphasis on wood-moisture relationships and the dimensional change which results from them. The drying of cut wood results in a gain in strength and a decrease in dimension. Even after wood is dried to an equilibrium state, it remains dimensionally responsive to moisture. Shrinkage varies by species of wood; a table lists shrinkage amounts for woods commonly found in painting panels. In addition to predictable linear shrinkage, wooden objects can suffer warp if moisture variation occurs unevenly.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings1.pdf

Hocker E., Almkvist G., Sahlstedt M., **The Vasa experience with polyethylene glycol: A conservator's perspective,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September, ed. Gril J., p. 175 - 182

Abstract: It is now fifty years since the raising of the Swedish warship Vasa, one of the first wooden shipwrecks and certainly the largest to have been conserved with polyethylene glycol (PEG). Now a standard material for waterlogged wood conservation, PEG has since been used on a number of other shipwrecks, thanks largely to the Vasa experience. As the second generation of conservators at the Vasa Museum in Stockholm, we are often asked our opinions about PEG, and whether we would still use the same materials and techniques should another ship like Vasa be raised today. What have we learnt and what would we do differently this time? In this paper, we examine the Vasa experience from the initial conservation decisions, through to the most recent research projects and examine how PEG has fared over the last fifty years. Finally, we take the lessons learned and apply them to the future, both for Vasa material and for newly found wrecks.
http://dx.doi.org/10.1016/j.culher.2012.01.017

Hopfner I., **The Development of Flexible Auxiliary Support Systems for Panel Paintings and the Monitoring of Panel Movement by Strain Gauges,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 69 - 81

Abstract: This paper discusses the conservation treatment, undertaken between 2000 and 2006, of four panel paintings from the collection of the Kunsthistorisches Museum in Vienna. All of the panels were thinned and cradled during the nineteenth century. Warping and cracks had occurred because of shrinkage of the wood. In addition, flaking of the paint film and other negative effects made treatment inevitable. Because the wood panels had been thinned to a fraction of their original thickness, the construction of an auxiliary support system was necessary. The aim was to fabricate a secondary support that could be applied easily, without loss of original material, that would be completely reversible, and that would have sufficient flexibility to allow for the movement of wood under changing climatic conditions. The system selected is based on aluminum panels that have openings to allow access and visual control of the reverse of the painting. The design of the supporting units evolved incrementally: an adjustable system

with a screw mechanism was followed by a more sophisticated, spring-loaded version that could be modified according to the size and weight of the panel. Although the springs allow movement of the wood panel in three dimensions, the system is strong enough to support the panel securely. In the latest version of the design, leaf springs were equipped with strain gauges to monitor the movement of the panel perpendicular to the front. Under construction (but not yet implemented) is an improved version that collects data for online processing or digital storage on a flash card or similar electronic storage medium.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Horns J.S., Buck R., **The Development and Use of the Balsa Backing for Panel Paintings,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 289 - 303

Abstract: In the 1930s and 1940s Richard Buck, first of the Fogg Art Museum (Cambridge, Massachusetts) and later of the Intermuseum Conservation Association (Oberlin, Ohio), developed a system of balsa block backing for panel paintings. Initially the system was applied to severely damaged paintings with unstable design layers and supports, wood deterioration and deformation, and inappropriate reinforcement. Later it was used for works less critically damaged that needed backing and reinforcement. One objective of end-grain balsa block reinforcement applied with a wax-resin mortar was to provide an avenue for moisture movement to reduce the cause of deformation. Another goal was to relieve the stresses of panel and other support elements, combining the virtues of fixed mechanical control with a relaxation of the panel. Application of the backing also served to concentrate stress at the back of the panel away from the paint layer. Numerous treatment examples and outcomes are cited.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

Hulbert A. C., **Conservation of the Fourteenth-Century Ceiling at Saint Helen's Church, Abingdon,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 287 - 300

Abstract: Relates the materials used, build-up in the painting, and conservation treatments used to treat the painting.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Hunt D., **Properties of wood in the conservation of historical wooden artifacts,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 10 - 15

Abstract: The properties of wood that are important in the conservation of historical wooden objects are described. These include the densities and mechanical properties of some typical species. This is followed by a résumé of the moisture relations in wood, and their consequences for dimensional changes and/or the development of restraining stresses. A third important property of wood is its susceptibility to various kinds of biological degradation, including effects of insects, fungi and bacteria. This is followed by a summary of the difficulties and wood properties associated with various applications. The subjects of these applications include buildings, furniture, musical instruments, painted panels, ships and boats, wood foundation poles, sculpture and carving, and watermills and windmills.

http://dx.doi.org/10.1016/j.culher.2012.03.014

Inagaki T., Yonenobu H., Tsuchikawa. S., **NIR Spectroscopic Monitoring of Water Adsorption/Desorption Process in Modern and Archeological Wood,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage 5-7 November, Braga 2008. Firenze University Press, 2010, p. 199 - 202

Abstract: The NIR diffuse-reflectance spectroscopy was applied to monitor the diffusion process of deuterium-labeled molecules in hinoki wood, where the sample was thermally treated for increasing periods of time. The saturation accessibility varied characteristically with thermal treatment time reflecting the OH groups in different states of order in the wood substance. The variations of saturation accessibility with hydrothermal treatment time were applied to reveal the hydrothermal change of crystalline and amorphous regions in cellulose.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Jackson J.B., et al, **A Survey of Terahertz Applications in Cultural Heritage Conservation Science,** IEEE Transactions on Terahertz Science and Technology, 2011, 1, 1, p. 220 - 231

Abstract: The authors present a review of the advances that have been made to establish terahertz applications in the cultural heritage conservation sector over the last several years. This includes material spectroscopy, 2D and 3D imaging and tomographic studies, using a broad range of terahertz sources demonstrating the breadth and application of this burgeoning community.

http://centaur.reading.ac.uk/23200/

Jakieła S., Bratasz Ł. and Kozłowski R., **Acoustic Emission for Tracing the Evolution of Damage in Wooden Objects,** Studies in Conservation, 2007, p. 101 - 109

Abstract: The monitoring of acoustic emission (AE) has allowed direct tracing of the fracturing intensity in wooden cultural objects exposed to variations in temperature and relative humidity (RH). High-frequency components produced by the mechanical fracturing were extracted from the raw AE signals using wavelet transforms. The accumulated energy of these components depended on the magnitude and rate of RH variations. The AE activity became negligible below the allowable magnitude for rapid RH variation established by numerical modelling, or when the time interval allowed for the RH variation was long enough. On-site AE monitoring of a wooden altarpiece in an historic church further confirmed the usefulness of the technique in tracing climate-induced stress in wood. The development of practical AE sensors to indicate risk to wooden objects in museums and at historic sites, or during their transportation, is discussed.

http://www.cuf-kr.edu.pl/~ncbratas/aboutus/StudiesCons52_2007.pdf

Jakiela S., Bratasz L., Kozlowski R., **Numerical modeling of moisture movement and related stress field in lime wood subjected to changing climate conditions**, Wood Science Technology, 42, 2008, p. 21 – 37

Abstract: Numerical modelling was used to follow the evolution of the moisture content gradient and the stress field resulting from the restrained differential dimensional response across a wooden cylinder, simulating sculptures, in response to variations in temperature (T) and relative humidity (RH). Material properties of lime wood (Tilia sp.) were used in the modelling as this wood species was historically widely used. The allowable RH variations, below which mechanical damage will not occur, were derived as functions of the amplitude, time period and starting RH level of the variation. Lime wood can endure step RH variations of up to 15% in the moderate RH region, but the allowable domain narrows when RH levels shift from the middle range. The allowable amplitude of the variations increases when time allowed for the change increases. The stress field does not vanish even for slow, quasi-static changes in RH due to structural internal restraint resulting from the anisotropy in the moisture-related dimensional change.
http://libra.msra.cn/Publication/39679861/numerical-modelling-of-moisture-movement-and-related-stress-field-in-lime-wood-subjected-to

Janssens K., et al, **Photon-Based Techniques for Nondestructive Subsurface Analysis of Painted Cultural Heritage Artifacts,** Accounts of Chemical Research, 2010, 43, 6, p. 814 - 825

Abstract: Often, just micrometers below a painting's surface lies a wealth of information, both with Old Masters such as Peter Paul Rubens and Rembrandt van Rijn and with more recent artists of great renown such as Vincent Van Gogh and James Ensor. Subsurface layers may include underdrawing, underpainting, and alterations, and in a growing number of cases conservators have discovered abandoned compositions on paintings, illustrating artists' practice of reusing a canvas or panel. The standard methods for studying the inner structure of cultural heritage (CH) artifacts are infrared reflectography and X-ray radiography, techniques that are optionally complemented with the microscopic analysis of cross-sectioned samples. These methods have limitations, but recently, a number of fundamentally new approaches for fully imaging the buildup of hidden paint layers and other complex three-dimensional (3D) substructures have been put into practice. In this Account, we discuss these developments and their recent practical application with CH artifacts. We begin with a tabular summary of 14 IR- and X-ray-based imaging methods and then continue with a discussion of each tech-

nique, illustrating CH applications with specific case studies. X-ray-based tomographic and laminographic techniques can be used to generate 3D renditions of artifacts of varying dimensions. These methods are proving invaluable for exploring inner structures, identifying the conservation state, and postulating the original manufacturing technology of metallic and other sculptures. In the analysis of paint layers, terahertz timedomain spectroscopy (THz-TDS) can highlight interfaces between layers in a stratigraphic buildup, whereas macrosopic scanning X-ray fluorescence (MA-XRF) has been employed to measure the distribution of pigments within these layers. This combination of innovative methods provides topographic and color information about the micrometer depth scale, allowing us to look "into" paintings in an entirely new manner. Over the past five years, several new variants of traditional IR- and X-ray-based imaging methods have been implemented by conservators and museums, and the first reports have begun to emerge in the primary research literature. Applying these state-of-the-art techniques in a complementary fashion affords a more comprehensive view of paintings and other artworks.

http://pubs.acs.org/doi/abs/10.1021/ar900248e

Jensen P. and Gregory D.J., **Selected physical parameters to characterize the state of preservation of waterlogged archaeological wood: a practical guide for their determination,** Journal of Archaeological Science 33, 4, 2006, p. 551 - 559

Abstract: Non-destructive and destructive methods for determining the physical parameters of waterlogged wood Such as the porosity. the water content, the wet and dry bulk densities plus the density of the cell wall material are presented. Considerations in respect to determination of masses. volumes and sampling size are discussed. The influence of the density increment of the water, sorbed to the cell wall material, is discussed and introduced by a model for the constituents of waterlogged wood including volumes and masses of the cell wall material. the free water in the pores/cell lumen and the sorbed water in the cell wall. The density increment is introduced, as a correction factor in the equations for determination of the physical parameters. If the equations are used without the correction factor they are similar to the most frequently used methods for determining physical parameters of waterlogged wood. By including the correction factor and thereby incorporating the increased density of the sorbed water in the calculations, the presented equations make it possible to correctly determine values for the physical parameters of waterlogged archaeological wood. (c) 2005 Elsevier Ltd.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=235573

Jensen P., **Diffusion in waterlogged wood: computer models,** Proceedings of the 6th ICOM Group on Wet Organic Archaeological Materials conference, Ed. Per Hoffmann, Thomas W. Daley, Tara Grant and James A. Spriggs, Bremerhaven, ICOM Committee for Conservation, Working Group on Wet Organic Archaeological Materials, 1997, p. 451 - 470

Abstract: The paper summarizes the results from a larger project dealing with diffusion in relation to conservation processes in waterlogged wood. Diffusion systems in conservation processes are being described by: diffusion coefficients, objects, reservoir and boundary conditions. Methods for modeling diffusion systems by stochastic methods, analytical mathematical solutions, or numerical methods are discussed. A simple numerical method, the Successive Finite Difference Method, which has been developed is explained in detail. The method is based on Fick's first law and is able to handle anisotropic 1-, 2-, or 3-dimensional diffusion with varying boundary conditions. A package of three computer programs is presented. The programs, computerized diffusion models, can simulate impregnation of waterlogged archaeological wood by analytical or numerical models, depending on how accurate the diffusion process shall be simulated and how well the diffusion system can be described. Parameters characterizing diffusion systems which are necessary for the computerized models are discussed.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=173327

Jeremic D., and Cooper P., **PEG quantification and examination of molecular weight distribution in wood cell walls**, Wood Science and Technology 43, 3-4, 2009, p. 317 - 329

Abstract: The amounts of polyethylene glycol (PEG) of a range of molecular weights (200-20000) and their mixtures in wood cell walls were estimated by preferential extraction of PEG from the cell lumens. PEG extracted by toluene over 1 h extraction periods was examined by matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) spectroscopy. The assumption that a non-polar solvent would not extract PEG from the cell walls was shown to be invalid. Only about 0.07-0.08 g PEG per g dry wood was retained in wood after 12 h-toluene extraction and this value was not significantly affected by PEG molecular weight (MW). This relatively low cell wall content can result in as high as 50% cell wall bulking (CWB) which is dependent on MW. Samples treated with mixture of PEG MWs indicated preferential penetration of lower MW into cell walls.
http://www.cabdirect.org/abstracts/20093140692.html;jsessionid=529961A8038E45D2656

2D9D73D828CC4

Jeronimidis G., **Fracture of Wood and Factors which Influence it**, Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 7 - 10

Abstract: The application of fracture mechanics to the failure of wood is described. The various systems of crack propagation are discussed, together with the energy-absorbing mechanisms associated with them and the factors which can influence them.

http://www.iiconservation.org/node/1669

Jorissen A., **Structural interventions, Wood Science for conservation,** Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 57 - 63

Abstract: Wood has been available throughout history to most cultures all over the world. Consequently, it can be found in many applications such as tools, pieces of art and structures. Wood has always been one of the few (natural) materials used for structural design. Wood is still one of the major structural building materials resulting in many modern structures. Wood is among the few natural materials, which is able to resist compression, tension and bending stresses. Consequently, regarding older and historical buildings, wood can be found everywhere in structural design. From foundation piles, from which according to a rough guess about 25 million are still supporting all kind of structures in (mainly) the western part of the Netherlands, to timber floors, walls and roof structures. These (timber) structures are safeguarding our society for centuries already and they are supposed to continue doing this. However, being vulnerable to decay and, most probably, to ageing, (sometimes) structural interventions are necessary. Only interventions due to unacceptable loss of structural safety are regarded and discussed. This paper also discusses briefly a (theoretical) framework for the development of an assessment matrix for timber structures. Some intervention techniques used in practice are shown.

http://dx.doi.org/10.1016/j.culher.2012.05.001

Kalypso M., **Cases of damage to the ground and paint layers of icons: presentation of their conservation, treatment and restoration,** The conservation of late icons, New Valamo 2-6 June 1997, St. Petersburg 7-11 June 1997, Helsinki 12-13 June 1997, Crete 2-24 October 1997, Valamo Art Conservation Institute, Uusi-Valamo, Finland,1998, p. 81 – 96 [ISBN: 951-97952-0-0]

Abstract: The following presentation is based on case studies of Byzantine and post-Byzantine icons from the Benaki Museum collection. It begins with a brief report of the general guidelines on which conservation treatment is based in the Benaki Museum laboratories. After this, it concentrates on three issues; first, the assessment of damage to the ground and paint layers: second, the treatments which are usually adopted in order to prevent further damage to the icons and to stabilize their condition; and finally their restoration and presentation in the exhibition halls of the museum.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=180322

Karydis C., **The fabric support in portable icons: deterioration, documentation & conservation, Icons: approaches to research, conservation and ethical issues,** ICOM Committee for Conservation international meeting, Special Interest Icons Group, Athens 3-7 December 2006, abstracts, Hellenic National Committee ICOM, 2006.

Abstract: Traditionally, one of the first stages in the construction of a portable icon is application of the fabric (pavoloko) directly on the wooden support, using either organic or, more recently, synthetic adhesives prior to application of the gesso layer. The author aims to raise awareness in the icon conservator/restorer regarding the need to adopt an approach to the treatment and documentation of fabric material properties comparable to that for other component materials. This presentation is split into three main sections: deterioration factors, methods of documentation, and conservation of the fabric. As an organic material, fabric is subject to particular types of deterioration that can be caused by unstable environmental conditions (relative humidity and temperature) in display and storage. This can create potentially incompatible expansion and contraction of both wooden and textile supports, and stresses may result. There is also potential for the development of microorganisms and insect infestation. Other types of deterioration identified in the fabric support are its separation from the wood, splits and losses, mechanical decay, and decomposition from biological agents. These all need careful documentation when the icon is first investigated. Previous restoration,

which may have used a variety of varnishes often mixed with pigments and other natural products to "camouflage" damaged areas for aesthetic reasons or varnishes applied on the fabric layer as a final coating, may have caused further problems. Although the fabric is a critical element in the icon in that it may secure the paint layer onto a decaying support, icon conservators do not always give proper attention to this material during documentation. Analytical and investigative techniques could play an integral role in the identification of the fabric and its material and technological details as part of standard documentation prior to any treatment. Identification of fibers under the microscope will show different structures (linen, jute, cotton) upon examination of both longitudinal and cross sections. The author also gives emphasis to two basic weaving types found in icons, which are very familiar to textile conservators but perhaps not to conservators specializing in different fields. In identifying the construction of the textile and its weaving technology, the icon conservator/restorer gains further knowledge about the pathology of the artifact, important for selection of appropriate materials to use in the treatment and to avoid further damage to the cellulose or protein fabric structure with strong alkali and acid adhesives or solvents. The author proposes a unified approach to documentation of this important element of the icon's structure, which can be used across monastic and museum collections stored and displayed in Greece, suggesting a database suitable for the archival purposes of both textile researchers and icon conservators. He concludes with an investigation of synthetic and organic adhesives used for the treatment of fragile historic and archaeological textiles and presents related case studies investigating the application of these adhesives to the artifacts in various chronological periods by different workshops. This suggests further research into the adhesive treatments that may be considered in the future.

http://teiion.academia.edu/ChristosKarydis/Papers/1573918/The_Fabric_Support_in_Portable_Icons_Deterioration_Documentation_and_Conservation

Kawai S., Yokoyama M., Matsuo M., Sugiyama J., **Research on the Ageing of Wood in RISH,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage, 5-7 November, Braga 2008, Firenze University Press, 2010, p. 52 - 56

Abstract: This paper reviews the research activities of the Research Institute for Sustainable Humanosphere (RISH) on the aging of wood, these are, 1) Collection and identification of wood samples from cultural properties and historical buildings, 2) Characterization of the naturally aging wood, 3) Characterization of the accelerated aging treated wood, 4) Establishment of the database on the wood

quality from historical building, and 5) Organizing symposia: Wood Culture and Science series.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Keene S., **Managing Conservation in Museums** (2nd edition), Butterworth Heinemann, 2002

Abstract: Explaining and critically reviewing management procedures such as performance indicators and strategic planning, this book shows how techniques from mainstream management can be used to facilitate a holistic and professional approach to the business of conservation and collection preservation. It offers practical guidance on strategy, quantitative planning and condition surveying, and presents many solutions to the challenges faced by museum staff and conservation specialists. This new edition takes into account changes such as the arrival of the Heritage Lottery Fund, policies for access and the growing convergence of museums, libraries and archives. It also highlights the advent of digital collections and the use of information and communications technology.

http://www.amazon.co.uk/dp/0750656034?tag=museumscollec-21&camp=1406&creative=6390&linkCode=as1&creativeASIN=0750656034&adid=1N7R5T61RWZR8Y72FCN7&&ref-refURL=http%3A%2F%2Fwww.suzannekeene.info%2Fbooks.html

Knaebe M.T. and Williams R.S., **Field Study on the Effect of Acidic Conditions on the Adhesion of Paint to Western Red cedar,** John W. Spence, North Carolina State University, 1996

Abstract: Previous research results involving sulfur accumulation on cross section of wood coated with latex paint led us to investigate whether acidic conditions could affect the bonding strength of paint and be a factor in catastrophic paint peeling. Through simulation of acidic dew under outdoor conditions, the study reported herein determined the effect of acid rain and/or dew on painted wood siding. Painted wood was soaked before dawn in various acid solutions for two hours each day, then exposed outdoors for the remainder of the day and night during the summer near Madison, WI. From October to May, the specimens were exposed but not soaked. After four years of exposure to weather and acid, only the painted wood interface for specimens soaked in sulphurous acid at pH 2 indicated deterioration as measured by fracture toughness testing.

http://128.104.77.228/documnts/pdf1996/knaeb96a.pdf

Kozlowski R., Bratasz L., Lasyk L., Lukomski M., **Allowable Climate Variations for Painted Wood: Direct Tracing of Damage Development,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 158 - 164

Abstract: Specimens simulating historic panel paintings were subjected to cycles of mechanical stretching and compression to imitate dimensional changes induced by repetitive fluctuations of relative humidity (RH) in the microenvironment of painted wood. Up to 36,000 cycles, equivalent to 100 years of diurnal fluctuations, were performed in order to estimate the cumulative damage of strain cycles. Development of cracks in the decorative layer was monitored using a laser speckle decorrelation technique that enabled physical fracturing to be monitored at the micro level before damage was discernible from the macroscopic perspective. Plots of cumulative crack length versus number of cycles causing that fracture were obtained. Strain of 0.15% was found to be tolerated by the specimens even for the maximum number of cycles, whereas strain of 0.25% produced initial cracking after 5000 cycles only. Therefore, strain of approximately 0.2%, close to the yield point of gesso, was confirmed as a critical level that the polychrome wood could endure without damage. Local variations in strain reflecting the anisotropic elongation of the wood substrate need to be determined to assess the magnitude of RH variations necessary to cause the critical strain. The slow response of panel paintings to rapid variations in RH and their usual deformation, which reduces the effective movement experienced by the decorative layer, as well as stress relaxation of gesso during long-term variations, all have a bearing on the susceptibility of painted wood panels to cracking due to cyclic environmental changes.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Kozlowski R., **Climate induced damage of wood: numerical modeling and direct tracing,** in Experts Roundtable on Sustainable Climate Management Strategies, The Getty Conservation Institute, 2007

http://www.getty.edu/conservation/our_projects/science/climate/paper_kozlowski.pdf

Kretschmann D.E., **Material mechanical properties of wood,** Wood Handbook- Wood as an Engineering Material, Forest Products Laboratory, United States Department of Agriculture Forest Service, Madison, Wisconsin, 2010

Abstract: The mechanical properties presented in this chapter were obtained from tests of pieces of wood termed 'clear' and 'straight grained' because they did not contain characteristics such as knots, cross grain, checks, and splits. These test pieces did have anatomical characteristics such as growth rings that occurred in consistent patterns within each piece. Clear wood specimens are usually considered 'homogeneous' in wood mechanics. Many of the mechanical properties of wood tabulated in this chapter were derived from extensive sampling and analysis procedures. These properties are represented as the average mechanical properties of the species. Some properties, such as tension parallel to the grain, and all properties for some imported species are based on a more limited number of specimens that were not subjected to the same sampling and analysis procedures. The appropriateness of these latter properties to represent the average properties of a species is uncertain; nevertheless, the properties represent the best information available.

http://www.fpl.fs.fed.us/products/publications/several_pubs.php?grouping_id=100&header_id=p

Krug K., et al, **Relics in medieval altarpieces? Combining X-ray tomographic, laminographic and phase-contrast imaging to visualize thin organic objects in paintings,** Journal of Synchrotron Radiation, 2007, p. 55 - 61

Abstract: X-ray radiography is a common tool in the study of old master paintings. Transmission imaging can visualize hidden paint layers as well as the structure of the panel or canvas. In some medieval altarpieces, relics seem to have been imbedded in the wooden carrier of paintings. These are most probably thin organic fibrous materials such as paper or textile, which in traditional radiography are shadowed by the more absorbing surrounding material. This paper studies the application potential of synchrotron-based tomographic and laminographic imaging complemented with phase-contrast imaging for detection of such relics. The techniques are applied to a dummy painting. The results demonstrate that by using these imaging methods it is possible to threedimensionally visualize hidden cavities in panels and detect thin fibrous low-Z materials sandwiched between a high-Z paint layer and a thick wooden panel.

http://www.ncbi.nlm.nih.gov/pubmed/18097079

Kusunoki T., Nagase T., Kibayashi M., Oshiumi S., Hayashi Y., Ueda T., **Experimental Study on the Creep Behaviour of Structural Component of Traditional Wooden Buildings,** Journal of Asian Architecture and Building Engineering, May 2005, p. 185 - 191

Abstract: The purpose of this study is to identify the bending creep behaviour of sawn lumber beam of Japanese Cypress and the compressive creep behaviour of full-size masugumi, which is one of the most important components in old wooden Japanese buildings in terms of both structure and decoration. As the former, practical size sawing (120×240×6000mm) was applied, and bending creep test was carried out for 4 years. As a result, approximate formula for bending creep behaviour was obtained. According to this formula, total deflection after 100 years later is estimated to be about two and a half times as big as initial deflection. As the latter, by using full-size masugumi component, which was modelled on that in national treasure building "Toshodaiji Kondo", compressive creep test was carried out for 4 years. As a result, approximate formula for compressive creep behaviour was obtained. According to this formula, total compressive deformation after 100 years is estimated to be about five times as big as initial deformation.
http://ci.nii.ac.jp/naid/110006345808

Lappalainen T., Kanko T., Olkkonen H. and Ahola P., **An automated method and device for the measurement of coating flexibility,** Materials and Structures, 26, 10, 1993, p. 614 - 620

Abstract: A new method for determining the flexibility of paints and other coatings has been developed. Coated aluminium strips are stretched and the damage caused to the coating during stretching is monitored by means of an automatic image processing system. The stretching device, with a lighting and camera system specially designed to withstand cold conditions down to –25°C, gives useful information about the performance of coatings in cold climates. In addition to the elongation at which the paint film starts to crack, the development of cracking is also measured. A reduction in the test temperature was found to impair the flexibility properties of paints. Ageing can either impair or improve the flexibility properties of paints. The effect depends on the pain and the weathering time.
http://www.springerlink.com/content/466150013u456356

Larsen R., **Conservation-restoration education in the light of the European Qualification Framework for Life Long Learning,** ENCoRE, Journal of Conservation-Restoration Education, 1, 2008,

Abstract: This paper presents the most important aspects of the development of the academic conservation/restoration education in Europe focusing on the most recent activities in relation to the Bologna process for higher education institutions in Europe including the European Qualification Framework (EQF) and accreditation. This development and the fact that more and more conservation-restoration education programmes have adapted the Bologna structure for Higher Education (HE) lead to the suggestion of ENCoRE for a European Qualification Framework for Conservation-Restoration education (C-R EQF). This defines the generic learning outcomes according to EQF levels 6, 7 and 8 and is intended for the formulation of Qualification Frameworks at national level (C-R NQF).
http://www.encore-edu.org/ENCoRE-documents/JCRE/JCRE%201-2008.pdf

Lasyk L., Lukomski M., Bratasz L., **Simple digital speckle pattern interferometer (DSPI) for investigation of art objects,** Optica Applicata 2011, 41, 3, p. 687 - 700

Abstract: Technical development and practical evaluation of a simple digital speckle pattern interferometer (DSPI) for the non-invasive, non-contact detection and characterization of early-stage damage of painted objects of art, like fracturing and layer separation, are reported. One of the most important features of the presented measuring system is a possibility to progress stepwise from the simplest version of the instrument based on the digital image correlation (DIC), to more advanced and accurate ones: DSPI for thermally- and sound-induced surface deformation. Analysis of the resonant frequency of a vibrating delaminated paint layer was, for the first time, used to detect the damage progress in polychrome wood and proved to be extremely sensitive and accurate. This method, together with two other presented in the article makes the multilevel analysis of the preservation state of the object's surface possible and provides information on the damage on a desired level of complexity and accuracy.
http://www.if.pwr.wroc.pl/~optappl/article.php?lp=930

Lasyk Ł., Łukomski M., Olstad T.M., Haugen A., **Digital speckle pattern interferometry for the condition surveys of painted wood: Monitoring the altarpiece in the church in Hedalen, Norway,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 102 - 108

Abstract: Digital Speckle Pattern Interferometry (DSPI) and Speckle Decorrelation (DIC) were used in condition surveys of a wooden altarpiece in the church of Hedalen, Norway. Two surveys were conducted, one before and one after the heating season in the church to trace the possible development of damage in the paint layer caused by relative humidity variations induced by the heating system. The measurements demonstrated that the speckle techniques can contribute to detecting irregular areas on the paint surface and in the paint structure. They proved particularly effective in tracing paint detachments at an incipient stage which cannot be easily detected by an unaided eye or manual inspection. The results of the speckle techniques may thus guide a traditional conservation survey, or the use of further microscopic or analytical survey techniques. The speckle techniques could be routinely used by conservators who are not scientists if simple, portable instruments were available on the market.

http://dx.doi.org/10.1016/j.culher.2012.01.008

Lebas F.J.M., **The Cradling of a Relief of the Annunciation Attributed to Martin Schaffner,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 359 - 363

Abstract: The limewood relief had two cracks running up the entire length of the panel, with two shorter ones starting upward from the bottom of the panel. The wood had been heavily eaten by Anobium punctatum worms. The cradle which had created the stresses in the panel that caused the cracking was removed. A new lightweight cradle made of small balsa wood pieces glued in two staggered layers, with the grain direction following that of the relief, was selected as a replacement. Before attaching the cradle, sheets of limewood veneer were adhered to the back of the panel, and holes were filled to even out the surface. The balsa pieces were dipped in hot wax and arranged side by side before they were glued. Once the cradle was completed, the frame was reattached by adding four boards to the inside of the frame, then gluing cleats on the cradle and screwing springs onto the cleats to hold the relief in the frame.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Leevers P.S. and Moreno L., **Surface layer stiffness effects on fracture of polymer multilayers: a linear elastic model,** Engineering Fracture Mechanics, 72, 2005, p. 947 – 959

Abstract: A tough thermoplastic polymer may show a transition to brittle behaviour when a skin of different properties forms on, or is painted or bonded onto, its free surfaces. A small-scale yielding, linear elastic analysis of the core material, in combination with an axisymmetric plate analysis of the skin, is used here to explore the role in this phenomenon of skin-core modulus inequality. When applied to the homogeneous (equal modulus) case, this very simple constraint model appears to provide independent support for the ASTM thickness criterion for plane-strain LEFM test validity. When applied to previously published impact fracture data from inhomogeneous (polyethylene-polypropylene) sandwich plates, the model successfully explains the shift in brittle-tough transition temperature precipitated by bonding a polypropylene skin to a polyethylene core. The model offers specific predictions for the effect, on transition temperature shift, of variables such as skin thickness and core properties; these predictions remain to be verified.

http://spiral.imperial.ac.uk/bitstream/10044/1/1213/1/Leevers2005b.pdf

Lehmann E.H. and Mannes D., **Wood investigation by means of radiation transmission techniques,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 35 - 43

Abstract: The basics and experimental details of transmission radiation techniques in the application to conservation of wooden cultural objects are described. Standard and synchrotron X-rays, as well as neutrons, can provide very useful options for the non-invasive analysis of the wood structure, its conservation state and the influence of wood treatment in the conservation and decontamination process. The working and application range specific to each kind of radiation is discussed. Although X-ray methods (standard tube systems and synchrotron light source facilities) can cover a wide range in object size and wood density, neutrons can be used preferentially to study and quantify substances with high hydrogen content (moisture, resin, glues, wax) inside the wooden structure. Several examples chosen from studies performed within COST Action IE0601 illustrate the results that can be obtained using these techniques and their combination. The need for further studies using the performances available at large-scale facilities is discussed as a way to establish routine approaches for wood conservation and museums objects.

http://dx.doi.org/10.1016/j.culher.2012.03.017

Lennon, T., **The Transfer of a 16th Century Panel Painting: Use of Lightweight Paper Honeycomb** Material as a Support, Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 185 - 190

Abstract: A sixteenth century panel painting was examined and found to satisfy the prerequisites for a transfer. To retain the aesthetic and textural qualities of a panel painting and to eliminate some of the disadvantages of wood, a composite panel incorporating plywood and honeycomb material was designed. The painting was faced with PVA and heavy tissue, then wax resin and cotton muslin fabric. Then the cradle and the panel were removed. The new support was constructed by gluing a piece of linen to 3-ply aircraft quality plywood with epoxy. The paint film was then adhered to this in a vacuum envelope using wax-resin. Then paper honeycomb (nylon-fiber reinforced) was glued to the reverse of the plywood with epoxy. Finally another sheet of plywood was glued with epoxy to the other side of the honeycomb panel.

http://www.iiconservation.org/node/1708

Liang H., et al, **En-face optical coherence tomography – a novel application of non-invasive imaging to art conservation,** Optics Express, 13, 6, 2005, p. 6133 - 6144

Abstract: Optical Coherence Tomography (OCT) is an optical interferometric technique developed mainly for in vivo imaging of the eye and biological tissues. In this paper, we demonstrate the potential of OCT for non-invasive examination of museum paintings. Two en-face scanning OCT systems operating at 850 nm and 1300 nm were used to produce B-scan and C-scan images at typical working distances of 2 cm. The 3D images produced by the OCT systems show not only the structure of the varnish layer but also the paint layers and underdrawings (preparatory drawings under the paint layers). The highest ever resolution and dynamic range images of underdrawings are presented and for the first time it is possible to find out non-invasively on which layer the underdrawings were drawn.

http://www.opticsinfobase.org/oe/abstract.cfm?uri=oe-13-16-6133

Lin J.K., Ladisch M.R., Patterson J.A. and Noller C.H., **Determining pore-size distribution in wet cellulose by measuring solute exclusion using a differential refractometer,** Biotechnology and Bioengineering 29, 8, 1987, p. 976 - 981

Abstract: Solute exclusion was used to determine the pore volume and micropore size distribution of wet cellulose materials. Glucose, cellobiose and polyethylene glycol (PEG) (8 to 130 Å in diameter) were used as molecular probes. Four replicates of cellulosic samples, with each sample being analysed 4 to 8 times, gave the concentrations of each molecular probe before and after contact with cellulose. Sugar concentrations were determined by the DNS method and PEG concentrations by a differential refractometer. Deviations arising from sample-to-sample variability result in variations of solute uptake from which the pore size distribution was determined. The need for replicate samples and a statistical approach to data analysis is indicated. Consequently, the data were fitted to an empirical logistic model function based on the minimum of the residential sum of squares using the finite-difference, evenberg-Marquardt algorithm. A smooth increasing function resulted. We report experimental methodology employing a differential refractometer common in many laboratories having a liquid chromatograph instrument, combined with statistical treatment of the data. This method may also find application in determining pore size in wet, hydrophylic polymers used in some types of membranes, chromatographic supports, and gel-type resins.
http://www.ncbi.nlm.nih.gov/pubmed/18576547

Loskutov S.R. and Aniskina A., **Swelling of larch wood in organic liquids,** Holzforschung 62, 3, 2008, p. 357 - 361

Abstract: The swelling of larch wood in 1-butanol, dimethyl sulfoxide, N,N-dimethyl formamide, ethylene glycol, ethanol, methyl cellosolve, 1-propanol and toluene was investigated at room temperature. The volumetric, tangential and radial swelling completion was lagging behind the liquid absorption process. The kinetic indices of swelling of larch wood were determined based on the equation of Kolmogorov-Erofeev. The volumetric swelling was related to molecular mass, molar volume, dielectric permittivity and integral heat of wood wetting. The anisotropy of wood swelling was characterized by the ratio of equilibrium tangential swelling to radial swelling (alpha(t)/alpha(r)). It was demonstrated that alpha(t)/alpha(r) is related to the dipole component of Hansen's parameter and cannot exceed the value 3.
http://www.degruyter.com/view/j/hfsg.2008.62.issue-3/hf.2008.052/hf.2008.052.xml

Luckenbach C., **Die Johannestafel in der Stadtkirche Bad Wimpfen,** 2002

Abstract: In der Restaurierungswerkstatt des Landesdenkmalamtes Baden-Württemberg wurde von Mai 1999 bis Juli 2000 ein spätgotisches Holztafelgemälde aus der Wimpfener Stadtkirche restauriert, das eine besondere Würdigung verdient. Die Durchführung der Maßnahmen sowie die damit verbundene technologische Untersuchung führte das Landesdenkmalamt in Zusammenarbeit mit der Staatlichen Akademie der Bildenden Künste Stuttgart durch. Die Untersuchungen zum Bestand des Tafelbildes brachten überraschende Sachverhalte zu Tage: Unter der heute sichtbaren Malerei liegt partiell eine ältere Malschicht. Im Rahmen einer Semesterarbeit sollte von einer Studentin des Studienganges Restaurierung und Technologie von Gemälden und gefassten Skulpturen geklärt werden, inwieweit sich Aussagen über Qualität, Umfang und Erhaltungszustand dieser Schicht sowie deren Beziehungen zur heute sichtbaren Malerei machen lassen.
http://www.baufachinformation.de/denkmalpflege.jsp?md=2002097108366

Łukomski M., **Painted wood: What makes the paint crack?,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September, ed. Gril J., p. 90 - 93

Abstract: Painted wooden panels are multi-layered structures composed of wood, animal glue, gesso and paints, in which the gesso layer is particularly vulnerable to humidity fluctuations due to the development of internal stresses and fracture. This study established experimentally a relationship between the strain magnitude leading to the first fracture of the gesso and the number of cycles at that strain, that is, the vulnerability of the gesso layer to fatigue damage. Specimens of single, wood panels coated with gesso were subjected to cycles of mechanical stretching and compression to imitate dimensional changes induced in the system by repetitive fluctuations of relative humidity (RH). The development of cracks in the gesso layer was monitored using a laser speckle decorrelation technique. Numerical modelling was used to calculate the amplitude of sinusoidal RH cycles which are allowable so as not to exceed the critical mismatch between the climate-induced responses of the unrestrained wood panel and the gesso layer respectively, which would lead to the first fracture of the virgin gesso after a defined period of cycle occurrence–100 years in this study. The allowable amplitudes were derived as a function of cycle duration, panel thickness and the configuration of moisture exchange by a panel with the environment. The worst-case duration of the RH cycles, for which the allowable amplitude is at its minimum, were calculated for varying thicknesses of the panels. The analysis of the results revealed that the

10 mm panel with two faces permeable to the water vapour flux and subjected to fluctuation cycles lasting 10 days represents the 'absolute' worst case in the study performed, allowing only the fluctuation amplitude of ±14%.
http://dx.doi.org/10.1016/j.culher.2012.01.007

Madsen L.D., Rosenzweig Z., Cook K.D., Scott M.J. and Jacobson A., **Science at the Interface with Art**, Mater. Res. Soc. Symp. Proceedings 1319, 2011

Abstract: The Cultural Heritage Science (CHS, formerly SCIART) Program seeks to enhance opportunities for chemistry and materials research at the interface between science and art. The objective is to promote collaboration between cultural heritage scientists, mainly located in US museums and chemists and/or materials scientists in US academic institutions to address grand challenges in the science of cultural heritage. Through the first competition, eight projects, two to three years in duration, were funded at $270,000 to 495,000 each. Every successful proposal demonstrated a clear need for collaboration with good synergy between the collaborating groups, and provided plans for meaningful training experiences for students and/or postdoctoral researchers in the field of cultural heritage science. It is anticipated that the CHS Program will continue for two additional years in a similar fashion. During this period, researchers should be able to more easily identify the disciplinary programs in materials research or chemistry relevant to their work, and their proposals will be reviewed together in panels. Proposals falling outside of the CHS specifications may be submitted directly to the relevant program/s of interest at the National Science Foundation (NSF) as unsolicited proposals. After the CHS Program ends, unsolicited proposals will remain the key mechanism for obtaining NSF funding in this research area.
http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8256816

Maev R.G., et al, **Modern Non-Destructive Physical Methods for Paintings Testing and Evaluation**, 9th International Conference on NDT of Art, Jerusalem, Israel, 2008

Abstract: There are several rapidly developing non-destructive physical methods that are increasingly used for the analysis and assessment of art objects. These technologies are posed to bring about drastic changes in the attribution and inventory characterization procedures carried out by museums, private collections, art dealers, and art community as a whole. Certainly today nondestructive evaluation (NDE) of art objects is becoming more and more sophisticated. The applica-

tions of these methods include but not limited to deterioration detection, authentication, revealing forgeries and fakes, and attribution. There are numerous physical techniques that are currently adopted for various tasks related to NDE in the art world, many of which have been specifically developed for particular applications of paintings evaluation. While some of these methods are well-known, others remain rather obscure. This article is an attempt to review a few physical techniques that could be successfully used for the conservation and authentication of paintings. The methods described here include multi-spectral illumination methods, thermographic techniques, scanning acoustic imaging, air-coupled ultrasound, Raman spectroscopy and imaging, and Mass-spectroscopy.
http://www.ndt.net/article/art2008/papers/042Maev.pdf

Maev R.G., Green R.E. Jr. and Siddiolo A.M., **Review of Advanced Acoustical Imaging techniques for Nondestructive Evaluation of Art Objects,**
Research in Nondestructive Evaluation 16, 4, 2006, p. 191 - 204

Abstract: Proper preventative diagnosis of different art objects, including wooden, bronze and marble sculptures, frescoes, and paintings (on canvas, wood, metal, and glass), is very important for conservation purposes. Various advanced ultrasonic imaging methods for analysis and assessment of art objects can bring about drastic changes in the regular evaluation and inventory carried out by museums and can bring advanced, powerful, and new techniques for objective assessment of physical conditions of museum resplendence. Using these methods, it will be possible to plan ad hoc repair works on art objects, and, as a result, we will preserve our heritage. The goal of this review is to introduce recent advances in acoustical imaging and quantitative acoustical imaging for the evaluation of art objects. Physical principles as well as experimental fundamentals for quantitative characterization of the contrast response in the acoustic imaging, together with the recent results of technical developments in this field, are discussed. Based on the most successful research results, examples of different applications are provided.
http://www.tandfonline.com/doi/abs/10.1080/09349840600981088

Marchant R., **The Development of a Flexible Attached Auxiliary Support,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 382 - 402

Abstract: Presents two case studies of large deformed and damaged panel paintings that needed to have earlier supports and repairs removed and reworked to reduce stress on the panels. If an unframed panel can't be handled or support its own weight when horizontal, an external support structure is considered beneficial. This structure serves to provide reinforcement and restraint of wood to bending caused by fluctuation of relative humidity. Calculation of the strength of a panel and of its dimensional instability in ambient conditions is essential for the design of a support and will vary for each panel worked on. In the cases cited, support structures consisted of a latticework of flexible battens attached to the backs of panels by slotted retaining blocks, with variable pressure applied by spring bridges attached to the battens. The edges of the latticework were fitted with ball bearings that can move inside the frame. The author reports that restraining curvature of a panel by less than 30% of its natural tendency does not cross the threshold at which stress damage occurs.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Marcon B., Dureisseix D., Dionisi-Vici P., Gril J., Uzielli L., **Experimental and Numerical Mechanical Study of a Framing Technique for Cupping Control of Painted Panels Combining Crossbars and Springs,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage, 5-7 November, Braga 2008, Firenze University Press, 2010, p. 219 - 224

Abstract: This communication deals with theoretical and experimental researches being carried out by the authors in order to model an actual wooden support, and its deformational behaviour, after a back frame has been applied by means of springs, in a Florentine restoration laboratory. Such a device is aimed to serve as a framing technique useful for conservation of one-sided painted boards of wooden artworks. The main outcome of such a research, still ongoing, is a calibrated mathematical and numerical model, which allows one to choose the most appropriate mechanical parameters for springs, according to expected environmental conditions, in order to achieve a balance between deformation control and stress control.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Marcon B., Mazzanti P., Uzielli L., Cocchi L., Dureisseix D., Gril J., **Mechanical study of a support system for cupping control of panel paintings combining crossbars and springs,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 109 - 117

Abstract: Spring mechanisms have been developed, since late 1970s, to provide some freedom of deformation to the wooden supports of paintings; however, no scientific method is up to now available for optimizing their design parameters. This article deals with theoretical and experimental work on the replica of an actual wooden support restored in a Florentine laboratory. A model is developed to describe its deformational behaviour after an auxiliary support has been applied by means of springs. The main outcome of such a research, still on-going, is a numerical model verified experimentally, enabling a restorer to choose the most appropriate mechanical parameters for springs in order to obtain the desired control of deformations and stresses produced by the expected environmental conditions.
http://dx.doi.org/10.1016/j.culher.2012.04.003

Maritato R., Snider D., **Wood consolidation. Consolidation of non-archaeological wood, without structural functions, either deprived or coated with polychromatic layers and damaged by insects – The Care of Painted Surfaces,** Materials and Methods for Consolidation, and Scientific Methods to Evaluate their Effectiveness, Proceedings of 3rd International Conference - Colour and Conservation – Materials and Methods in the Conservation of Polychrome Artworks, edited by Cesmar7, Milan, November 10-11, 2006, p. 149 – 152,

Abstract: The consolidation of three-dimensional wooden objects – either deprived or coated with polychromy – which are damaged by insects, with the exception of structural and archaeological wooden objects, is still a critical operation. Many doubts remain on the modalities, on the most adequate material, as well as on the effectiveness of the treatment.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=369894

Mazzanti P., Uzielli L., **Strength and MOE of Poplar Wood (Populus Alba L) Across the Grain: Experimental Data,** Conference Proceedings, Wood Science for the Conservation of Cultural Heritage. 5-7 November, Braga 2008, Firenze University Press, 2010, p. 62 - 66

Abstract: The paper is centred on the mechanical characteristics of poplar wood (Populus alba L.), particularly on selected short term loading tests (strength and modulus of elasticity) across the grain. The reason for such work arises from the necessity to deepen the knowledge of the mechanical behaviours of this species to apply it to a better conservation of painted panels. Tension and compression tests perpendicular to the grain, at three different wooden moisture content values, are described. The results show no evident differences at various moisture content values and for different loading tests.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Mazzanti P., Togni M., Uzielli L., **Drying shrinkage and mechanical properties of poplar wood (Populus alba L.) across the grain,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 85 - 89

Abstract: Painted panels are made of a wooden support, ground layers, paint layers and varnish, making them complex objects whose proper preservation relies, among other factors, on investigating their responses to climatic variations. In central Italy, panels used for paintings between the thirteenth and sixteenth centuries were predominantly made of poplar wood (Populus alba L.) not only because of its local provenance but also because of its technological and processing characteristics. This paper reports on laboratory tests that focused on determining the drying shrinkage and the mechanical properties of this wood species. Mechanical tests to measure the strength and stiffness across the grain along three anatomical directions (radial, tangential and intermediate) and for three different equilibrium moisture contents (7%, 11% and 15%) were carried out. Furthermore, creep tests (only the viscoelastic behaviour was investigated) were performed at 65% relative humidity and a temperature of 20 °C for three load levels and along the three anatomical directions previously mentioned. A drying shrinkage test was also carried out. The calculated shrinkage values highlighted the dimensional stability of poplar wood. The mechanical properties showed a dependence both on moisture content and anatomical directions. In particular, the latter had more of an effect on the parameters.

http://dx.doi.org/10.1016/j.culher.2012.03.015

McClure I., **History of Structural Conservation of Panel Paintings in Great Britain,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 237 - 251

Abstract: Records describing painting conservation practice in Britain are rare before the middle of the 20th century. Knowledge of the development of structural conservation techniques before the 1930s can be gained by the study of the backs of paintings and by consulting documentary sources such as notes and other entries in inventories of collections, artists' manuals, and the few reports written by conservators. It was only in the 1930s that the beginnings of the conservation profession as we know it began in Britain, with treatments proposed, reported, and discussed. Examples of the usefulness of archival materials for detailing the early history of conservation are discussed. The inventories of the Royal Collection by Abraham van der Doort during the reign of Charles I and by Richard Redgrave during Queen Victoria's reign are highlighted.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

McGlinchey C. and Yuan B., **The development of ultra-cool melt adhesives for mounting resin-coated (RC) photographic papers,** 7th Symposium on Materials Issues in Art and Archaeology, held at the 2004 MRS Fall Meeting, ed. P.B. Vandiver, J.L. Mass and A. Murray, Materials Research Society, Original edition, Materials Issues in Art and Archaeology VII, 2004

Abstract: The development of an adhesive that is a hybrid between a pressure sensitive adhesive and a heat seal adhesive is described. The goal of this project, which is a joint collaboration between the Museum of Modem Art and the Polymer Research Institute, is to develop a preservation quality adhesive for application to RC print photographs. RC prints are clad in polyethylene, a low surface energy (LSE) polymer that requires special consideration when devising an adhesive to adhere to it. In arriving at a formula for this purpose research has focused on a combination of hydrocarbon-based polymers and low molecular weight oligomers. In addition, this work addresses other aspects such as activation conditions and joint design, factors critical to developing an adhesive that has the potential to satisfy the stringent criteria of a material acceptable to conservation applications.

http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=8007384&fulltextType=RA&fileId=S1946427400080830

Mecklenburg M.F., Tumosa C.S. and Erhardt D., **Structural response of painted wood surfaces to changes in ambient relative humidity,** Painted wood: history and conservation, Dorge Valerie (Editor) and Howlett F. Carey (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 464 - 483

Abstract: Determining the structural response of any object to environmental influences requires the determination of the mechanical and dimensional properties of its materials. In the case of painted wood objects, the materials in question are a variety of paints, hide glues, gessos, and woods. This study measured the mechanical and dimensional properties of several of those materials with the view of determining the failure mechanisms of such composite structures and identifying the factors that assist in reducing and preventing new or additional damage. In examining the materials in question, the study has helped determine allowable relative humidity fluctuations under the worst case conditions of a fully restrained structure. The results of the research program suggest that there are significant allowable fluctuations that restrained artists' materials can undergo without damage. In addition, it has become apparent that extreme changes in environmental moisture are the primary cause of mechanical damage. The allowable fluctuations can be determined by calculating the true swelling coefficients from measured swelling isotherms of a material and measuring their yield points.
http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood6.pdf

Mecklenburg M.F., **Determining the Acceptable Ranges of Relative Humidity and Temperature in Museums and Galleries,** Smithsonian Museum Conservation Institute, 2007

Abstract: Most exhibition spaces in museum and galleries set the temperature for the comfort of the visitors and staff. Altering this temperature can have a significant effect on the long term stability of the collections. This is universally true for museum collections since elevated temperatures increase the chemical processes that promote deterioration. By promoting deterioration, high temperatures weaken the structure of all materials. The converse is true in that lower temperatures can reduce chemical deterioration and enhance chemical and mechanical stability. However there are significant limitations in allowing lower temperatures. This section will focus on the effects of lower temperatures.
http://si-pddr.si.edu/jspui/handle/10088/7055

Meijer M. de, Thurich K. and Militz H., **Comparative study on penetration characteristics of modern wood coatings,** Wood Science and Technology, 32, 5, 1998, p. 347 - 365

Abstract: The penetration characteristics of five modern wood coatings (three waterborne, one high solid and one solvent borne) into pine sapwood, spruce and dark red meranti have been systematically compared. The degree of coating penetration is mainly determined by the ability of the coating to flow into wood capillaries. Binder type, pigmentation, solid matter content and drying speed appeared to influence this ability. In softwoods the following different coating penetration routes are observed: the flow into open ends of longitudinal early- and latewood tracheids, the flow into ray cells and the transport from rays through the cross-field into longitudinal tracheids adjacent to rays. The possibility for the coating to follow the latter route is strongly influenced by the existing type of cross field pitting and to a lesser degree by the pigmentation of the paint. Clear differences between pine and spruce have been found with respect to the flow into ray parenchym and ray tracheids. The flow into open ends of longitudinal tracheids is strongly influenced by the grain angle of tracheids. Penetration into dark red meranti is mainly limited to vessels and rays. Tylose membranes can prevent the complete filling of vessels. The impact on penetration of the removal of extractives and of sanding of the surface has also been studied but appears to be of only minor importance.

http://libra.msra.cn/Publication/39679418/comparative-study-on-penetration-characteristics-of-modern-wood-coatings

Miller Mendoza, Philipp Hass, Falk K. Wittel, Peter Niemz and Hans J. Herrmann, **Adhesive penetration of hardwood: a generic penetration model,** Wood Science and Technology 46, 1-3, 2012, p. 529 - 549

Abstract: An analytical model to predict the penetration of adhesives into hardwood is proposed. Penetration into hardwood is dominated by the vessel network which prohibits porous medium approximations. The model considers two scales: (1) a one dimensional capillary fluid transport of a hardening adhesive through a single, straight vessel with diffusion of solvent through the walls of the vessel; and (2) a mesoscopic scale based on topological characteristics of the vessel network. Given an initial amount of adhesive and applied bonding pressure, the portion of the filled structure could be calculated. The model was applied to beech samples joined with three different types of adhesive (PUR, UF, PVAc) under various growth ring angles as described by Hass et al (2011). The model contains one free parameter that can be adjusted in order to fit the experimental data
http://rd.springer.com/article/10.1007/s00226-011-0422-2

Michalski S., **The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model,** Experts' Roundtable on Sustainable Climate Management Strategies, Getty, Tenerife, Spain, 2007,

Abstract: The conventional (late-twentieth-century) approach to climate control specifications for museums has been to find a single target associated with "ideal" conditions and, failing that, to specify "compromise" or "relaxed" conditions. It was assumed that the further one strayed from the ideal target, the greater the damage to the collections. Despite a steady undercurrent of thoughtful critiques from the very beginning of the climate control boom in museums (e.g., Rogers 1976) this fundamentalist approach to specifications has proven remarkably persistent. Much of the success of a simplistic approach has nothing to do with whether or not museums actually believe that ideal control is ideal for collections, but with the fact that a single target makes life much easier for architects, HVAC engineers, curators, collection managers, exhibit designers, preparators, and, not least, conservators. I do not mean simply operationally easier in museums where it is achieved but intellectually easier in any museum, whether it is achieved or not. Many decades have passed since the encouragement of the first magic numbers for climate control in museums—the 60°F, 60% relative humidity (RH) rule of Rawlins, (Rawlins 1942)—and the last three decades have seen widespread implementation of museum climate control "improvements." An entire generation of conservators

and conservation scientists have watched the accumulation (or not) of damage in collections modified (or not) by climate control. The next generation faces painful decisions about sustainability. It is time to take stock and to consider what advice to pass on.

http://www.getty.edu/conservation/ourprojects/science/climate/paper_michalski.pdf

Michalski S., **A physical model of the consolidation process, particularly of paintings,** The care of painted surfaces: materials and methods for consolidation, and scientific methods to evaluate their effectiveness, Third international congress on Color and Conservation, Materials and Methods of Restoration of Movable Polychrome, Milan, 10-11 November 2006, Works proceedings, Padua, Il Prato, 2008

Abstract: Explains the physical process of consolidation with the aid of illustrations and tables. The author first discusses application methods (brushes, syringes, spraying, misting, evaporation barriers, vacuum-assisted techniques, etc.) and why they are important. Penetration of the consolidating solution depends upon the pore network of the material and capillary action. A number of factors influence the process: consolidant separation during application; consolidant migration during drying; evaporation; and the drying of porous materials. Other factors briefly discussed are appearance and color change and strength of consolidation. The article is interspersed with practical summaries and suggestions on each topic, marked for readers to find easily. For scientific readers, an appendix supplies detailed equations for the model: capillarity; adsorption layer; adsorption lag; funicular flow region during drying; migration, and appearance, as well as the symbols and units used.

http://cci-icc-gc.academia.edu/StefanMichalski/Papers/886692/2008._A_physical_model_of_the_consolidation_process_particularly_of_painting

Michalski S., **The ideal climate, risk management, the ASHRAE chapter, proofed fluctuations, and towards a full risk analysis model,** Experts Roundtable on Sustainable Climate Management Strategies, The Getty Conservation Institute, 2007.

http://www.getty.edu/conservation/our_projects/science/climate/paper_michalski.pdf

Miller M.A., Bisacca G., Galitzine D., **The Development of a Spring Mechanism for Use in Conjunction with Auxiliary Supports for Previously Thinned Panels,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 59 - 68

Abstract: Secondary supports for excessively thinned panels (usually the result of previous interventions such as cradling) have always presented a challenge. Modern solutions have attempted to offer additional support while allowing for movement of the panel during humidity fluctuations. Many such systems have included the use of spring components. A new, adjustable mechanism was developed over the past year by the Metropolitan Museum of Art in collaboration with Design Development Associates, and it was first used on Albrecht Durer's painting Adam at the Prado Museum. The evolution of spring-loaded mechanisms in secondary supports was reviewed and evaluated in the initial phase of development. Various prototypes were tested and repeatedly modified before a production model was achieved. Simplicity, versatility, and cost were primary considerations. Individual mechanisms and kits will be mass-produced and made commercially available by Design Development Associates.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Miller, M.A., **Marvelseal Envelopes at the Metropolitain Museum of Art,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 207 - 208

Abstract: Microclimate packages are often used to isolate panel paintings from fluctuating environmental conditions. The Metropolitan Museum of Art in New York uses a system referred to as a Marvel Seal envelope, which has evolved since it was first developed in the early 1990s. Because of the volume of paintings lent by the Metropolitan each year, it is important that we use a system that is both effective and practical. The Marvel Seal envelope, a self-contained package made from easily obtained and inexpensive materials, can be easily inserted and removed from a frame. It can be assembled quickly, modified simply to accommodate most paintings, and readily opened and resealed. Instructions for assembling a Marvel Seal envelope are given in figures 1a–f. If the envelope is assembled properly, it contains a minimal amount of air and has an extremely low rate of leakage.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing4.pdf

Monfardini P.P., **Structural and Climate Control Systems for Thinned Panel Paintings,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui. Los Angeles, Getty Conservation Institute, 2011, p. 48 – 58

Abstracts: The thinning of the wooden support of paintings on panel was considered in the past and, in fact, until recent times the correct way to resolve the problem of warping, in order to render the painting flat again. The operation of reducing the thickness of the support was carried out on deformed panels according to their curvature, to allow the thinned support to be reinforced in a flat position with a rigid auxiliary support. Analysis of past interventions has demonstrated that this type of operation completely altered the work, exponentially increasing problems of stability and support of the surface. Our research consists of the application of a buffer system on the reverse of the panel, with the aim of artificially restoring the response of the support to gradients of humidity similar to what it might have had originally, in order to slow shrinkage and expansion and therefore deformation in response to hydrometric jumps. The buffer system has been in use for a decade now and has been successfully applied in many cases—an example being the Madonna and Child Enthroned with Saints Francis and Nicasio or Liberale (Pala di Castelfranco) by Giorgione (ca. 1504), in the Duomo of Castelfranco Veneto (Treviso).

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Morigi M.P., et al, **CT investigation of two paintings on wood tables by Gentile da Fabriano,** Nuclear Instruments and Methods in Physics Research A, 2007, p. 735 - 738

Abstract: A couple of small paintings on wood, property of the National Gallery of Bologna and attributed to Gentile da Fabriano, have been analyzed by means of different diagnostic nondestructive techniques in order to have a complete characterization of their conservation state. Adopted techniques are X-ray fluorescence, infrared reflection imaging, radiography and computed tomography (CT). In this work we will focus mainly on results obtained with CT, which was carried out with a CT system developed by the authors at the Physics Department of the University of Bologna. The CT system has already been used for the full-volume examination of archaeological samples and works of art and mainly consists of a cone-beam X-ray source, a rotational stage for sample manipulation and a Gd2O2S:Tb scintillator screen, optically coupled to a CCD camera. The CT investigation has given us important information on the conservation state of the two

tables and on the spatial distribution of the different materials and pigments, besides providing an evidence of a particular technique used by the painter for outlining the figures of the Saint Apostles.

http://www.researchgate.net/publication/222199815_CT_investigation_of_two_paintings_on_wood_tables_by_Gentile_da_Fabriano

Moutsatsou A.P., Kouloumpi E., Olafsdottir J., Trompeta M., Tsaroucha C., Doulgeridis M., Groves R.M. and Tornari V., **Protocols for the construction and characterization of model panel paintings for the evaluation of structural diagnostic techniques,** Proc. Wood Science for Conservation of Cultural Heritage 2007, ed. Uzielli L. Florence, Firenze University Press, 2009, p. 105 - 109

http://www.fupress.com/Archivio/pdf%5C4099.pdf

Mukudai J. and Yata S., **Further modeling and simulation of viscoelastic behavior (bending deflection) of wood under moisture change,** Wood Science and Technology, 1987, p. 49 - 63

Abstract: It has been possible to interpret the characteristics of viscoelastic behavior of wood under moisture change cycles based on the hypothesis that the looseness between the S1 and S2 layers in the microstructure of the cell wall caused a slippage between them during drying. A viscoelastic bending model consisting of elementary models on the basis of the hypothesis was proposed. Creep and recovery deflection under moisture change cycles were simulated with computer by the use of the bending model. The characteristics of the viscoelastic deflection obtained from the simulation agreed well with those of published experimental results.

http://rd.springer.com/article/10.1007/BF00349717

Mukudai J. and Yata S., **Modeling and simulation of viscoelastic behavior (tensile strain) of wood under moisture change,** Wood Science and Technology, 1986, p. 335 - 348

Abstract: A hypothesis was proposed on the mechanism of the characteristic viscoelastic behavior of wood under moisture change. The hypothesis was based on the inference in which the characteristic behavior might be attributed to the looseness of the interface between the S1 and S2 layers in a cell wall. A mechanical model representing the behavior of a single cell wall on basis of the hypothesis and the results of simulation by the use of the mechanical model with the computer were shown in this report. The characteristics of the viscoelastic strain obtained from the simulation agreed well with those of published experimental results.
http://rd.springer.com/article/10.1007/BF00351586

Murray A., **Air-coupled ultrasonic system: a new technology for detecting flaws in paintings on wooden panels,** JAIC, 1996, p. 145 - 162

Abstract: Air-coupled ultrasound, a noncontact, nondestructive testing technique, has detected splits, checks, delaminations, cleavage, and voids in various materials. The system has inspected highly anisotropic and inhomogeneous materials such as wood and wood products, with surfaces layers of gesso, gesso and linen, paper, and wood veneer. Two paintings were tested; one was an oak-cradled panel painting and the other was illustration board mounted on hardboard. The air-coupled ultrasound technique yielded information additional to that provided by visual examination, xeroradiography, and infrared thermography.
http://cool.conservation-us.org/jaic/articles/jaic35-02-005_indx.html

Murray, Alison, **Air-Coupled Ultrasound Used to Detect Flaws in Paintings on Wooden Panels,** MCI 28998, Dissertation, 1993 [Old BCIN Number: 174729 BCIN Number: 117370]

Abstract: The risk of damage to paintings on wood (panel paintings) increases with the presence of cracks, delaminations, and their associated stress concentrations. Such flaws can originate and increase in size as a result of fluctuations in temperature and relative humidity, as well as shock and vibration. Many flaws are internal and therefore cannot be detected visually or by traditional testing techniques; thus it is difficult, for example, to assess the risk that transportation poses to panel paintings. Air-coupled ultrasound can be used to assess the condition of panel paintings in a non-contact, non-intrusive manner; it provides information complementary to that given by radiography. It has been demonstrated that the ultrasonic system is clearly more suitable for detecting certain flaws, such as in-plane cracks and delaminations. The system enables measurements to be easily made of highly anisotropic and inhomogeneous materials such as wood. The ultrasonic system used in this study has a superior signal-to- noise ratio because it uses efficient transducers, low noise pre- amplifiers, and a phase-sensitive superheterodyne ultrasonic system which contains analog signal averaging and filtering components. The signal can be exploited to yield both amplitude and phase information. Amplitude measurements detect delaminations and cracks, while phase measurements detect cracks. The ultrasonic system also incorporates a mechanical scanner to produce easily interpreted two-dimensional images of large areas of paintings to give clear indication of their condition. The results can be further enhanced by using image processing techniques. The ultrasonic system reliably detected cracks and delamination in the panel paintings Parental Admonition (a copy of the original), Sunset Scene, and Woman Gathering Yucca Plants. More applications have demonstrated the successful examination of a wide range of simulated panel paintings with different supports (white oak, tulip poplar, and hardboard), surfaces (gesso, gesso and linen, veneer, and paper), and flaws (cracks and delaminations). By using certain measurement techniques, the structural information in the ultrasonic scan was not obscured by the paint layer. The support layers were of thicknesses comparable to those of panel paintings.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=117370

Murray A., Boltz E.S., Renken M.C., Fortunko C.M., Mecklenburg M.F. and Green R.E. Jr., **Air-coupled ultrasonic system for detecting delaminations and cracks in paintings on wooden panels,** Department of Materials Science and Engineering and the Center for Non-destructive Evaluation, The Johns Hopkins University, Baltimore, MD, 21218 National Institute of Standards and Technology, Boulder, CO, 80303, The Conservation Analytical Laboratory, The Smithsonian Institution, Washington, D.C., 20560 in Non-destructive characterization of materials VI, edited by R.E. Green Jr, K.J. Kozaczek and C.O. Ruud, 1995, p. 103

Abstract: It has been established that the risk of damage to paintings on wood ("panel paintings") increases with the presence of cracks, delaminations, and their associated stress concentrations. Such flaws can originate and increase in size as a result of fluctuations in temperature and relative humidity, as well as shock and vibration. Many internal flaws cannot be detected either visually or by traditional testing techniques, and it is difficult, therefore, to assess the risk transportation poses to panel paintings. Air-coupled ultrasound has been used to assess the condition of two panel paintings (Parental Admonition [a copy of the original] and Women Gathering Yucca Plants), in a non-contact, non-intrusive manner; this method provides information complementary to that given by radiography. It has been demonstrated that the ultrasonic system is clearly more suitable for detecting specific types of flaw, such as in-plane cracks and delamination. The system enables measurements to be easily made of highly anisotropic and inhomogeneous materials such as wood. The ultrasonic system used in this study has a superior signal-to noise ratio because it uses efficient transducers, low noise pre-amplifiers, and a phase-sensitive superheterodyne ultrasonic system that has analog signal averaging and filtering components. The signal can be exploited to yield both amplitude and phase information. The ultrasonic system also incorporates a mechanical scanner to produce easily interpreted two-dimensional images of large areas of paintings to give a clear indication of their condition. The results can be further enhanced by using image processing techniques.

http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA290727#page=121

New B. and Marchant R., **The Repair and Support of Thinned Panel Paintings: A Case Study in Modifying Established Techniques,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 36 - 47

Abstract: The wooden panels of this sixteenth-century triptych, The Deposition, The Presentation of the Virgin, and The Marriage of the Virgin from the Fitzwilliam Museum, Cambridge, had been thinned and cradled. The treatments, carried out at the Hamilton Kerr Institute in Cambridge, included repair and attachment of flexible supports to the wings. The thickness of the central panel measured less than 1 mm (0.04 in.) in parts and therefore required a different approach. A modified balsa backing was developed. The rationale behind the treatments, the empirical testing of the materials leading to the choice of facing and backing adhesives, and the backing technique are described.
http://www.getty.edu/conservation/publications_resources/pdf_publications/facing2.pdf

Niemz P., Mannes D., **Non-destructive testing of wood and wood-based materials,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 26 - 34

Abstract: Methods of non-destructive wood testing continue to gain importance. Online tools, for example to control production, have effectually been in use for years. Based on a measuring systematics (physically active principle and important influencing factors), a summary of methods to assess cultural heritage objects is given. To adopt methods based on physical effects, profound knowledge of wood physics is essential, particularly knowledge of interdependencies.
http://dx.doi.org/10.1016/j.culher.2012.04.001

Nilsson T., Rowell R., **Historical wood – structure and properties,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 5 - 9

Abstract: To understand what has happened to a historic wooden object, it is important to understand the wood structure and the chemistry of the original wood as well as the structure and chemistry of the historic wood. With this information, it is possible to understand the degradation that has occurred over time.

With this knowledge, it is also possible to describe a possible method of conservation and preservation.

http://dx.doi.org/10.1016/j.culher.2012.03.016

Noguchi T., Obataya E., Ando K., **Effects of aging on the vibrational properties of wood, Wood** Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 21 - 25

Abstract: Vibrational properties of aged wood (121-296 years old) were compared with those of recently cut "new" wood (8 years old). The aged wood showed higher sound velocity (VL) and lower mechanical loss tangent (tan-L) than the new wood. The ratio of Young›s modulus and shear modulus (EL/GL) remained unchanged or increased slightly during the aging period. These results coincide with musicians' empirical observations that the acoustic quality of wooden soundboards is improved by aging. In addition, the reduced tan-L of the aged wood indicates the qualitative difference between the naturally aged and heat-treated wood. The experimental results were explained by using a cell wall model when we assumed the following: increase in the volume fraction of cellulosic microfibrils; reduction in the shear modulus of amorphous matrix substances, and; reduction in the loss tangent of the matrix. These assumptions appear reasonable when we consider the crystallization of cellulose, depolymerization of hemicelluloses, and cross-linking in the lignin complex during aging.

http://dx.doi.org/10.1016/j.culher.2012.02.008

Odegaard N., **An investigation of the nature of paint on wood objects in the indigenous Southwest of North America,** Painted wood: history and conservation, Dorge Valerie and Howlett F. Carey (Editors), The Getty Conservation Institute, 1998, p. 255 - 267

Abstract: Discusses the nature of paint in the indigenous American Southwest. Background on the materials, technology, quality, and condition of painted wood artifacts are presented. Information for this study is based on direct observation of several museum collections, collection documentation, firsthand archaeological field work, field notes, conservation treatment experience, material analysis, published ethnographic literature, and interviews with Native Americans, archaeologists, ethnologists, collectors, and other specialists. Previous technical studies have focused primarily on pigment identification and on the iconography of the decorated surfaces. Questions concerning the binding media, technological

methods, and preservation have not been widely addressed. Painted wood objects in the American Southwest region have been recovered from archaeological sites of the Mogollon, Hohokam, Sinagua, and Anasazi cultures. Traditional paint on wood technologies evolved and continued into the historic period that began after European contact in 1540. The cultures of this region are distinctive in that they have survived to a greater extent than anywhere on the continent. These cultures are represented by the Western Pueblos (Zuni, Hopi, Acoma, Laguna), Athabaskans (Apache and Navajo), O'odhams (Tohono, Akimel, and Hiatch), Yumans (Mojave, Quechan, Cocopa, Yavapai, Havasupai, Walapai), Cahitan (Yaqui, Mayo), and Seri, as well as the peoples of the Rio Grande Pueblos. Traditional objects of painted wood from the Southwest are characterized by strong colorful patterns and iconography utilizing powdery, matte, high volume pigment-low binder paints. For the most part, collections of archaeological and early ethnographic painted wood held in museums today have been inadequately studied, treated, and stored. Background in contextual information and technical study of the interaction of wood and paint may clarify the conservation needs for these objects. This report focuses on the broad topic of painted wood technology within this cultural and ecological area. It avoids specific discussion of ritual functions or of religious materials which are considered inappropriate.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood3.pdf

Olstad T.M. and Haugen A., **Warm feet and cold art: is this the solution? Polychrome wooden ecclesiastical art: climate and dimensional changes,** Museum microclimates: contributions to the Copenhagen conference, 19-23 November 2007, National Museum of Denmark, Copenhagen, Denmark, 2007, p. 43 - 49

Abstract: The installation of heating systems in the early 20th century in previously unheated Norwegian churches caused thermal stress on polychrome wooden sculptures, resulting in dimensional change and peeling paint layers. Though intermittent or localized heating directed toward users was developed as a solution in the 1970s, the impact on wooden objects was still poorly understood. The research project "Ecclesiastical Art: Climate and Dimensional Changes", led by the Norwegian Institute for Cultural Heritage Research (NIKU), is investigating this problem together with institutions in Poland and Sweden. In a first experiment, wood dimensional changes were tracked in a climate room test. The wood surfaces reacted to environmental changes after only a few minutes of exposure; additionally, dimensional change was larger over distances of 1 millimeter than over 100

millimeters, demonstrating that the changes (both shrinking and swelling) did not occur evenly over the entire surface. Upcoming collaborative research between NIKU and the Polish Academy of Sciences will centre on observing reactions in painted wood exposed to varying climate: laser vibrometry, direct monitoring using acoustic emission and computer modeling are proposed to document paint layer changes in response to climatic variation. A further project undertaken between NIKU and Gotland University will investigate whether intermittent heating has in fact damaged polychrome wooden objects in churches, by monitoring in situ 100 to 200 objects located in heated, unheated and intermittently heated buildings.

http://eprints.sparaochbevara.se/29/

Paoletti D., et al, **An Automatic Measurement Method for Surface Defects,** J. Optics (Paris), 21, 6, p. 247 - 251

Abstract: A method for the detection and measurement of surface defects is described : it includes the use of a holographic system and the application of digital image processing and automated computer analysis for quantitative information. Calibration tests on defects of known sizes have been effected the possibility of applying the method to studying the state of artwork conservation is examined.

http://iopscience.iop.org/0150-536X/21/6/002/

Parker R.H. and Sixbey P.L., **Jeffrey: Horse of a Different Color, Painted Wood: History and Conservation,** J. Paul Getty Trust, Singapore, 1998, p. 383 - 397

Abstract: The over-the-jumps carousel, located in Little Rock, Arkansas, is one of fewer than 180 intact wooden carousels of the more than5,000 carousels that once operated in the United States (Morgan 1994). It is the only surviving example of an undulating-track carousel manufactured by Spillman Engineering Corporation in the 1920s in North Tonawanda, New York. It was a familiar sight on amusement ride circuits, including the Arkansas State Fair. In 1942, the forty hand-carved wooden horses and four chariots found their way to War Memorial Midway in Little Rock, where the carousel continued to operate until 1991 (Anderson and Story 1989). During its forty-nine-year period of operation, up to thirty layers of "park paint" were applied to the carousel animals as part of ongoing maintenance. Recent conservation surveys and treatments indicate that most of the original paint layers remain intact (Parker 1994). Roads to extinction are often paved with good inten-

tions. Numerous well-intended preservation attempts have compromised the integrity of many wooden carousels; very few retain original painted surfaces beneath restoration colors, and even fewer survive intact with their original surfaces exposed. Indeed, restoration efforts have put existing original paint surfaces and designs on "the endangered list." Carousels have a long and important tradition in many cultures; we should apply the highest conservation standards to the increasingly rare intact examples of this unique, painted wooden art form.
http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Pattyranie C. and Ulfvarson U., **The blistering of paints on wood induced by moisture,** Part I, The influence of some structural variables of pine wood on the blistering induced by moisture of an alkyd paint film, Part II, The influence of various treatments of pine wood on blistering caused by moisture, Journal of the Oil and Colour Chemists' Association 55, 3, 1972, p. 207 – 226

Abstract: The authors found that blistering of pigmented alkyd paints on pine panels which were subjected to moisture diffusion from the back was influenced by structural factors as follows: heartwood gave more intense blistering than sapwood, radially sawn more than tangential; the density of annual rings did not influence blistering in heartwood but sapwood panels with dense annual rings which were also radially sawn gave more blistering than other combinations, and in general the higher the density of the wood the lower the blistering. Pretreating the wood by soaking in water at different pH values at different temperatures, treating with steam, heating and soaking in ethereal solutions, led to the conclusion that extractable constituents of the wood which diffuse to the wood/paint interface under the influence of heat or moisture, or both in combination, are responsible for blistering of the paints rather than heat or moisture alone. Pretreatment of the wood can increase the blister resistance of paints subsequently applied to it. These artificial blister tests are used mainly in testing modern paints for use outdoors on window frames, siding, etc., but the general conclusions may be of interest to those working on art objects where wood and paint are involved.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=57782

Payer C., et al, **The Interior Decor of the Ursuline Chapel in Quebec City: Research and Conservation,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 301 - 317

Abstract: During the eighteenth century, the interior of few churches in New France could rival that of the Ursuline Chapel, in the complexity of iconography, the richness of carving, or the extent and variety of gilded and polychromed surfaces. It was one of the rare interiors to survive the bombardment of Quebec City by the British in 1759. It has also been spared from fire and saved from the dispersal that often accompanies changing tastes. Today, it is the only assemblage of furnishings from the French regime that is nearly intact, making it one of the oldest extant in North America. For these reasons, it is exceptional. The first Ursulines arrived in New France in 1639 to establish a school for girls. In 1642, they moved to a building situated on the heights of Quebec City, on a plot of land that their convent still occupies today. An initial fire in 1650 and a second in 1686 obliged them to completely rebuild twice. After the second fire, they had to wait until 1723 before their new chapel was finished. It was a stone building, featuring a nave (or outer chapel), reserved for the general population; a sanctuary, later to be embellished with the rich carved furnishings that are the subject of this article; and, to the right (liturgical south) of the sanctuary, the nuns' chapel, a place of prayer for the Ursulines and their pupils. Since this was a cloistered community, the nuns' chapel was enclosed by a screen.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Popescu C-M., Sakata Y., Popescu M-C., Osaka A. and Vasile C., **Degradation of lime wood painting supports,** E-preservation science, scientific research for the preservation of cultural heritage 2, 2005, p. 19 – 29 [ISSN 1854-3928]

Abstract: Degradation of wood, being a natural process, leads to destruction of wooden objects of historical and cultural value, resulting in loss of cultural heritage. Wood can survive centuries or even thousands of years if kept in an environment that limits microbial activity. In an unfavorable environment, physical, chemical, and morphological modifications of wood also take place as a result of biodegradation. It is important to know the type of degradation and how the processes influence material properties if wooden items are to be properly preserved. The objective of this study is to present new knowledge on non-invasive techniques useful to assess the preservation status of lime wood in art objects. The methods of investigation were optical and electronic microscopy, wide angle x-ray

scattering (WAXS), and Fourier transform infrared (FTIR) spectroscopy. Following a deconvolution process of the diffraction patterns, crystalline index, apparent lateral crystallite size, proportion of crystallite interior chains, orientation index, mesomorphism, and cellulose fraction have been determined and shown to change with increasing age of painting supports. Structural modifications were assessed by FTIR spectrometry and 2-D correlation FTIR spectroscopy, while morphological modification were characterized using scanning electron microscopy (SEM). The principal heteroelements of the lime wood samples were detected by energy dispersive x-ray analysis (EDX). It can be concluded that only a multianalytical approach can provide the information needed on wood degradation processes. (Author's Abstract) AATA No. 42-634

http://www.morana-rtd.com/e-preservationscience/2005/Vasile-18-05-2005.pdf

Rachwał B., Bratasz Ł., Krzemien L., Łukomski M., Kozłowski R., **Fatigue damage of gesso in panel paintings subjected to changing climate conditions,** Strain, an international journal for experimental mechanics, 2011

Abstract: Numerical modelling was used to follow the moisture movement and strain in a composite system – an unrestrained, single wood panel coated with a layer of gesso, in response to cyclic sinusoidal variations in relative humidity (RH). The allowable magnitude of the variations, below which physical damage of the gesso layer on the wood does not occur over a selected time of exposure, was derived as a function of cycle duration, panel thickness and moisture diffusion configuration. The dimensional response of wood substrate becomes subject to restraint by the applied layer of gesso. The panels do not respond significantly to diurnal fluctuations or shorter irrespectively of the panel thickness. The panels respond more and more significantly when the duration of the fluctuations increases until a certain critical period at which the panel fully responds to each cycle. The lowest allowable amplitude of fluctuations determined in this study was ±14% RH for a panel 40 mm thick and 0.5 mm thick gesso layer of composition and mechanical parameters commonly used in the restoration of panel paintings. The reduction of allowable amplitude of RH cycles due to decrease of the gesso's modulus of elasticity and thickness is discussed.

http://onlinelibrary.wiley.com/doi/10.1111/j.1475-1305.2012.00844.x/abstract

Rachwal B., Bratasz L., Lukomski M., Kozlowski R., **Response of wood supports in panel paintings subjected to changing climate conditions,** Strain, Volume 48, Issue 5, 2012, p. 366 – 374

Abstract: The finite element method was used to model the moisture movement and strain in the wood supports of panel paintings, in response to changing climate conditions – temperature and relative humidity (RH). The material properties of lime wood (Tilia sp.), determined experimentally, were used in the modelling. Critical amplitudes of cyclic sinusoidal RH fluctuations generating strain of 0.002 in the most responsive tangential direction of the unrestrained, single wood panel, which the pictorial layer was assumed to endure without damage, were derived for the mid-RH region as a function of cycle duration, panel thickness and diffusion configuration. Panels do not respond significantly to diurnal fluctuations or shorter. The panels respond more and more significantly when the duration of the fluctuations increases until the panel fully responds to each cycle. These fluctuation periods are 14 and 90 days at 20 °C for a panel thickness of 10 and 40 mm, respectively, with two faces of a panel diffusively opened. Sinusoidal RH variations bringing about wood's full response have the critical amplitude of ±6% RH, that is strain of 0.002 endangering the pictorial layer is produced at such amplitude in the tangential direction of the unrestrained panel.

http://onlinelibrary.wiley.com/doi/10.1111/j.1475-1305.2011.00832.x/abstract

Rawat S.P.S., Khali D.P., Hale M.D. and Breese M.C., **Studies on the moisture adsorption behaviour of brown rot decayed and undecayed wood blocks of Pinus sylvestris using the Brunauer-Emmett-Teller theory,** Holzforschung 52, 5, 1998, p. 463 - 466

Abstract: Comparative studies of the moisture adsorption behaviour of undecayed and brown rot decayed wood blocks of Pinus sylvestris were made. Experimental adsorption isotherms were obtained. Analysis of adsorption data in terms of primary and secondary water were carried out using the theory of Brunauer, Emmett and Teller (BET). A good agreement between experimentally obtained adsorption isotherms with those obtained using BET theory, validating the use of BET theory in the elucidation of adsorption mechanism.

http://www.deepdyve.com/lp/de-gruyter/studies-on-the-moisture-adsorption-behaviour-of-brown-rot-decayed-and-ZPWgLKCPKn

Ray S.L. and Reilly J.A., **The Treatment of Painted Wooden Folk Art,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 373 - 382

Abstract: In The Early Twentieth Century, the first assemblages of folk art were gathered by collectors who found great aesthetic appeal in the sometimes quaint and often curious expressions of artists who worked outside the mainstream of art. Abby Aldrich Rockefeller was a pioneer in the collecting of American folk art. She began collecting during the 1920s when folk art was mostly ignored by others. In 1935, she loaned a large part of her collection to the Colonial Williamsburg Foundation, and in 1939, this loan became a gift. The Abby Aldrich Rockefeller Folk Art Center (AARFAC) was constructed at Colonial Williamsburg in 1957 by John D. Rockefeller Jr. as a memorial to his wife. The AARFAC collection contains more than 3,300 objects from the eighteenth, nineteenth, and twentieth centuries and reflects the innate creative skills of many craftspeople and artisans. The collection includes banners, toys, furniture, sculpture, decoys, figures, signs, weather vanes, whirligigs, carousel animals, tools, and advertisements. In early 1987, the curatorial and administrative staff, in collaboration with Foundation conservators, selected 182 objects to go on a traveling exhibition to nine cities across America. The purpose of the exhibition was to share AARFAC's exceptional collection of American folk art with a broader audience while its building was closed for expansion and renovation. After the chosen objects were surveyed, those requiring treatment prior to travel were sent to the various laboratories in the Department of Conservation. The treatments ranged in complexity from simple superficial cleaning to more complicated structural stabilization and cosmetic reintegration. After the traveling exhibition, these objects were returned to Williamsburg in 1991. Along with 250 additional objects, they were installed in the new wing at AARFAC, which added an additional 1767 m2 (19,000 sq. ft.) of exhibition and storage space to the museum. This additional group of objects was also surveyed, and conservation treatment was performed on those with the greatest need. In total, 155 of the objects treated were of painted wood, and the survey and subsequent conservation produced a prodigious amount of documentation. A review of the treatment records made it clear that there were relationships between construction methods and current condition. It is this information that forms the basis for this article.
http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Reeve A.M., **Structural Conservation of Panel Paintings at the National Gallery, London,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 403 - 417

Abstract: The National Gallery, London, has over 1,000 panel paintings in its collection. Current conservation methods for these panels are described including: fumigation; surface consolidation; facing of the surface before structural consolidation work; removal of old nails or fixings and treatment of cracks and joins; moisture treatments; consolidation and impregnation of woodworm-affected areas; moisture barriers; infills of balsa wood; panel trays; balsa-wood build-up; transfers; and panel fittings. Frame fitting for exhibiting the conservation of a panel fragment of the Annunciation by Cosmè Tura is described in detail. Infrared and x-ray examination showed that there was extensive restoration down an off-center vertical crack, that wormholes had been filled with chalk, glue, and pigment, and that there were several insets of a different wood. The original panel had been planed down to a thickness of no more than 2 mm and was surrounded by thin oak strips veneered onto mahogany. The cradle of oak sliding bars and mahogany fixed battens had caused a slight concave warp on the length of the panel. Treatment of the panel in 1915 had caused subsequent cracking, blistering, and flaking. The picture was faced to protect it during cradle and veneer removal. Cracks and wormholes exposed by removal of the veneer were filled, and distorted parts were realigned. The panel was treated with controlled moisture to reduce the warp that had occurred after the removal of the additions and consolidation of the cracks and joins. Interleaf materials were applied to the back of the panel to even out ripples and distortions before a balsa-wood build-up was attached. Two layers of balsa running with the grain of the panel were applied. The sides and back were covered with linen canvas. Subsequently, the holes in the picture were filled and the picture was varnished.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Richard M., **Factors Affecting the Dimensional Responses of Wood,** Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 131 - 135

Abstract: The use of moisture barriers to retard sorption/desorption of moisture in wood panel paintings is described with reference to experimental work using Acryloid B72, polyvinyl acetate (AYAA), paraffin and Saran F-310 as coatings using short cycle humidity variations between 32 and 75%. Dimensional changes were measured with strain gages.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=11470

Richard M., **Further Studies on the Benefits of Adding Silica Gel to Microclimate Packages for Panel Paintings,** Facing the Challenges of Panel Painting Conservation: Trends, Treatments, and Training, proceedings of a symposium at the Getty Centre, 17-18 May 2009, Phenix Alan (Editor) and Chui Sue Ann (Editor), The Getty Conservation Institute, Los Angeles, California, 2011, p. 140 – 147

Abstract: Panel paintings are frequently housed in microclimate packages when exhibited in less-than-ideal environments. At the "Museum Microclimate" conference in Copenhagen in November 2007, the author presented results of studies on the behavior of panel paintings in microclimate packages to which silica gel had been added (Richard 2007). These studies were undertaken to address a concern raised by some conservators and conservation scientists: since the adsorption properties of silica gel and the wooden support of the painting differ, might the disparity result in damage to the painting when a microclimate package is exposed to temperature variations? The author's research indicates that, while silica gel is unnecessary in well-designed and well-constructed packages, adding moderate quantities of properly conditioned silica gel is not only safe but potentially beneficial for packages with an air exchange rate that is higher than anticipated. Studies carried out since the Copenhagen conference lend further support to these findings.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Richard M., Mecklenburg M., Tumosa C., **Technical Considerations for the Transport of Panel Paintings,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 525 - 556

Abstract: A thorough examination of panel paintings considered for loan is probably the most crucial aspect of the loan process. Paintings that have recurring problems such as flaking paint are poor candidates for loans, unless the cause of the problem is clearly understood and controllable. There are four environmental conditions that should be considered when evaluating any painting for possible loan: relative humidity, temperature, shock, and vibration. The overall safety of a painting during transit is gauged by any expected response to these conditions. This response must then be evaluated in terms of what the painting will be able to withstand and what protection the proposed transport is able to provide. There are several things to consider about the painting itself when contemplating a possible loan, including the site of the painting, its materials and construction, the condition of the design (paint and ground) layers, and the condition of the wood supports. For the most part, determining the risks inherent to the transport of a panel painting is an engineering problem that requires a knowledge of the mechanics of artists' materials.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Richard M., **The benefits and disadvantages of adding silica gel to microclimate packages for panel paintings,** Museum microclimates: contributions to the Copenhagen conference, 19-23 November 2007, Padfield Timothy (Editor), Borchersen Karen (Editor), and Christensen Mads Chr. (Editor), Nationalmuseet Denmark, Copenhagen, 2007, p. 237 - 243

Abstract: Microclimate packages are used frequently for paintings exhibited in less than ideal environments. In order to minimize adverse effects caused by leakage, silica gel is often added to the packages to buffer the relative humidity. Concern has arisen that the difference in adsorption properties of silica gel and materials in panel paintings might cause damage during temperature changes. Research at the National Gallery of Art (Washington, DC) studied panel paintings in microclimate packages with silica gel and panel paintings in microclimate packages without silica gel, observing their dimensional behavior during fluctuations in temperature. Various silica gels were tested. Additionally, panel paintings within microcli-

mate packages were monitored with data loggers while in shipment and on loan to other institutions. Results indicate that while silica gel is probably not necessary in well-designed and well-constructed packages, adding a moderate quantity of silica gel to microclimate packages used for panel paintings incurs no increased risks and may offer advantages.

http://natmus.dk/fileadmin/user_upload/natmus/bevaringsafdelingen/billeder/far/Museum_Microclimate/Proceedings/musmic150.pdf

Rijsdijk J.F., Laming P.B., **Physical and related properties of 145 timbers,** Kluwer Academic Publishers, Dordrecht, The Netherlands, 1994.

Abstract: The book contains data on the density, nominal specific gravity, equilibrium moisture content at various relative humidities, hysteresis loop, fibre saturation point, shrinkage, swelling, and dimensional stability of 145 timbers. The species are arranged alphabetically by standard name under softwoods or hardwoods. Data are also included on glulam and rattans. There is an index of botanical and standard names.

http://www.cabdirect.org/abstracts/19950604672.html;jsessionid=2366F47FC2FCF3B5E7F8A5EDD7F7DC97

Rostain E., **Rentoilage et transposition des tableaux,** Puteaux, EREC, 1981

Abstract: The relining of paintings was already used before 1698 and the transfer about 50 years later. The traditional techniques used by art restorers are described in detail: supports, small interventions, relining, transfer. Recipes of glues and other adhesives are given.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=7787

Rothe A., **Critical History of Panel Painting Restoration in Italy,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 188 - 199

Abstract: Modern Italian panel conservation techniques are directly related to a long history of panel construction that dates to antiquity and flourished from the Middle Ages to the Renaissance (see Uzielli, "Historical Overview," herein). The ingenuity and intuition of the woodworkers of the past compensated for their lack of scientific understanding of this complex and widely diverse material. Central Italy, in particular, produced a large quantity of paintings on panel. Many of them—such as the Cimabue Crucifix in the Church of Santa Croce in Florence—were constructed to the highest standards of craftsmanship. The early woodworkers often used techniques or methods similar to those applied by modern-day restorers in treating panels—techniques such as movable crossbars (Fig. 1) and coats of gesso, paint, or red lead to seal the backs of panels. These sealants were probably applied as humidity barriers and protection against wood-boring insects, and panels treated in this manner have often survived better than untreated panels. The large number of panel paintings in Italian churches and museums created the need for appropriate conservation work, particularly in modern times. The state-run centers of Florence and Rome have become the largest and most advanced in Italy and have generated a group of highly qualified experts in this field. The volume of panel work that has been executed in Florence far surpasses that of any other conservation center in the world.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

Rothe A., Marussich G., **Florentine Structural Stabilisation Techniques,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 306 - 315

Abstract: The 1966 flood in Florence caused panel paintings that were submerged to swell many inches beyond their original size. These paintings were gradually dried over several years, but many of them shrank considerably, causing severe blistering and cupping of the paint layers, as well as deformation of the supports. Many of the panel paintings had to be transferred to canvases and to new rigid supports. Oil

deposits from the flood waters were removed with a poultice made from Shellsol A and talc applied to a Japanese-tissue interleaf. During the conservation of the panels, a better understanding of the behavior of wooden artifacts was gained. Treatments are described that give the panels ample room to move while exerting a certain amount of restraint to keep them from deforming.
http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Ryhl-Svendsen M., Scharff M., Wadum J., **Gaseous Pollutants inside Microclimate Frames: Results from the PROPAINT Project,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 165 – 177

Abstract: PROPAINT is a European research project in which the protection of paintings kept in microclimate (mc) frames is studied. Major air pollutants in museum environments are ozone, nitrogen dioxide, and organic acids. Volatile organic compounds (VOCs) are often observed in high concentrations inside mc-frames; however, their effects on artists' materials are largely unknown. The level of external pollutants inside mc-frames will be low compared to the level in the ambient rooms because of large inner frame surface areas and a low air exchange rate. However, internally generated pollutants may occur at extremely high concentrations if a source is present inside the frame. Pollution measurements conducted in thirteen mc-frames are reported in this paper. Inside the frames ozone was observed in the range of 0.5–6.0 μg m-3, and nitrogen dioxide was seen in the range of 0–4 μg m-3. Organic acids (the sum of acetic and formic acid) ranged between 100 and 2100 μg m-3, and other VOCs ranged from 100 to 4500 μg m-3. A special "worst-case" mc-frame containing an emissive mock-up painting had extremely high concentrations: 2800 μg m-3 organic acids, and for other VOCs, 28,000 μg m-3. Organic acids were always observed in higher concentrations (10 times or more) inside the mc-frames than in the rooms. It is concluded that a low air exchange of
mc-frames effectively protects against the ingress of external pollutants. However, care should be taken to avoid high emission of organic compounds from frame construction materials—for example, by using inert materials for inner frame structures or by lining emissive surfaces with impermeable barrier films.
http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Saft S. and Kaliske M., **Computational approach towards structural investigations for the restoration of historical keyboard instruments,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 165 - 174

Abstract: Within this paper, research on static structural analysis of historical keyboard instruments is introduced. First, the structural modelling of these objects and the required steps to obtain an adequate simulation approach are described. The underlying simulation procedure is the Finite-Element-Method, which is standard in engineering analyses. Furthermore, the special characteristics of wood concerning the hygro-mechanical behaviour and the models used for the numerical simulation are introduced. The loadings, the instruments are subjected to, are specified. Subsequently, the simulation results of two particular pianofortes of very different construction are shown. The load bearing behaviour of both instruments is analysed and compared.

http://dx.doi.org/10.1016/j.culher.2012.05.007

Saft S. and Kaliske M., **Supporting the restoration of historical pianofortes by numerical simulation,** in International Conference on Wooden Cultural Heritage: Evaluation of Deterioration and Management of Change, Hamburg. COST Action IE0601 Wood Science for Conservation of Cultural Heritage, 2009

Abstract: Historical music instruments belong to the great achievements of culture. Next to the conservation of the original substance, their restoration is often aimed at the maintenance of the original usage. Instruments that are kept in playable state often show large deformations and considerable damages. The reason can be found in loading by the tensioned strings enforced by climatic fluctuations. Furthermore, the influence of long-term effects has to be taken into account. Therefore, a time-dependent, coupled material model is required for the realistic description of the structural behaviour of historical pianofortes.The basis for the development of restoration concepts and the decision, if or on which conditions a keyboard instrument can be playably restored and in the long term be used in concerts, is the knowledge about its load bearing behaviour. Therefore, the analysis of the structural behaviour of historical keyboard instruments is carried out within the outlined project using the Finite Element Method. After the characterisation of the basic systems, the conclusions will be applied for the restoration of a particular pianoforte.

http://www.woodculther.com/wp-content/uploads/2009/09/Saft.pdf

Sakuno T. and Schniewind A.P., **Adhesive qualities of consolidants for deteriorated wood,** Journal of the American Institute for Conservation 29, 1, 1990, p. 33 - 44

Abstract: Polymer solutions used on douglas fir wood. These bonds were not as strong as dispersion type joins but good enough, if the correct solvent is used. Elmer Wite Glue (a common wood working adhesive) was the dispersion comparison. All materials applied at 15%. B-72 in acetone or toluene; B98 in ethanol or toluene/ethanol, 60/40; AYAT in ethanol or toluene. The viscosites are in the range 10-360cP, all execpt B98 below 100. Static and impact shear tests using blocks bonded and tested by ASTM D950. The B-72 & AYAT adhesives in polar solvent (acetone) had much higher strengths than toluene applied. The B98 strength was much the same for either and about the same as the acetone adhesives. Failure in the wood 20-30% occured with the higher strength static tests but only a small amount with impact tests for B-72 and AYAT. 26-40% wood failure with B98 in B98 impact. Elmer was high strength and 97% wood failure in both tests. The best adhesive B98 matched the previously reported best consolidant B98.
http://cool.conservation-us.org/jaic/articles/jaic29-01-003_indx.html

Sandu I.C.A., Brebu M., Luca C., Sandu I. and Vasile C., **Thermogravimetric study on the ageing of lime wood supports of old paintings,** Polymer degradation and stability 80, 1, 2003, p. 83 - 91

Abstract: Presents thermogravimetric data of some samples of soft lime tree (linden) (Tilia cordata Mill) wood from the structure of the supports of paintings (portable icons and iconostases) 100-200 years old. In order to determine the aging processes, the physical, structural, and chemical changes that have occurred in time under environmental influence have been correlated with thermogravimetric data. It has been established that the thermal characteristics for the elimination of physically adsorbed water depend on the sample's age and on the conservation treatments. The variation of the thermal characteristics with the wood age is important for the main decomposition step. The temperatures for the onset and the maximum rate of degradation as well as the global activation energy increase with the wood's age while the weight loss decreases. These characteristics could be used to assess the age and conservation status of the paintings. The variation of the characteristics could be due both to the loss in time of the volatile compounds that lead to lower thermal characteristics and to the structural changes occurring in the wood that, for the highly deteriorated and/or degraded wood leads to a totally different thermal behavior.
http://www.deepdyve.com/lp/elsevier/thermogravimetric-study-on-the-ageing-of-lime-wood-supports-of-old-kiea48GQJV/1

Schellen H.L. and Schijndel A.W.M. van, **Setpoint control for air heating in a church to minimize moisture related mechanical stress in wooden interior parts,** Building Simulation: An International Journal, 4(1), 2011, p. 79 – 86

Abstract: The paper presents the setpoint control for air heating in a church to minimize moisture related mechanical stress in wooden interior parts, with the focus on the preservation of a monumental organ. The setpoint operation of the HVAC system is evaluated by simulation using MatLab, COMSOL and Simulink models. The next main model components are presented and combined in a single integrated SimuLink model: 1) a HAMBase Simulink building model for simulating the indoor temperature and relative humidity, 2) a COMSOL partial differential equation (PDE) model for simulating detailed dynamic moisture transport and related mechanical stresses in the monumental wood (organ) and 3) a Simulink controller model. The main advantage of the integrated model is that it directly simulates the impact of HVAC control setpoint strategies on the indoor climate and the related mechanical stresses in wooden objects, like a monumental organ. As control strategy the limited indoor air temperature changing rate is discussed. Recommendations from international literature suggest that 1) a limitation of the relative humidity changing rate of 2 to 5RH%/h will preserve the interior of churches. This study shows that a limitation of indoor air relative humidity changing rate of 2RH%/h can reduce mechanical stresses by a factor of 2.5, compared to maximum capacity heating.

http://www.tue.nl/publicatie/ep/p/d/ep-uid/247644/?no_cache=1

Schellen H.L., **Heating Monumental Churches: Indoor Climate and Preservation of Cultural Heritage,** Dissertation, Eindhoven University of Technology, 2002

Abstract: The structure of old monumental churches differs a lot from contemporary buildings.The structural materials were wood, bricks and stone. In order to construct high buildings with huge spans, thick massive walls and many massive columns were needed. Originally these buildings had no heating and for centuries the indoor climate of these buildings was mainly determined by the outdoor climate. Because of the massive walls, the large indoor air volume, the relatively small windows and most often relatively limited natural ventilation, the indoor climate was much more stable than the outdoor climate. There was hardly a difference between the day and night temperature. In summer the indoor air climate was cool compared to outdoors, in winter indoor conditions were warmer.

As a consequence of the large heat and moisture capacity the indoor air and surface temperatures and the indoor air and surface humidity led to a reasonably even climate under our external climate conditions. The monumental interior of this kind of building stood up to the climate elements for centuries. Apparently the indoor climate in this kind of building was not very unfavorable to the monumental interior. In a large number of these buildings heating systems were installed, varying from warm air heating to floor heating, (infrared) radiant heating, radiator panel and convector heating, local and pew heating. From literature there is evidence that severe phenomena gave the insight to limit the unrestricted use of heating systems in churches. Due to rapid changes in society the demands of the churchgoers changed in the last decades. As a consequence of the high thermal comfort in modern day buildings, this was also required in churches. Another major change was attending the services without winter coats due to the use of cars by churchgoers. A heating system in the church had to compensate for the evident lack of thermal comfort. In the last 30 years church going decreased dramatically in a major part of Western Europe. Church buildings therefore had to be used for alternative purposes in order to provide for extra financial income. In the Netherlands, monumental churches are nowadays used for concerts and other musical events, exhibitions, dinners, examinations and several other events. People are dressed appropriately for these events, e.g. evening dress, but not in accordance with the indoor climate in a church. Winters, like the winter of 1962 to 1963 in Western Europe, caused serious damage to church organs and other valuable church interior parts (Knol 1971). Further research showed that these were no isolated cases. Long periods of very low relative humidity, characteristic of the combination of heating and severe frost, appear to be correlated to damage to church organs and other parts of church interiors. Literature documents damage to pulpits, altars, wainscoting, and paintings like wall, ceiling and panel paintings. In the nineteen sixties and seventies the progressive understanding of these Thus, nowadays, the original use of the church is changing. Where a lot of churches are in need of a major restoration or renovation, adapting the heating system becomes an important point of study. In this study a distinction was made between the most important heating systems in the Netherlands and abroad. Making use of a literature study, laboratory research and several case studies in Dutch churches, common patterns and relations between typical church heating systems and their effects on the deterioration of monumental churches were identified. Drying out of the monumental wooden furniture, like organs, altars and other organic materials and the related shrinkage and damage to the materials under cold winter conditions; Surface condensation due to low surface temperatures on walls and stained and protective glazing, in combination with high air humidity due to excessive moisture sources like open-air infrared gas heating; Indirectly related

problems are contamination due to pollution sources like soot from candles in relation to relatively large airflows, e.g. generated by floor heating; Related building physical aspects of church heating are annual energy consumption and thermal comfort problems due to relatively large airflows and low surface temperatures of walls and glazing. Performance requirements for church heating systems with respect to preservation, energy requirements, thermal comfort and aesthetics were formulated. When performance requirements are known, prognoses have to be made for the most suitable design of a heating system in a particular monumental church. Simulation models and tools and their application for monumental churches were proposed. Furthermore the church characteristic input for these models was determined. A final check is the measurement in situ to evaluate and to prove that the heating system meets the performance criteria. Methods of measurement and some new ways to interpret them are proposed. For the choice and design of a heating system advantages and drawbacks of different systems are summarized. Finally a checklist to structure the choice and design of a heating system is included.

http://repository.tue.nl/561673

Schiessl U., **History of Structural Panel Painting Conservation in Austria, Germany and Switzerland,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 200 - 236

Abstract: After a brief introduction to the history of conservation literature and the profession of paintings restoration in Austria, Germany, and Switzerland, the author presents an extensive history of conservation of supports of panel paintings. Early conservation techniques were executed to render the panel painting into a particular aesthetic form in accordance with contemporary taste rather than for conservation-related requirements. The procedure of sawing double-sided panels, or splitting, is an example of this type of technique. Other procedures described are thinning of the support, pest control, consolidation of panels damaged by insects and fungi, flattening of warped panels without cradling or other auxiliary constructions, flattening by cradling, transfer to a new support, rejoining broken and cracked panels, and protection of unpainted backs of panels.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings3.pdf

Schiessl U., **Konservierungstechnische Beobachtungen zur Festigung wäßrig gebundener, kreidender Malschichten auf Holz (Observations about conservation techniques regarding the consolidation of water-bound chalk paint layers),** Zeitschrift für Kunsttechnologie und Konservierung 3, 2, 1989, p. 293 - 320

Abstract: Describes a series of experiments for consolidating powdering paint layers on wood. Methods for consolidation were sought which do not result in any visual changes of the surface: gloss, stains, margins, or darkening of the color. Chalking paint and plaster result from using water-soluble binders. Calcium carbonate, gypsum, iron oxide and chalk, and artificial ultramarine were applied to wood without any binder. Consolidant solutions included gelatin in water, caseinate in water/alcohol, hydroxypropylcellulose in water, hydroxypropylcellulose in propanol, poly(vinyl alcohol) in water, poly(vinyl acetate) in organic solvents, ethyl methacrylate in organic solvents, and acrylic emulsions and dispersions. The solutions were prepared in various dilutions. Changes in appearance are considered from both a theoretical and practical viewpoint, aided by observing film formation and resin distribution microscopically (both visual and electron microscope). Factors discussed include: the ability to penetrate the pigment layer and solidify within the layer; over-solidification of a porous, unpolished pigment layer; formation of pore holes in the pigment layer and in the consolidant substance; cavities at the interface of pigment and substrate; peeling off of the layer and widespread formation of flakes; reaction to humidity; formation of dark margins (tide marks), relocation of pigment particles during the wet phase of consolidation; and added gloss, darkening, or transparency. Concludes that the manner of the technique of application plays the most essential role. Stresses the fact that the inhomogenity of an actual multi-color painting reduces the relevance of observations and explanations of the consolidation of homogenous, prepared samples.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=130006

Schirripa Spagnolo G., Ambrosini D. and Paoletti D., **Image decorrelation for in situ diagnostics of wooden artifacts,** Applied Optics, 36, 32, 1997, p. 8358 - 8362

Abstract: Local decorrelation of speckle patterns scattered by a surface is used for nondestructive evaluation of the state of conservation of wooden artifacts. Some experiments have been carried out on models with simulated internal flaws and on real, ancient, wooden panel paintings. The setup is very simple and can easily be used by nonoptically skilled operators.

http://www.opticsinfobase.org/ao/abstract.cfm?uri=ao-36-32-8358

Schirripa Spagnolo G., Ambrosini D. and Guattariz G., **Electro-optic holography system and digital image processing for in situ analysis of microclimate variation on artworks,** J. of Optics, Paris 28, 1997, p. 99 - 106

Abstract: In this work we present an integrated system, suitable to relate the deformations of the object under test to the microclimate variations. The system, driven by a PC, is based on an electronic speckle pattern interferometer (ESPI). Measurements can be performed in situ. Some experimental results are presented.
http://iopscience.iop.org/0150-536X/28/3/002/

Schirripa Spagnolo G., Majo R., Ambrosini D. and Paoletti D., **Digital moiré by a diffractive optical element for deformation analysis of ancient paintings,** Journal of Optics A: Pure and Applied Optics, 2003, p. S146 - S151

Abstract: In this paper we propose a digital projection moire system for full-field measurement of outof- plane deformation of cultural heritage objects. The method is based on a new fringe generator realized by a diffractive optical element illuminated by a spherical wave phase. Two grating patterns on an object before and after deformation are captured by a CCD camera and stored in a computer. With the aid of fast Fourier transform, signal demodulating techniques and a robust and fast phase-unwrapping algorithm, a 3D mapping of deformation can be visualized. The simplicity of the system and the fact that only readily available and unsophisticated equipment is required characterize the proposed method. The theoretical basis of the device is presented. Furthermore, experimental results made with a test object and a real ancient wooden panel painting are presented to demonstrate the validity of the technique.
http://iopscience.iop.org/1464-4258/5/5/356/

Schniewind A. P., **On the reversibility of consolidation treatments of deteriorated wood with soluble resins,** Wooden Artifacts Group Specialty Session, New Orleans, June 5 1988, Papers. Washington, DC, American Institute for Conservation, 1988

Abstract: Extensive experiments have been carried out on reversibility of treatments with Butvar B98, Acryloid B72, and AYAT, using both polar and nonpolar solvents. Most experiments were made using Soxhlet extraction, but removal by soaking, with and without agitation, was also investigated. With resin loading levels after treatment in the range from 21.5 to 27.7%, residual resin levels after extraction and before correction for removal of wood extractives ranged from -0.97 to 6.0%.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=114941

Schniewind A. P., **Consolidation of wooden panels,** The Structural Conservation of Panel Paintings, Proceedings of a Symposium at the J. Paul Getty Museum, April 1995, ed. Kathleen Dardes and Andrea Rothe, Los Angeles, Getty Conservation Institute,1998, p. 87 - 109

Abstract: The basic objective of consolidation is to assure the stability and safety of an object. In addition, specific objectives will vary with the intended use. The most demanding of these is when consolidation is required to reestablish full functionality of an object. Usually this will be the case when the object serves a significant structural function, as, for instance, structural wood members in a building or the legs of a chair that people will sit on. A less demanding level would be when stabilization is required through all or most of the interior of an object. Finally, in some cases, only a consolidation of surface layers may be required to prevent damage by abrasion. Objects in museum collections would rarely require reestablishment of full functionality but must be able to withstand some handling and perhaps the rigors of shipping. Consolidation is a major intervention that is not to be undertaken lightly. In particular cases of advanced deterioration, however, it may become a necessary treatment. Once the necessity for consolidation is determined, a number of decisions must be made regarding materials and methodology. These decisions include choice of a consolidant, solvent (and level of solution concentration), and suitable method of application. Much will depend on the nature of the object to be treated, the type and condition of the material, and the functional requirements of the object. Usually structural function, as well as visual aspects, will be addressed. The present discussion will be directed to a comprehensive examination of various aspects of the consolidation of deteriorated wood, proceeding from consideration of the general to the more specific problems that might be encountered in the consolidation of wooden panels that support paintings. Hereafter, all references to wooden panels refer to painting supports. No attempt will be made to consider the consolidation of waterlogged wood, because that process presents problems and requires approaches not applicable to panel paintings.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings1.pdf

Schniewind A.P.and Eastman P.Y., **Consolidant distribution in deteriorated wood treated with soluble resins,** Journal of the American Institute for Conservation 33, 3, 1994, p. 247 - 255

Abstract: Scanning electron microscopy was used to study the distribution of synthetic resin consolidants after treatment of deteriorated wood samples by vacuum impregnation. These resins included Butvar B98 (poly(vinyl butyral), Acryloid B-72 (acrylic), and Butvar B90 (poly(vinyl butyral). After the samples had been completely saturated with consolidant, evidence of resin could be found throughout cross-sections, although examination of the samples showed that the resin was not uniformly distributed. Most strikingly, some tracheids could be observed to have heavy deposits of resin, which in some cases completely filled the cell lumen, while adjacent tracheids contained little or none. The percentage of earlywood tracheids with visible resin deposits in a given sample area was then used as an indicator of resin content. Results showed that there was greater concentration of resin in the surface layers of radial or tangential faces than in the specimen core, as well as a tendency toward increasing concentration toward the end surfaces.

http://cool.conservation-us.org/jaic/articles/jaic33-03-002.html

Serck-Dewaide M., **Support and Polychromy of Altarpieces from Brussels, Mechlin, and Antwerp Study,** Comparison, and Restoration, Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 82 - 99

Abstract: Composite Altarpieces, comprising painted and sculpted elements (really pieces of liturgical furniture) had already appeared in great number by the middle of the fourteenth century in different regions. They functioned at this time as tabernacles, and cupboards for relics and for individual figures of saints and narrative scenes. Gilded architectural elements, baldachins, and rhythmic colonnettes strictly compartmentalized the space. The painted wings served to close these "cases," revealing the figures to the faithful only on feast days. Altarpieces were popular throughout Europe in the fifteenth and sixteenth centuries. The regional workshops—for example, Germanic, Franco-Flemish, Spanish, and Italian—evolved differently, varying the dimensions, space, perspective, lighting, and polychromy of the altarpieces (Skubiszewski 1989). Only altarpieces from the historic Brabant region are considered here—in particular, the sculpted parts of these Brabantine altarpieces. In the fifteenth century, Brabantine altarpieces evolved toward a more realistic expression and a more accentuated relief. Compo-

sitions were grouped in successive arrangement, presenting scenes of small characters, related as in a theatrical setting. Over time, the architecture changed, reducing in size, until eventually there was no more than a frame presenting scenes consecrated to the Virgin, to the lives of the saints, or to cycles of the infancy and Passion of Christ. This evolution progressed very slowly during the mid–sixteenth century, from late Gothic decoration to Renaissance motifs. From the second half of the fifteenth century, Brabantine altarpieces became so successful that, in order to satisfy the demand, a division of labor became necessary. The production of altarpieces was divided between the hutch maker, the sculptors of the architectural elements, the sculptors of the figures, the gilders, the polychromists, and the painters (Jacobs 1989). The regulations of the guilds were very strict. It was mandatory that the works be marked as a way of guaranteeing their place of origin and their quality. This method of serial production reflected a systematization in the formal creation of the altarpieces and in the application of the polychromy in the principal Brabantine workshops. Includes a discussion of the treatment of a number of polychrome sculptures and painted wooden altarpieces on pages 91 to 95.

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood2.pdf

Sfarra S., et al, **Importance of integrated results of different non-destructive techniques in order to evaluate defects in panel paintings: the contribution of infrared, optical and ultrasonic techniques,** O3A: Optics for Arts, Architecture, and Archaeology III, Munich, Germany, SPIE, 2011.

Abstract: The increasing deterioration of panel paintings can be due to physical processes that take place during exhibition or transit, or as a result of temperature and humidity fluctuations within a building, church or museum. In response to environmental alterations, a panel painting can expand or contract and a new equilibrium state is eventually reached. These adjustments though, are usually accompanied by a change in shape in order to accommodate to the new conditions. In this work, a holographic method for detecting detached regions and micro-cracks is described. Some of these defects are confirmed by Thermographic Signal Reconstruction (TSR) technique. In addition, Pulsed Phase Thermography (PPT) and Principal Component Thermography (PCT) allow to identify with greater contrast two artificial defects in Mylar which are crucial to understand the topic of interest: the discrimination between defect materials. Finally, traditional contact ultrasounds applications, are widely applied for the evaluation of the wood quality

in several characterization procedures. Inspecting the specimen from the front side, the natural and artificial defects of the specimen are confirmed. Experimental results derived by the application of the integrated methods on an Italian panel painting reproduction, called The Angel specimen, are presented. The main advantages that these techniques can offer to the conservation and restoration of artworks are emphasized.

http://vision.gel.ulaval.ca/~bendada/publications/Id905.pdf

Sfarra S., Theodorakeas P., Ibarra-Castanedo C., Avdelidis N.P., Paoletti A., Paoletti D., Hrissagis K., Bendada A., Koui M. and Maldague X., **Evaluation of defects in panel paintings using infrared, optical and ultrasonic techniques,** Insight 54, 1, 2012, p. 21 - 27

The increasing deterioration of panel paintings can be due to the physical processes that take place during exhibition or transit, or as a result of temperature and humidity fluctuations within a building, church or museum. In response to environmental alterations, a panel painting can expand or contract and a new equilibrium state is eventually reached. These adjustments, though, are usually accompanied by a change in shape in order to accommodate the new conditions. In this work, a holographic method for detecting detached regions and microcracks is described. Some of these defects are confirmed by the thermo graphic signal reconstruction (TSR) technique. In addition, pulsed phase thermography (PPT) and principal component thermography (PCT) allow two artificial defects in Mylar to he identified with greater contrast, which is crucial to understand the topic of interest: the discrimination between defect materials. Finally, traditional contact ultrasound applications are widely applied for the evaluation of the wood quality in several characterisation procedures. Inspecting the specimen from the front side, the natural and artificial defects of the specimen are confirmed. Experimental results derived by the application of the integrated methods on an Italian panel painting reproduction, called The Angel specimen, are presented. The main advantages that these techniques can offer to the conservation and restoration of artworks are emphasised.

http://www.ingentaconnect.com/content/bindt/insight/2012/00000054/00000001/art00007

Shuichi K., Misao Y., Miyuki M. and Junji S., **Research on the Aging of Wood in RISH,** proceedings of the International Conference held by COST Action IE0601 30, 2008, p. 51 – 56

Abstract: This paper reviews the research activities of the Research Institute for Sustainable Humanosphere (RISH) on the aging of wood, these are, 1) Collection and identification of wood samples from cultural properties and historical buildings, 2) Characterization of the naturally aging wood, 3) Characterization of the accelerated aging treated wood, 4) Establishment of the database on the wood quality from historical building, and 5) Organizing symposia: Wood Culture and Science series.

http://www.fupress.com/Archivio/pdf%5C4502.pdf

Siddiolo A.M., et al, **Wooden Panel Paintings Investigation: An Air-Coupled Ultrasonic Imaging Approach,** IEEE transactions on ultrasonics, ferroelectrics, and frequency control, 54, 4, 2007, p. 836 - 846

Abstract: In this paper, a method for the study of wooden panel paintings using air-coupled acoustica imaging is presented. In order to evaluate the advantages of the technique, several samples were made to mimic panel paintings along with their typical defects. These specimens were tested by means of both single-sided and through transmission techniques using planar transducers. Image data were processed by means of a two-dimensional (2-D)-fast Fourier transform-based algorithm to increase the S/N ratio and 2-D representations (C-scans) were generated. The simulated defects were imaged using both configurations. Investigations were undertaken on four antique paintings from a private collection. The results presented and discussed in this investigation confirm both the robustness and the effectiveness of the technique in detecting defects such as delaminations and cracks in wooden panel paintings.

http://www.ncbi.nlm.nih.gov/pubmed/17441593

Sitnik R., Krzesłowski J. and Maczkowski G., **Archiving shape and appearance of cultural heritage objects using structured light projection and multispectral imaging,** Optical Engineering, 51, 2, 2012, p. 021115

Abstract: To create faithful reproduction of a cultural heritage object, it is crucial to gather information on intrinsic optical properties of the object's surface, as well as its geometry. An integrated device has been developed that performs a three-di-

mensional measurement using structured light projection, followed by multispectral imaging for precise color retrieval and directional illumination for estimating bidirectional reflectance distribution function (BRDF) parameters. The main advantage shown in this work is the use of only one detector during the whole acquisition process to assure ideal correspondence of multimodal surface data in the image space. A method is shown for performing the measurement using an integrated device. Methods of data organization and processing are described facilitating robust operation of the developed software. A prototype setup for the integrated system is presented together with measurement parameters and sample measurement.

http://spiedigitallibrary.org/oe/resource/1/opegar/v51/i2/p021115_s1

Sodini N., Dreossi D., Chen R., Fioravanti M., Giordano A., Herrestal P., Rigon L., Zanini F., **Non-invasive microstructural analysis of bowed stringed instruments with synchrotron radiation X-ray microtomography,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 44 - 49

Abstract: The structural analysis of historical musical instruments is a fundamental tool for the definition of restoration and conservation protocols, as well as for the study of ancient manufacturing techniques and the acoustic analysis related to this class of cultural objects. The importance and the value of typical bowed stringed instruments, on the other hand, require a non-destructive approach with strict environmental control, fast acquisition times and high spatial resolution. Feasibility studies have been carried out at the SYRMEP beamline of the Elettra synchrotron laboratory in Trieste with the aim of demonstrating the advantages and evaluating the effectiveness of synchrotron radiation X-ray microtomography as a suitable technique. The particular geometry of the X-ray beam and the use of a novel detector allow structural evaluation of the main details of the instruments with unprecedented richness of details. This, in turn, will allow the characterization of their internal structure, defects, wood thickness and density as well as the dendrochronological investigation of historical violins.

http://dx.doi.org/10.1016/j.culher.2012.04.008

Sozzani L., **Microclimate Vitrines for Panel Paintings: An Update,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 148 – 157

Abstract: Since the early 1990s, the practice of protecting panel paintings against shortterm environmental changes by housing individual objects in microclimate vitrines has become a widely used procedure in museums around the world. This paper provides a brief update on the use of microclimate vitrines for framed paintings, following up on a previous work on the use of the picture frame as the primary vitrine housing. Construction techniques and materials for creating microclimate vitrines that use the picture frame are reviewed. Brief observations are also made on the use of buffering materials, on framing concerns, and on record keeping. New developments using the flexible laminate material Marvel Seal are introduced. Early examples of sealed packages from the National Gallery of Art in Washington DC are described, as is the construction of a sealed envelope microclimate vitrine system frequently used at the Metropolitan Museum of Art in New York. Outstanding questions concerning the conditions inside sealed microclimate vitrines—issues such as temperature difference within the closed system; occurrences of condensation, bloom, and mold; and the effect of off-gassing on a work of art—are considered, as pointers to further research on this form of environmental protection for panel paintings.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Spurlock D., **The Application of Balsa Blocks as a Stabilizing Auxiliary for Panel Paintings,** Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 149 - 152

Abstract: The difference in the behavior of the wood and the paint it supports is the principal cause of damage to panel paintings. One method to reduce the movement of wood is by the use of moisture barriers. This report describes the removal of old cradle, coating with Saran resin, acopolymer of vinylidene chloride and acrilonitrile (25% in methyl ethyl ketone) followed by fiberglass marquisette, and the application of a continuous auxiliary support of balsa wood blocks attached with a wax-mortar adhesive.

http://www.iiconservation.org/node/1700

Steeman H.J., et al, **Coupled simulation of heat and moisture transport in air and porous materials for the assessment of moisture related damage,** Building and Environment, 2009, p. 2176 - 2184

Abstract: This paper describes the coupling of a model for heat and moisture transport in porous materials to a commercial Computational Fluid Dynamics (CFD) package. The combination of CFD and the material model makes it possible to assess the risk of moisture related damage in valuable objects for cases with large temperature or humidity gradients in the air. To couple both models the choice was made to integrate the porous material model into the CFD package. This requires the heat and moisture transport equations in the air and the porous material to be written down in function of the same transported variables. Validation with benchmark experiments proved the good functionality of the coupled model. A simulation study of a microclimate vitrine for paintings shows that phenomena observed in these vitrines are well predicted by the model and that data generated by the model provides additional insights in the physical mechanisms behind these phenomena.

http://users.encs.concordia.ca/~raojw/crd/reference/reference003383.html

Teissier B., **Polychrome panel of Madonna and Child - An Interim report,** The Laboratories of the National Museum of Antiquities of Scotland, National Museum of Antiquities of Scotland, Edinburgh, AATA Number 22, 2, 1951, p. 54 - 61

Abstract: Discusses the examination and partial treatment of a 16th-century spruce and cherry wood polychromed Madonna and Child. The structure was fairly sound, although the paint was in poor condition (due, in part, to an inexpertly executed prior cleaning). The piece was treated for worm infestation, the surface was washed with Lisapol solution and then consolidated with PVA emulsion, a waxy layer was mechanically removed from it, and small areas of ex posed gesso were inpainted. The pigments were analyzed by x-ray fluorescence spectroscopy, optical microscopy, and microchemical tests (the results are presented in appendices), and the entire piece was x-rayed.

http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=83049

Thizy C., Groves R.M., Hatzigiannakis K., Bernikola E., Rochet J., Hustinx G.-M., Pedrini G., Tornari V. and Georges M., **Le projet MULTIENCODE: développement d'un multisenseur holographique pour la détection des signatures des oeuvres d'art mobiles,** CMOI 2009, Reims.
http://www.club-cmoi.fr/content/le-projet-multiencode-d%C3%A9veloppement-d%E2%80%99un-multisenseur-holographique-pour-la-d%C3%A9tection-des-sil

Thompson G., **The Museum Environment,** London, Butterworth-Heinemann, 1978.

Abstract: The Museum Environment is in two parts; Part I: intended for conservators and museum curators and describes the principles and techniques of controlling the environment so that the potentially damaging effects of light, humidity and air pollution on museum exhibits may be minimised. Part II: the author brings together and summarises information and data, hitherto widely scattered in the literature of diverse fields, which is essential to workers in conservation research.
http://www.amazon.com/Museum-Environment-Butterworth-Heinemann-Conservation-Museology/dp/0750620412

Tiozzo V., ed., **Dal decalogo Edwards alla Carta del Restauro. Pratiche e principi del restauro dei dipinti**, Padua, Il Prato 2001

Tolvaj L., Molnar S., **Photodegradation and Thermal Degradation of Outdoor Wood,** Conference Proceedings Wood Science for the Conservation of Cultural Heritage, 5-7 November, Braga 2008, Firenze University Press, 2010, p. 67 - 72

Abstract: In this study, wood samples were exposed to thermal treatment in dry- and humid conditions and to light irradiation. The results showed that neither xenon lamp nor mercury lamp can simulate properly the effect of sunlight. Light irradiated samples put behind an aluminium plate also suffered considerable chemical changes, measured by infrared technique and colour measurement. Degradation of lignin was inconsiderable in the shadow. Carbonyl groups generated by sunlight were partly contrary to those generated in shadow. The latewood suffered considerably less photodegradation than earlywood. Thermal degradation was much greater in humid condition than in dry condition.
http://www.fupress.com/Archivio/pdf%5C4502.pdf

Tornari V., Tsiranidou E. and Bernikola E., **Interference fringe-patterns association to defect-types in artwork conservation: an experiment and research validation review,** Appl Phys A 106, 2011, p. 397 - 410

Abstract: The paper is directed to all classes of optical inspection technologies that are causing a fringe pattern like output, such as interferometry, fringe projection, holography, speckle techniques. The explanations given here are also valid for incoherent fringe projection, moire, and short-coherent techniques, which are producing fringe-like output correlated with the surface structure and the surface change, respectively. Identification of interference fringe patterns with defect type is a long-standing engineering problem with the ambiguities in cause-effect relation dominating the Cultural Heritage structural diagnosis. The ambiguities refer to fringe pattern formation in regard to a hidden defect cause in the subsurface and the effect on the surface of the size or depth of the defect. In order to solve the concerned ambiguities, a review is made here to be confirmed a correlation of fringe pattern appearance to defect cause. The methodology is employed in the paper to achieve ageneralized description of fringe morphology for a common type of inner defect as interlayer de-cohesion termed in art conservation as detachment and crack. The objective is to provide the required concept and procedure through which the validation of any defect-indicative fringe-pattern can serve as a direct-visual-control of structural condition in artwork examination. In this context, theoretical and experimental results starting from simulation algorithms, through knowledge based experiments and experimental verification to correlation procedures and mathematical analysis are combined to allow fringe pattern generalized validation. The result allows performing by means of modern optical metrology direct artwork documentation of structural diagnosis in complex art conservation problems. It helps to utilize it in other research objectives targeting in automated defect-recognition and multisensory technology. It helps to advance theoretical and practical routines in everyday practices of art conservation applications, to confirm the direct fringe pattern concept in a new diagnostic field, and develop associations to cause-effect relations in other art conservation problems.
http://rd.springer.com/article/10.1007/s00339-011-6695-3

Tornari V., Bernikola E., Hatziyannakis K., Osten W., Groves R.M., Georges M., Thizy C., Hustinx G.-M., Rochet J., Kouloumpi E., Doulgeridis M., Green T. and Hackney S., **Multifunctional encoding system for the assessment of movable cultural heritage and resulted prototype device,** Proc. FRINGE 09, Stuttgart, 2009, p. 1 – 8

Abstract: Implementation of non destructive and non contact holographic techniques is being exploited for providing responses of the artwork in the encoded form of fringe patterns. The parametrical usage of the fringe formation allows correlation to originality and impact versus time. Signatures of artwork are formed and if monitored over time provide impact and originality assessment. The paper refers to a European Commission funded research project during the 6th framework program with special task in impact assessment in movable cultural heritage.
http://rd.springer.com/chapter/10.1007/978-3-642-03051-2_113

Unger A., **Decontamination and "deconsolidation" of historical wood preservatives and wood consolidants in cultural heritage,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 196 - 202

Abstract: In the past, wood artifacts were treated with a variety of wood preservatives formulated on the basis of inorganic and organic biocides. Most of these biocides have a high human toxic potential and pollute the environment. Some of them even cause damage to the objects they were meant to preserve. This poses a considerable challenge to the handling, exhibition, storage and restoration of such wooden works of art. In addition, biocide-containing structural wood members in historic buildings pollute the indoor-air, and represent a permanent health risk. Wood artifacts previously damaged by organisms and subsequently preserved and consolidated with mixtures of vegetable oils and natural resins now show characteristics of renewed deterioration. An important condition for the re-treatment of such objects is the exact detection of the substances originally utilized for their conservation. Non-destructive and in situ-measurements have priority among the listed analytical methods. The various decontamination procedures currently used are classified in regard to their mode of operation. Preferred methods include mechanical cleaning, thermo desorption, washing with water and detoxicants, and leaching as well as extraction with liquid or supercritical carbon dioxide. The masking with various sealers to prevent biocide evaporation into the indoor-air is limited to application to structural wood members. Leaching of degraded natural consolidants in wood artifacts is currently undertaken in a testing plant.
http://dx.doi.org/10.1016/j.culher.2012.01.015

Uzielli L., **Historical Overview of Panel-Making Techniques in Central Italy,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 110 - 135

Abstract: This article reviews the practice of panel-making in central Italy in the 13th-16th centuries. The panel maker produced supports to the specifications of artists or their patrons. Initially coniferous woods were most commonly used, but from the late 13th through early 15th centuries poplar became dominant because of its local availability and useful characteristics. Lacking tannins, poplar did not resist adhesion of glues and ground layers. Its wood was strong, light, homogeneous in texture and grain, and dimensionally stable in the presence of moisture. The author discusses the cutting, sizing, seasoning, arrangement, and joining of boards, the treatment of defects in the wood, and the many systems of supports devised to keep the panel intact, planar, and stable. Crossbeams and backframes were applied to assure the structural integrity of the panel even if slight separations of boards occurred. Many techniques evolved to fasten the backframes to the panel and frame, each a product of the designer's creativity. Some crossbeams were nailed or glued to panels. Connective members were devised to permit crossbeams to slide across the panel through bridges, pins, wooden guides, or dovetail joints. Large polyptychs might be moved in pieces and assembled on-site with interlocking crossbeams connecting the sections. Since backsides of panels were often intended to be seen, they were sometimes finished quite elaborately, even decorated or painted. Finally, the author explains the design and function of engaged frames added to many panels.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings2.pdf

Uzielli L. and Gril J., **Wood science and conservation: Activities and achievements of COST Action IE0601**, Journal of Cultural Heritage, Volume 13, Issue 3, Supplement, September 2012, p. S1 – S4

Abstract: COST Action IE0601 (2007–2011) aimed at promoting the science needed for the conservation of wooden cultural heritage. It involved 26 COST countries and three institutions from non-COST countries, allowed the organisation of five international conferences, 12 focused meetings and five training schools. This special issue of Journal of Cultural Heritage gathers significant contributions to the field. It is structured in seven parts: basic wood science for conservation; examining

wooden cultural heritage objects; timber structures; painted wood; waterlogged wood; musical instruments; treatment and retreatment of wooden objects.

http://www.sciencedirect.com/science/article/pii/S1296207412001008

Uzielli L., Cocchi L., Mazzanti P., Togni M., Jullie D., Dionisi-Vici P., **The Deformometric Kit: A method and an apparatus for monitoring the deformation of wooden panels,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 94 - 101

Abstract: This paper describes the "Deformometric Kit" (DK), which is both a methodological approach and an equipment conceived, designed and made at DEISTAF (University of Florence). The DK's main purpose is to carry out measurements and monitoring of the deformation dynamics of wooden objects. The monitoring can take place in virtually any environment, for any desired duration (minutes, hours, weeks, years, and so on). The measurement can be carried out mainly, but not exclusively, in connection with fluctuations of ambient temperature and relative humidity. The DK provides a reliable and accurate record (a first step towards understanding) of the behaviour of original panel paintings placed in their usual exhibition location, enabling curatorial staff and researchers to (a) obtain information about the behaviour of individual supports, in order to evaluate the impact of climate on their conservation state, help to make decisions for future restoration interventions; and (b) provide reference data for calibrating and validating numeric models. It can also provide data on the deformation of a panel while it is handled and transported, enabling an evaluation of stresses to which it is subjected during this operation. The device consists of two displacement transducers, which are fixed (in a low-impact, reversible way) to the back face of the panel, perpendicular to the grain, at different distances from the panel's surface. The two transducers not only measure the in-plane shrinkage/swelling of the panel, but since they are located at different distances, their measurements can also be combined with simple geometrical calculations to indicate the amount of distortion (cupping) which the panel undergoes. This paper explains the geometrical principles on which the DK is based, as well as its construction. Some examples of the data which have been obtained during actual monitoring by the DK are also included.

http://dx.doi.org/10.1016/j.culher.2012.03.001

Uzielli L. and Gril J., **Wood Science and conservation: Activities of COST Action IE0601,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September 2012, ed. Gril J., p. 1 - 4

Abstract: COST Action IE0601 (2007–2011) aimed at promoting the science needed for the conservation of wooden cultural heritage. It involved 26 COST countries and three institutions from non-COST countries, allowed the organisation of five international conferences, 12 focused meetings and five training schools. This special issue of Journal of Cultural Heritage gathers significant contributions to the field. It is structured in seven parts: basic wood science for conservation; examining wooden cultural heritage objects; timber structures; painted wood; waterlogged wood; musical instruments; treatment and retreatment of wooden objects.
http://dx.doi.org/10.1016/j.culher.2012.06.001

Veliz Z., **Wooden Panels and their Preparation for Painting from the Middle Ages to the Seventeenth Century in Spain,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 136 - 148

Abstract: Discusses Spanish methods of preparing panels, often dictated by contracts and trade regulations. Sometimes a painter received the prime contract for a piece and subcontracted out portions of the work to carpenters and other painting studios; sometimes carpenters received separate contracts. Guarantees occasionally demanded that the work remain free of fault or failure for a period of time. Woods chosen for panels varied by region. Contracts often specified methods of preparing layers of panels; treatment of knots, joining of boards, application of textile reinforcement, method of joining crossbars to the panel, number and type of glue layers, formulation of gesso, and addition of a priming layer were matters governed by local custom and contractual demand. Assembly of a retable often involved rough construction methods to affix the painted panels in a pre-existing architectural space.
http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings2.pdf

Von Imhoff H.C., **Reinforcing a Thin Panel Painting,** Conservation of Wood in Painting and the Decorative Arts, Preprints of the Contributions to the Oxford Congress, 17-23 September 1978, p. 157 - 164

Abstract: A thin panel painting, 100 x 120 cm but only 5 mm thick, had to be reinforced to reduce internal stresses and make it self-supporting. Balsa wood cubes, cut very precisely, were applied to the back of the panel using 'Master-model paste,' a carvable adhesive of epoxy resin with microscopic halls as filler called Araldite SV 426. HV 426. The cubes allowed for a movement of several millimeters over the surface of the panel. The adhesive can be removed mechanically and it allows for some moisture protection.

http://www.iiconservation.org/it/node/1702

Wadum J., **Historical Overview of Panel-Making Techniques in the Northern Countries,** structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 149 - 177

Abstract: Looks at guild regulations and painters' manuals as well as panels themselves to learn how panels were prepared in the 15th-17th centuries in northern Europe. Guilds regulated the woods used for panels, the duration of seasoning, the joinery of planks, the treatment of surfaces, the construction and attachment of frames, and, later, the ground applied to finished panels. All panels had to be inspected by the dean of the guild, assuring quality control of artists' materials. Over time, panel sizes became standardized. Various marks visible on the back sides of panels represent the signatures of lumberjacks, timber salesmen, panel makers, and guild inspectors. Brands stamped or drawn on the wood after approval by the dean help identify the panel maker of a number of old masters paintings. From the late 16th century onwards, ground was applied in the panel maker's workshop, creating a ready-to-paint product.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings2.pdf

Wadum J., **Microclimate Boxes for Panel Paintings,** The structural conservation of panel paintings: proceedings of a symposium at the J. Paul Getty Museum, 24-28 April 1995, Dardes Kathleen (Editor) and Rothe Andrea (Editor), The Getty Conservation Institute, Los Angeles, California, 1998, p. 497 - 524

Abstract: Changes in relative humidity (RH) produce measurable changes in the dimensions of wooden panels. Microclimate boxes can be used to control the moisture content and protect panel paintings. The evolution of the use and design of microclimate boxes is described. Studies on the relationship of temperature and RH in closed cases have contributed to the design of three types of boxes: those using an active buffer material to stabilize the internal RH; a more recent box containing no added buffer material; and boxes with an altered gas content. The historical development of microclimate boxes from vitrines hanging on the wall, enclosing painting and frame inside, to small boxes placed behind and within the frame is covered.

http://www.getty.edu/conservation/publications_resources/pdf_publications/panelpaintings4.pdf

Wadum J., **Technical art history: painters' supports and studio practices of Rembrandt, Dou and Vermeer,** Amsterdam, Dissertation, 2009, http://dare.uva.nl/record/307191

Webb M., **Four Japanned Cabinets: A Variety of Techniques,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 328 - 336

Abstract: The preparation for the opening of the second wing of European Decorative Arts at the Royal Ontario Museum has afforded the conservators and curators the opportunity to examine in detail many of the japanned pieces in the collection. This furniture has been in storage for many years because some of the pieces were considered unexhibitable due to their poor condition. The type of japanning evidenced on these cabinets first became popular in the seventeenth century, as contacts with the Far East through the Dutch East Indies Company and the East India Company became more frequent. As the popularity increased, the demand could not be met by Asian lacquerwares alone. Early attempts to import the raw lacquer and to cultivate the trees that produce it failed, and, although it was being imported to England by the mid–eighteenth century, it was considered too

dangerous for common use. Robert Dossie writes in The Handmaid to the Arts (1764:408), "Its poisonous qualities are almost constantly fatal to those who work with it any length of time and sometimes even on very slight meddling with it." New formulas were developed to produce a hard lustrous surface. This collection of four cabinets demonstrates several different techniques of japanning in use during the seventeenth, eighteenth, and nineteenth centuries.
http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Wiedenhoeft A., **Wood Handbook, Wood as an Engineering Material,** General Technical Report FPL-GTR-190, Madison, WI, U.S, Department of Agriculture, Forest Service, Forest Products Laboratory, 2010

Abstract: Summarizes information on wood as an engineering material. Presents properties of wood and wood-based products of particular concern to the architect and engineer. Includes discussion of designing with wood and wood-based products along with some pertinent uses.
http://www.fpl.fs.fed.us/products/publications/specific_pub.php?posting_id=18102&header_id=p

Williams D.C., **Some Experiences with Flexible Gap-Filling Adhesives for the Conservation of Wood Objects,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 113 - 124

Abstract: The functional requirements of gap-filling adhesives for use in the structural conservation of panel paintings impose considerable constraints on the choice of materials for this purpose. Some degree of flexibility in the adhesive is considered an important material characteristic. The paper presents an evaluation, based on accumulated personal experience from the practice of furniture conservation, of the properties and performance of a range of adhesive systems for gap-filling applications. Adhesive types considered include natural and synthetic water-based materials: animal-hide glue and acrylic and polyvinyl acetate polymer emulsion products—the latter group comprising both regular white PVA glues and aliphatic resin glues (yellow carpenter's glues), which have improved water resistance and setting properties. Other adhesive systems evaluated include hot melt products, such as ethylene vinyl acetate (EVA) and multiplecomponent reactive systems of several types: rigid epoxies, flexible epoxies, and room temperature vulcanization (RTV) silicones. The use of isolating layers, to aid reversibil-

ity or to prevent penetration of the gap-filling adhesive into the porous structure of the wood, is discussed in connection with specific adhesive types.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Williams M. A., et al, **Technology and Conservation of Decorative Surface Systems of Horse-Drawn Vehicles,** Painted Wood: History and Conservation, J. Paul Getty Trust, Singapore, 1998, p. 345 - 362

http://www.getty.edu/conservation/publications_resources/pdf_publications/paintedwood4.pdf

Williams R.S., Plantinga P.L. and Feist W.C., **Photodegradation of wood affects paint adhesion,** Forest products journal 40, 1 ,1990, p. 45 - 49

Abstract: Freshly planed panels of southern pine [Pinus "Southern"], Pseudotsuga menziesii, Liriodendron tulipifera, Picea engelmannii, and Thuja plicata were exposed outdoors, oriented vertically facing south, for four or eight weeks in summer 1987 at Madison, Wisconsin. Unexposed panels and the exposed panels were then painted with an alkyd or acrylic latex primer. Blocks were prepared by gluing hard maple (Acer saccharum) to the painted surface with an emulsion polymer isocyanate adhesive. The blocks were tested in shear to determine paint adhesion to the exposed surface. The change in shear strength was dependent on type of primer, exposure time, and wood species. Panels painted with acrylic latex primer failed primarily at the wood/paint interface, and shear strength decreased with time of exposure. Panels painted with alkyd primer had no general failure trend for specimens exposed for zero or four weeks; specimens exposed for eight weeks failed primarily at the wood/paint interface. Alkyd primer adhesion decreased with increased exposure time for the two lower-density species (T. plicata and Picea engelmannii), but increased with exposure for the three higher-density species.

http://www.cabdirect.org/abstracts/19920656873.html;jsessionid=7442EAC6866C1905E1B216A6A2BD99F9

Williams R.S., William C., Feist W.C., **Durability of paint or solid-color stain applied to preweathered wood**, Forest Products Journal 43, 1, 1993

Abstract: Weathered wooden support and delamination of paint layers. Models for testing interlayer behaviour Unfinished wood siding was exposed outdoors for 1 to 16 weeks. Following this preweathering, the specimens were finished with a variety of film-forming finishes (paints or solid-color stains) and placed outdoors again (weathered) for several years. The finished specimens were evaluated annually to determine the effect of preweathering on finish performance. The longer the preweathering time, the more rapidly the finish developed cracking and flaking. Applying a water-repellent preservative to the preweathered wood before painting slowed this paint degradation. An acrylic latex primer and topcoat system was slightly more durable than an oil-based primer/latex topcoat system. Paint systems were vastly superior to the one coat solid-color stains. The durability of the finishes was compared with the results of adhesion testing of similar panels that were not weathered. The paint/wood bond strength, measured shortly after the paint cured, was a good indication of the durability of the paint system.
http://www.fpl.fs.fed.us/documnts/pdf1993/willi93b.pdf

Williams, R.S., Winandy J.E. and Feist W.C., **Adhesion of paint to weathered wood,** Forest products journal 37, 11-12, 1987, p. 29 - 31

Abstract: Western red cedar (Thuja plicata) boards were weathered outdoors for up to 16 weeks, painted with alkyd oil or acrylic latex primer paints and then tested in shear or tension to determine paint adhesion. The tensile strength of the paint/wood bond decreased 50% from 2068 kilopascals in wood weathered for 4 weeks to 1034 kilopascals in wood weathered for 16 weeks. Shear strength decreased 33% from 5171 kilopascals to 3447 kilopascals.
http://www.bcin.ca/Interface/openbcin.cgi?submit=submit&Chinkey=107939

Woolston J., **Restoration-A Sound Practice,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 104 – 112

Abstract: Violins might appear to have little in common with panel paintings, as their function is to produce sound. Rosined horsehair rubbed against a string can produce a sound of extraordinary tonal range and volume. Similar to panel paintings, instruments are made of wood and decorated on one side-not usually

with paint but with fine varnish, which not only enhances the aesthetic quality of the material used but offers protection in everyday use. The thinly carved panels have to resist enormous pressure from the strings as well as adjust to climatic conditions. They have done this in some cases for nearly five centuries: the earliest violin with a dated label, by Andrea Amati, bears the date of 1564. This paper will examine from the perspective of a violin maker and restorer the following concerns: tools and methods for repairing cracks, causes of cracks, procedures for gluing cracks in perfect alignment, crack reinforcements, and methods to ensure that the repair will not cause future problems. The violin is a perfected and economic solution to an engineering problem, and no part is without its function. In order to maintain these instruments as both working tools and aesthetic creations, it is crucial to understand the methods and sequence.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Wörle M., Hubert V., Hildbrand E., Hunger K., Lehmann E., Mayer I., Ptrak G., Parcher M., Arx U. Von, Wülfert S., **Evaluation of decontamination methods of pesticide contaminated wooden objects in museum collections: Efficiency of the treatments and influence on the wooden structure,** Wood Science for conservation, Journal of Cultural Heritage, Volume 13, No. 3S, September, ed. Gril J., p. 209 - 215

Abstract: In the second half of the 20th century, many valuable wooden museum objects were massively treated with toxic chloride pesticides (such as DDT, pentachlorophenol [PCP] or lindane) to protect them against insect and mold infestation. In the following years, synthetic pyrethroids replaced the classic pesticides or the objects were even treated with mixtures of chemicals. Today, some of these toxic pesticides such as DDT have effloresced on the objects surfaces forming a white layer of crystals or they are emitted into the indoor air of storage rooms or exhibitions. In order to prevent the conservators as well as the visitors from health risks, it is inevitable to decontaminate these objects. Two COST projects were started in order to evaluate suitable decontamination methods and to investigate their influence on the wooden microstructure, the second project basing on the results of the first one. In the first project (SER COST project C07.0110 "Evaluation on the effectiveness of decontamination methods for wooden art objects treated with wood preservatives"), dummies of oak wood were soaked with a mixture of the pesticides pentachlorophenol, lindane und DDT and the distribution of the pesticides in the wood structure was determined by GC/MS, neutron radiography and µ-XRF. Then two decontamination methods were adopted to the wooden dummies: a vacuum washing system (bhd-decon®, developed by the German

company bhd Bautenschutz u. Hygienedienstleistungen GmbH, Dresden) and a vacuum temperature method (developed by the Berne University of Applied Sciences (Architecture, Wood and Civil Engineering) in collaboration with the Berne University of Applied Sciences (Berne University of the Arts)). The efficiency of both methods was evaluated by GC/MS and µ-XRF, creating depth profiles of the distribution of the remaining pesticides. The vacuum temperature method turned out to be too rough in means of temperature and pressure and was limited to a relatively small sample chamber. Therefore, the vacuum washing method was applied to historical objects and the efficiency was evaluated by µ-XRF mappings. During the investigations by passive sample measurements on the surface of museum objects, it became apparent that the pesticide concentration in the historical objects is much higher than assumed and, furthermore, that they contain a mixture of classic pesticides with synthetic pyrethroids as a result of repeated treatment. For this reason and for the investigation of a possible change of the wooden microstructure during decontamination, a second project (SER No. C09.0031 "Studies on the distribution of wood preservatives and on structural changes of the wooden structure during decontamination treatment of museum objects polluted by chlorinated and pyrethroid preservatives") was started. In this project, the wooden dummies were soaked in a mixture of pesticides of a higher concentration and the penetration depth was investigated depending on the use of different solvents by GC/MS and µ-XRF. The microstructure of the wood was investigated by micro X-ray tomography and 3D microscopy before and after decontamination treatment.

http://dx.doi.org/10.1016/j.culher.2012.01.006

Yokoyama M., et al, **Mechanical characteristics of aged Hinoki wood from Japanese historical buildings**, Comptes Rendus Physique, Volume 10, Issue 7, 2009, p. 601 – 611

Abstract: Wood is present in many cultural heritage objects in Japan thanks to its capacity to resist over a long period of time. However, the evolution of its properties in regular use remains insufficiently known. The present study on the effect of wood aging takes advantage of the Japanese context where building traditions have been maintained for centuries. 3-point bending tests were performed in longitudinal (L) and radial (R) directions on small clear wood specimens cut from 8 historical samples and one modern reference considered of high quality by craftsmen. Although aged wood appeared more rigid and stronger than recent wood, after density and humidity corrections were applied no significant variation of L and R rigidity or L strength was observed. The post-linear behaviour, however, was

drastically influenced by wood age especially in R direction where the strength and rupture energy decreased markedly with the time elapsed since the wood was processed. Well preserved aged wood considered as safe as long as it is not loaded perpendicular to grain.

http://www.sciencedirect.com/science/article/pii/S1631070509001157

Young C., New B. and Marchant R., **Experimental Evaluation of Adhesive-Filler Combinations for Joining Panel Paintings,** Facing the Challenges of Panel Paintings Conservation: Trends, Treatments, and Training, ed. Alan Phenix and Sue Ann Chui, Los Angeles, Getty Conservation Institute, 2011, p. 125 – 138

Abstract: This paper reports on an experimental evaluation of adhesive-filler combinations for joining panel paintings. The samples and tests were chosen on the basis that the gap to be rejoined was not suitable for a wood fillet, or it was too large to join without the addition of filler to the adhesive. In the present tests, the most mechanically suitable combinations from the previous tests have been subjected to thermal aging, and their properties are compared. Additionally, new combinations have been tested; they are based on materials used by conservators but not included in the original tests, and some combinations are ones that the authors consider to be suitable alternatives. Also investigated are the effect of priming the wood with a dilute adhesive and the influence of contaminants from residues of previous adhesives. The main criteria chosen to assess the suitability of the adhesive-filler combinations were strength of join, mode of join failure, workability, and mechanical stability.

http://www.getty.edu/conservation/publications_resources/pdf_publications/facing3.pdf

Young C., Ackroyd P., Hibberd R. and Gritt S., **The mechanical behaviour of adhesives and gap fillers for re-joining panel paintings,** National Gallery Technical Bulletin 23, 2002, p. 83 - 96

Abstract: Previously conserved panel paintings (which may have had a cradle removed) sometimes require gap fillers as well as thin films of adhesives to rejoin panels, and in some cases the treated panel will be returned to a building with little or no environmental control. Often the panels are connected by butt joins. The adhesive properties should be tailored to the wood properties and to the anticipated environmental exposure. Ideal properties for the adhesive and filler are defined, and the properties of existing synthetic and natural materials (with the

exception of fish glues) are discussed in these terms. Four-point bend tests on currently available materials are described and interpreted. All the adhesives used in hairline joints tended to cause failure of the wood or wood removal at the adhesive interface. Fillers of Resin W with coconut and microballoons showed cohesive failure within the joint and no damage to the wood, though their hygroscopic properties have not yet been characterized. Glue, PVAC, UF, urea formaldehyde, epoxy, araldite 2014, rye flour, wood flour, cellulose powder, coconut flour, phenolic microballoon, peak load, stiffness.

http://www.nationalgallery.org.uk/technical-ulletin/young_ackroyd_hibberd_gritt2002

Younus A., et al, **A Continuous Millimeter-Wave Imaging Scanner for Art Conservation Science,** Advances in Optical Technologies, 2011, p. 9

Abstract: A monochromatic continuous millimeter-wave imaging system coupled with an infrared temperature sensor has been used to investigate artistic objects such as painting artworks or antiquities preserved at the museum of Aquitaine. Especially, 2D and 3D analyses have been performed in order to reveal the internal structure of a nearly 3500-year-old sealed Egyptian jar.

http://www.hindawi.com/journals/aot/2011/275682/

Zhang H., Wang X., Zhu L., Sun Y., Ross R. J, Brashaw B.K., **An Integrated NDT Approach for Determining Residual Strength of Ancient Wood Structural Members,** 17th International Nondestructive Testing and Evaluation of Wood Symposium, Sopron, 2011

http://woodndt.nyme.hu/fileadmin/dokumentumok/fmk/faimei/docs/woodndt_-_pptk/7_historical/ok_7.2ZhangHoujiang.pdf

Zhang S.Y., **Variations and correlations of various ring width and ring density features in European oak: implications in dendroclimatology,** Wood Science and Technology, 1997, p. 63 - 72

Abstract: Variations and correlations of various ring width and ring density features were analyzed in 18 European oak (Quercus petraea and Quercus robur) trees from northeastern France. In light of these analyses, the goodness of various tree-ring features as a climatic parameter was discussed. In general, ring density features (viz. earlywood density, latewood density, average ring density, minimum density and maximum density) show a stronger response to calendar year, a comprehen-

sive climatic variable, than ring width features (viz. earlywood width, latewood width, total ring width and latewood percent). The response of latewood features (viz. latewood width, latewood density and maximum latewood density) is stronger than that of earlywood features (viz. earlywood width, earlywood density and minimum earlywood density). Average ring density seems to be the most sensible tree-ring feature in European oak in terms of the response to calendar year. Moreover, total ring width as a climatic parameter is not as good as latewood width, and maximum (latewood) density and minimum (earlywood) density appears not to contain as much climatic information as (average) latewood density and (average) earlywood density, respectively. http://rd.springer.com/article/10.1007/BF00705701

This overview of abstracts is an addition to the Research Agenda 2014-2020 of The Conservation of Panel Paintings and related objects.The Research Agenda can be downloaded from www.nwo.nl/science4arts

Contact
NWO
Laan van Nieuw Oost-Indië 300
PO Box 93138 – NL- 2509 AC Den Haag

Photographs on front and back of the cover:
Willem van de Velde (I), Seascape with the Dutch Men-of-War including the "Drenthe" and the "Prince Frederick-Henry". The Netherlands, 1630-1670. Oak, 70 x 90 x 1.5 cm. The panel consists of three horizontal boards. The joint show traces of previous reinforcements with canvas strips and glue blocks. © Rijksmuseum.


B.58 (22)
55