遗产研究国际动态

THE HERITAGE SPECTATOR

总第6期 Issue. 6

2022.11（内刊）

中国-葡萄牙文化遗产保护科学“一带一路”联合实验室

CHINA-PORTUGAL JOINT LABORATORY
OF CULTURAL HERITAGE CONSERVATION SCIENCE
SUPPORTED BY BELT AND ROAD INITIATIVE

《遗产研究国际动态》(内刊)
中国 - 葡萄牙文化遗产保护科学“一带一路”联合实验室
2022.11 总第 6 期

The Heritage Spectator (Newsletter)
China-Portugal Joint Laboratory of Cultural Heritage Conservation Science supported by the Belt and Road Initiative
2022.11 Issue. 6

封面图像：
拉奎拉（L'Aquila）市政厅保护与修复工程现场，意大利（2018）。
图像来源：王诗若摄
Cover Image:
L'Aquila Town Hall Conservation and Restoration Project Site, Italy (2018).
Cover Credit: WANG Shiruo

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特别鸣谢：
澳门城市大学
埃武拉大学 HERCULES 实验室
Special Thanks to
City University of Macau
HERCULES Laboratory, the University of Evora

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Conservation Science in Cultural Heritage: Reflections and Future Perspectives

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1 界定保护科学在文化遗产中的作用

尽管保护科学已经是一门公认的学科，特别是对于那些从事博物馆和美术馆工作的人来说，但目前还没有一个广泛认可的定义来涵盖保护科学家所从事的所有活动。然而，这些被承认的工作包括对材料的研究、保护处理以及预防性保护的原则和实践。在美国，保护科学家被美国保护研究所 (American Institute for Conservation， 简 称 AIC) 定义为“主要致力于应用专业知识和技能，在符合道德规范的前提下支持保护活动的专业科学家”(AIC, 1996)[1]。究竟是让科学家培养保护技能好，还是让保护专业人员掌握相关的科学知识好，这可能是一个有待商榷的问题，但关键是它附加给指导和区分所有保护工作的道德准则的重要性。在许多为历史建筑和纪念碑的保护而采取的措施中，科学和科学方法的应用都是必要的。以伯纳德·菲尔登（Bernard Feilden） (1999) 划定的参与建筑保护的 16 种不同类型的专业人员为例。 在这一系列“专业背景”中，“材料科学家”参与了 14 项已确定的专业任务中的 10 项。 这一领域广泛学科的价值往往没有得到充分认识。

通过科学探究解决问题是文化遗产保护的基石之一。保护科学是一个成熟的领域，科学和文化的新范式以及社会的期望使我们有必要重新审视现有的方法，特别是保护科学在遗产领域内外部运作和联系的方式。保护科学有多个接受者，除了面向专门受众的出版物之外，还有许多方式，通过这些出版物，这些不同的群体可以参与、塑造和分享其努力的结果。

1 Defining the role of conservation science in cultural heritage

Although conservation science is a clearly recognised discipline, particularly for those engaged in museums and galleries, there is currently no widely agreed definition that embraces the full range of activities undertaken by conservation scientists. Such work is, however, acknowledged to include the study of materials, conservation treatments, and the principles and practice of preventive conservation. Within the United States, a conservation scientist is defined by the American Institute for Conservation (AIC) as 'a professional scientist whose primary focus is the application of specialized knowledge and skills to support the activities of conservation in accordance with an ethical code' (AIC, 1996)[1]. Whether it is better for a scientist to develop conservation skills or for a conservation professional to acquire the relevant scientific knowledge may be a moot point, but the key point is the importance it attaches to the ethical code that guides and distinguishes all conservation work. The application of science and scientific methods is inherent in many of the approaches taken with the conservation of historic buildings and monuments. Take, for instance, the 16 different types of professional identified by Bernard Feilden (1999) as being involved in architectural conservation. In this set of 'profiles', the 'Material Scientist' is involved in 10 out of the 14 identified professional tasks. The value of this broad discipline is often not fully recognised.

Solving problems through scientific inquiry is one of the bedrocks of cultural heritage conservation. Conservation science is a well-established field, nevertheless, new paradigms in science and culture and the expectations of society make it imperative to revisit established approaches, especially in the ways conservation science operates and connects within the heritage sector and beyond. Conservation science has multiple recipients and there are numerous ways, over and above the production of publications addressed to specialized audiences, by which these various communities can engage with, shape and share the outcome of its endeavours.

1 Heritage A., Golfomitsou S., Conservation science: Reflections and future perspectives. Studies in Conservation. Vol. 60. 2015. P2.

2 保护科学的应用

科学在建筑保护方面的应用范围从相对直接的使用湿度计和其他形式的无损检测设备，到能够提供有关特定材料特性和破损现象的定性和定量数据的精密分析方法。在使用这些方法时，必须清楚预期的结果是什么，以及所得的资料如何实际地用于关联或巩固已计划的行动方针。在所有形式的分析中，解读比原始数据本身更重要。例如，对砂浆样品进行分析可以测定混合比例和组成材料，但如果没有仔细地解读，仍然可能采取不合适的砂浆作为修复材料。在为任何形式的分析取样时，必须了解获得具有代表性的数据的必要性——同一类历史材料也有很可能是非均质的，故需要多个样本才能获得有意义的信息。

通常只有不到 10% 的建筑结构可以在调查中直接观察和评估[2]，使用无损检测技术，如脉冲雷达、热像仪、光纤或微钻技术，可以帮助识别和确定建筑结构和结构在地下、建筑内部或隐藏在饰面下的状况。关键信息也可以通过间接方法获得，例如通过分析材料样本或解读远程收集的数据。例如，在测量含水率和吸湿性时，为了提高精度，可能需要采用重量分析 (湿重和干重比较) 或使用碳化钙计而不是标准电阻含水率计。可以使用长效传感器进行远程湿度监测。

类似的技术也可用于监测，以便在一段确定的时间内提供绝对或相对数据。包括结构变形和位移，材料劣化和环境参数。表 1 列出了可用于建成环境保护专业人员的一系列科学方法。重要的是要意识到每种方法都有其特定的

2 Application of conservation science

The application of science in architectural conservation can range from the relatively straightforward use of moisture meters and other forms of non-destructive survey equipment to sophisticated analytical methods that are able to provide qualitative and quantitative data about specific material properties and decay phenomena. In utilising such methods, one must be clear as to what is expected and how the resulting information might realistically be used to inform or enhance a planned course of action. In all forms of analyses, it is the interpretation that is of primary importance rather than the raw data themselves. For instance, having a mortar sample analysed can tell you about the mix proportions and constituent materials, but without careful interpretation an unsuitable replacement mortar may still be specified. When taking samples for any form of analysis, it is essential to understand the need for obtaining representative data - building materials are likely to be heterogeneous and more than one sample will be required to gain meaningful information.

With typically less than 10 percent of the fabric of a building available for direct observation and assessment during

2 Agnes W. Brokerhof. How can science connect with and contribute to conservation? Recommendations and reflections. Studies in Conservation. Vol. 60. 2015. P5.

优点和局限性，高级精密的方法不一定是最好的选择。使用相对简单的技术往往可以获得有用的信息。

a survey2, the use of non-destructive survey techniques - such as impulse radar, thermography, fibreoptics, or micro-

活动 ACTIVITY	方法 （举例） METHOD （WITH EXAMPLES)	信息获取 （举例） INFORMATION GAINED (WITH EXAMPLES)
无损勘察 NON-DESTRAUCTIVE SURVEY	• 指标解决方案 Indicator solution • 液体渗透剂 Liquid penetrant • 烟雾发生器 Smoke generator • 微钻 Micro-drilling • 闭路电视 Close-circuit • 光纤 (内孔表面检查仪、内窥镜) Fibre-optics (boroscope, endoscope) • 红外线摄影 Infrared photography • 热成像 Thermography • 脉冲或表面穿透雷达 Impulse or surface-penetrating radar • 声学测试 Acoustic testing • 磁力仪 Magnetometry • 微波分析 Microwave analysis • 射线照相 Radiography	• 施工确认 Confirmation of construction(s) • 地下异常和空洞 Sub-surface anomalies and voids • 路线跟踪 (排水管，烟道) Route tracing (drains, flues) • 物理损伤 (裂纹) Physical damage (cracks) • 化学反应 (碳化) Chemical reaction (carbonation) • 生物劣化 (甲虫虫害) Biological decay (beetle infestation)
缺陷监测 DEFECT MONITORING	• 裂缝宽度计 Crack width gauge • 校准位移指示器 Calibrated tell-tale • 固定螺柱游标规 Vernier gauges with fixed studs • 应变仪 Strain gauge • 电子传感器 Electronic sensor • 测斜仪 (水平表面) Inclinometer (horizontal surfaces) • 光学铅锤 (垂直表面) Optical plummet (vertical surfaces) • 激光干涉法 (振动) Laser interferometry (vibration)	• 结构变形 Structural distortion • 构件挠度 (楼板托梁) Member deflection (floor joists) • 运动 Movement • 振动 Vibration
环境监测 ENVIRONMENTAL MONITORING	• 手动 (旋转湿度计) Manual (whirling hygrometer) • 机械 (热成像仪) Mechanical (thermograph) • 电子 (手持仪表) Electronic (hand-held meters) • 远程 (数据记录器，遥测) Remote (data loggers, telemetry)	• 温度（空气、表面） Temperature (air, surface) • 湿度（绝对，相对） Humidity (absolute, relative) • 露点温度 Dewpoint temperature • 蒸汽压力 Vapour pressure • 光照水平（紫外线） Light levels (ultraviolet) • 污染（气态、颗粒） Pollution (gaseous, particulate)
简单分析方法 SIMPLE ANALYTICAL METHODS	• 放大镜检查 Hand lens examination • 光学显微镜 Optical microscopy • 现场沉降试验 Field settling test • 密度测试 Density test • 干重和湿重 Dry and wet weight • 碳化钙计 Calcium carbide meter • QuanTab@ 测试条 QuanTab@ test strips	• 表面检查 Surface examination • 总体特征 Gross characteristics • 物理性质 (质量、密度、孔隙度) Physical properties (mass, density, porosity) • 粒度分级 Particle size grading • 含水量 Moisture content • 可溶盐分析 (半定量) Soluble salt analysis (semi-quantitative)
精密分析方法 SOPHISTCATED ANALYTICAL METHODS	• 差热分析（DTA） Differential thermal analysis (DTA) • 热重分析 (TGA) Thermogravimetric analysis (TGA) • 离子色谱 Ion chromatography • 孔隙率测定法 orosimetry • 傅里叶变换红外（FTIR）光谱 Fourier transform infrared (FTIR) spectroscopy • 扫描电子显微镜 (SEM) 分布 Scanning electron microscopy (SEM) distribution • 能量色散 X 射线 (EDX) 分析 Energy dispersive X-ray (EDX) analysis • X 射线衍射（XRD） X-ray diffraction (XRD)	• 表面检测 Surface examination • 元素组成 Elemental composition • 化学成分 Chemical composition • 矿物鉴定和分析（砂、集料） Mineral identification and analysis (sands, aggregates) • 盐分析（定量阴离子和阳离子） Salt analysis (quantitative for anions and cations) • 孔隙率和孔径 Porosity and pore size

表 1：建成环境保护专业人员常用科学技术与方法
Table 1. Scientific technologies and methods for the built environment professionals involved in architectural conservation

3 全域视野：传递更好、更相关的科学

(1) 评估需求和结果

根据展示效益的需要，一个关键问题是充分评估需求和结果 : 确保研究侧重于相关的内容，并就目标社区内外的效益进行评估。为此目的，通用的评价工具来提供一种程序化的方法来确定需求、追踪活动和产出以及衡量结果。这些工具将为学习和改进提供支持，以提高成果和最大限度地发挥影响。

(2) 通过合作共享寻求可持续的解决方案

在任何应用科学领域，保持研究和实践之间的联系是至关重要的。与终端用户合作开展

drilling can assist in identifying and determining the condition of structure and fabric lying below ground, within the construction of the building, or hidden beneath finishes. Key information may also be gained by way of indirect methods, such as through the analysis of material samples or interpretation of remotely-gathered data. Where, for instance, the measurement of moisture content and hygroscopicity is undertaken, the need for greater accuracy might dictate the application of gravimetric analysis (wet and dry weight comparison) or use of a calcium carbide meter rather than a standard resistance moisture meter. Remote moisture monitoring may be undertaken using permanent sensors.

Similar techniques may also be used

以解决方案为导向的应用研究，重点是提供相关信息和工具，以可持续地解决遗产保护方面的首要挑战。这就需要一种参与式的研究方法，欢迎并鼓励文化遗产保护领域内不同研究方向之间的合作，并跨越该领域的边界，促进研究项目内的跨学科工作。此外，创造性的合作方，包括公民科学和众包倡议，可以加强和扩大保护社区，使其成为一个更具包容性、更有能力和更愿意与其他社区接触的社区。

在实操层面，为了提高效率、知识交流和减少不平等，非常需要机构之间共享资源和专门知识的机制。这可以通过建立国际研究基础设施来促进学术交流、共享设备和专家、提供研讨会和实习机会来实现。

（3）拓展和利用知识

认识到有助于保护文化遗产的知识体系的多样性是很重要的。除了多样化的科学学科，传统知识和工艺技能也是一个重要的资源，有潜力为当下的保护实践提供更好的选择。认识到这些知识体系的价值，并通过应用科学方法来理解和评估传统方法和材料，可以优化和提高其在遗产保护中的应用潜力。

然而，如果知识不能得到有效传播，那它将没有多少用处，因此提供获取知识的便利是至关重要的。信息应该以地点和形式共享，以便目标受众能够最容易地获取信息，最理想的是使用免费、开放的获取平台。适应受众和环境的知识基础设施和交互式教学工具可以帮助传播研究成果，并在从当地团体到全球网络的多个层次上促进最佳的实践。

（4）提升质量

为了确保高质量科学的传递能够紧跟时代并且贴近需求，保护科学专业人员需要与该领域以外的科学领域保持密切联系。此外，拓展学科领域外的研究可以发现文化遗产科学的新路径和新应用。改进方法，尽量减少实验过程中的误差和使用标准化的方法也将提高科学数据的质量。

（刘哲康参与编译）

to monitor conditions in order to provide absolute or relative data over a defined period of time. This might include structural distortion and movement, material deterioration, and environmental parameters. The range of scientific methods that might be of use to the built environment professional involved in architectural conservation is given in Table 1. It is important to be aware that each has its own specific advantages and limitations, and that the more sophisticated methods are not always necessarily the best choice. Useful information may often be obtained by using relatively simple techniques.

3 A broader vision: delivering better, more relevant science

(1) Assessing needs and outcomes

In line with the need to demonstrate benefit, a key issue is the adequate assessment of needs and outcomes: to make sure that research focuses on what is relevant, and to assess how well this is being achieved, in terms of the benefits for immediate client communities and beyond. To this end, common evaluation tools are needed to provide a structured means of identifying needs, tracking activities and outputs, and measuring outcomes. Such tools would provide a support for learning and improvement to enhance outcomes and maximize impact.

(2) Seeking sustainable solutions through collaboration and sharing

As in any applied science domain, maintaining the link between research and practice is vital. This is best served through solution-orientated applied research developed in partnership with end-users, which focuses on providing relevant information and tools to sustainably resolve priority challenges in heritage conservation. This requires a participatory approach to research that welcomes and encourages collaboration between different actors within cultural heritage conservation, and which also looks beyond the borders of the sector, to foster interdisciplinary working within research projects. In addition, creative partnerships, including citizen science and crowd-sourcing initiatives, can strengthen and expand the conservation community to become one that is more inclusive, capable and willing to reach out to engage with other communities.

On a practical level, mechanisms for sharing resources and expertise between institutions are much needed to increase efficiency, knowledge exchange, and reduce inequalities. This can be realized by creating international research infrastructures to foster scholarly exchanges, share equipment and experts, provide workshops, and facilitate internships.

(3) Expanding and utilizing knowledge

It is important to recognize the multiplicity of knowledge systems that can contribute to the conservation of cultural heritage. In addition to diverse scientific disciplines, traditional knowledge and craft skills are a vital resource, with the potential to provide improved options for conservation practice that are better suited to context. Recognizing the value of these knowledge systems, and through the application of scientific methods to understand and assess traditional methods and materials, their potential application within heritage conservation can be optimized and enhanced.

However, knowledge is of little use unless it is effectively disseminated, and so providing ready access to knowledge is vitally important. Information should be shared in locations and formats such that it can be most easily accessed by target audiences, ideally using free, open access platforms. Knowledge infrastructures and interactive teaching tools adapted to audiences and context can help disseminate research findings and promote best practice at multiple levels from local groups to global networks.

(4) Enhancing quality

To ensure delivery of high-quality science that is up to date and relevant to needs, conservation science professionals need to maintain strong links with scientific fields outside the sector. Moreover, outward looking research can lead to the discovery of new paths and applications of science for cultural heritage. Improving methods, minimizing errors in experimental processes and making use of standardized methodologies will also enhance the quality of scientific data.

(LIU Zhekang participates in translation)

人物 Figure

路易吉娅 · 宾达（1936–2016）
Luigia Binda (1936-2016)

资料来源 Source：
https://www.rilem.net/news/in-memoriam-prof-luigia-binda-1936-2016-209
https://www.wessex.ac.uk/news/general-news/obituary-luigia-binda
Anzani, A., Cardani, G., Condoleo, P. et al. Understanding of historical masonry for conservation approaches: the contribution of Prof. Luigia Binda to research advancement. Mater Struct 51, 140 (2018). https://doi.org/10.1617/s11527-018-1254-4

Luigia Binda 教授多年来一直担任米兰理工大学建筑学院的教授和名誉教授。她的研究领域是古建筑的保护和结构修复、结构的无损评估、侵蚀性环境引起的材料破损、砖石砌体结构的机械物理损伤评估、修复技术研究、材料的表征和耐久性、砖石砌体的长期变化和疲劳性能、诊断调查程序、固结技术的有效性等。

Luigia Binda 在国际层面积极讨论与保护历史文化中心和考古遗址现有砖石结构有关的众多问题。她能够促进建筑师和工程师、考古学家和材料科学家之间的科学对话，始终在学术界、工业界、公共和宗教机构、技术人员和专业人士之间推广多学科和多层次的方法。她在材料、结构、建设和保护技术、耐久性和兼容性、诊断、结构监测和建模方面的贡献，以及她乐于分享和完善研究方法的非凡态度，为推进研究提供了巨大帮助，推动人们以更负责任和更谨慎的态度使用历史建筑和文化遗产。

路易吉娅 · 宾达教授代表作

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6. Binda L, Baronio G, Tedeschi C,

路易吉娅 · 宾达教授
Professor Luigia Binda

Prof. Luigia Binda was Full Professor and Honorary Professor at the Faculty of Architecture, Politecnico di Milano for many years. Her interests were in preservation and structural restoration of ancient buildings, non-destructive evaluation of structures, material decay due to aggressive environment, the assessment of mechanical-physical damage in masonry structures, study of repair techniques, the characterization and durability of materials, the long-term and fatigue behavior of masonry, investigation procedures for diagnostics, effectiveness of consolidation techniques, etc.

Luigia Binda was active at an international level to debate many topics related to preservation of existing masonry construction in historical centers and archeological sites. She was able to foster scientific dialogue among architects and engineers, archeologists and material scientists, always promoting multidisciplinary and multi-level approaches among academy, industry, public and religious institutions, technicians and professionals. Her contributions on knowledge of materials, structures, constructive and conservation techniques, durability and compatibility, diagnosis, structural monitoring and modelling, and her exceptional attitude to share and refine her scientific approach provided a continuous inspiration and encouragement to advance research towards a responsible and more respectful use of historic buildings and cultural heritage sites.

Representatives publications of Professor Luigia Binda

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2.Binda L, Cardani G (2015) *Seismic vulnerability of historic centers: a methodology to study the vulnerability assessment of masonry building typologies in seismic area.* In: *Panagiotis GA, Vagelis P (eds) Handbook of research on seismic assessment and rehabilitation of historic structures.* IGI Global, Hershey.

3.Cardani G, Binda L (2015) *Guidelines for the evaluation of the load-bearing masonry quality in built heritage.* In: Toniolo L, Boriani M, Guidi G (eds) *Built heritage: monitoring conservation management.* Springer, Cham, pp 127–140. https://doi.org/10.1007/9783319085333

4.Binda L, Cardani G, Saisi A, Valluzzi MR, Munari M, Modena C (2007) *Multilevel approach to the vulnerability analysis of historic buildings in seismic areas, part 1: detection of parameters for vulnerability analysis through on site and laboratory investigations.* Restor Build Monum 13(6):413–426

5.Anzani A, Binda L, Mirabella Roberti G (2008) *Experimental researches into long term behaviour of historical masonry.* In: Binda L (ed) *Learning from failure: long-term behaviour of heavy masonry structures, series: advances in architecture*, vol 23. Witt Press Southampton, Boston, pp 29–55

6.Binda L, Baronio G, Tedeschi C, Tiraboschi C (2003c) *Experimental research for the choice of adequate materials for the reconstruction of the Cathedral of Noto.* Constr Build Mater 17:629–639. https://doi.org/10.1016/S0950-0618(03)00059-X

7.Binda L, Condoleo P (2009) *Construction techniques of the Mỹ Sơn temples.* In: *Hardy A, Cucarzi M, Zolese P (eds) Champa and the Archaeology of Mỹ Sơn (Vietnam).* NUS Press, Singapore.

8.Binda L, Condoleo P (2012) *Knowledge, preservation principles and intervention, in the architectural-archaeological restoration*

Tiraboschi C (2003c) 为重建诺托大教堂选择适当材料的实验研究．构造材料 17：629–639. https://doi.org/10.1016/S0950-0618(03)00059-X

7. Binda L, Condoleo P (2009) 美山亭寺庙的建造技术．发表于：Hardy A, Cucarzi M, Zolese P (eds) Champa 和美山亭考古学（越南）. 新加坡国立大学出版社

8. Binda L, Condoleo P (2012)，知识、保护原则和干预，在美山亭的建筑考古修复中．发表于：Boriani M, Premoli F (eds) EWEC 考古遗址．越南美山保护区的一个可持续项目．阿拉巴凤凰，库尼奥

路易吉娅· 宾达教授代表性观点

标题以路易吉娅·宾达用来提醒人们的代表性发言开头，一目了然地总结了这一特别的视角在整个主题中的重要性。这含蓄地表明了她具有创新性的洞察力以及她对于整体研究的非凡奉献。

“砖石是一种复杂的材料”：建筑遗产中的承重砌体质量评价

路易吉娅·宾达的大部分研究致力于研究砖石结构体系的历史建筑，并分析其在不同应力状态下的表现（图 1）。为了准确定义影响其机械性能的参数，她的研究被引导到了一种基于准确的目视检查和适当的诊断调查来评估砖石砌体质量的方法上。

of My Son. In: Boriani M, Premoli F (eds) *EWEC archaeosites. A sustainable project at My Son sanctuary in Viet Nam. Araba Fenice, Cuneo*

Typical perspectives of Professor Luigia Binda

The title starts with a typical sentence Luigia Binda used to remind people, which summarizes at a glance the importance of that specific aspect in the topic. It implicitly indicates the innovative character of her insights and her extraordinary dedication to research.

"Masonry is a complex material": the evaluation of load-bearing masonry quality in built heritage

A large part of L. Binda's research was dedicated at studying historic load-bearing masonry and to analyze its behavior under different states of stress (Figure 1). The definition of the parameters influencing its mechanical behavior guided her research to a methodology for evaluating the masonry quality based on both an accurate visual inspection and a proper diagnostic investigation.

"Diagnosis investigation increases awareness": on-site diagnosis and complementarity of procedures

The interest of L. Binda concerning the historic structures developed almost naturally from her being an Architect involved in structural research, and working in the School of Architecture

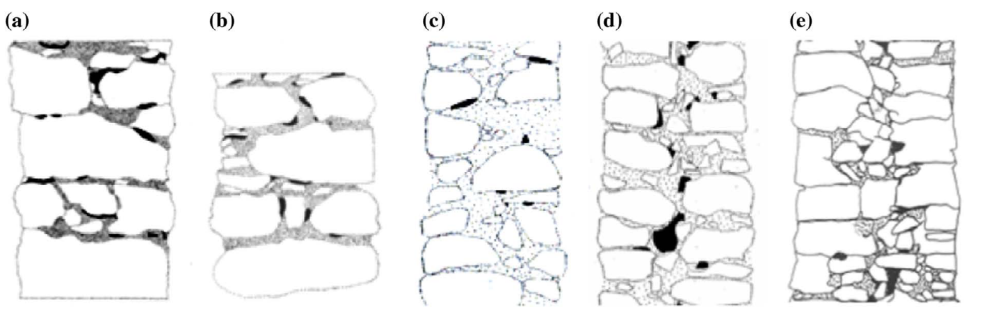

图 1：砖石砌体横截面示例：a. 单层砌体结构；b. 两层砌体紧密咬合（有横向连接石）；c. 两层砌体部分咬合；d. 两层砌体没有咬合；e. 三层或多层砌体

Figure 1. Examples of masonry cross sections: a one single leaf; b two leaves well interlocked (with transverse connecting stone); c two leaves partially interlocked; d two leaves not interlocked; e three leaves or multiple leaf

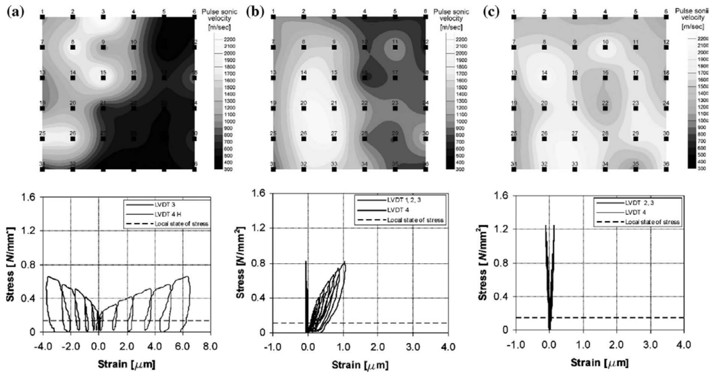

图 2：为评估砌体质量而进行的脉冲声波测试和单 / 双平板千斤顶测试结果

Figure 2. Results of pulse sonic tests and single/double flatjack testts carried out to evaluate masonry quality

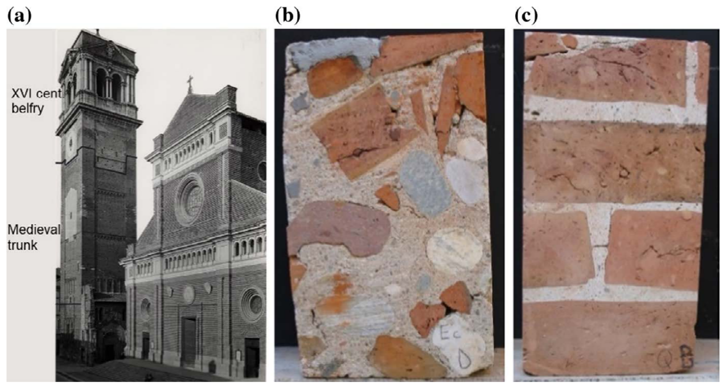

图 3：a. 帕维亚市民塔倒塌前景象；b. 中世纪瓦砾切面；c. 16 世纪平面砖石

Figure 3. a a view of Civic tower of Pavia before collapse; b medieval rubble inner leaf; c XVI cent. plain masonry

“诊断调查提高认识”：现场诊断与程序互补

路易吉娅·宾达对历史建筑的兴趣是在米兰理工大学建筑学院工作期间逐渐产生的，那时她作为一名建筑师参与结构研究。事实上，她早期的研究体现在建筑学院的几篇硕士论文中，与应用方法关系深远（图 2）；经过数次交流合作，她的观点随后逐渐成熟，首先是与 ISMES 的 P.P. Rossi 教授，后来与帕多瓦大学的 C. Modena 教授合作。

“砖石砌体也会蠕变”：大型结构的长期表现

在 1980 年代末，石材随时间变化的规律在岩石力学领域中广为人知，并已被用于表现硬粘土、软岩和混凝土在永久荷载条件下的反应。在新的砌体建筑中也观察到了这一现象，但是砖石历史建筑的风貌却从未被认为与时间相关。因为四名遇难者的死亡和一座非凡的纪念碑的倒塌——帕维亚市民塔的

of the Politecnico di Milano. Her early research, in fact, was carried out within several Master Theses of the School of Architecture, still very relevant for the applied methodology (Figure 2); her interest subsequently matured thanks to several collaborations, firstly with P.P. Rossi of ISMES and later with C. Modena of the University of Padua.

"Also masonry suffers creep": the long-term behavior of massive structures

At the end of the 1980s, time-dependent behaviour was well-known in rock mechanics and had been studied to describe the response of stiff clays, soft rocks and concrete to permanent loading conditions. It had also been observed in the case of new brickwork constructions, whereas the behaviour of historic masonry had never been referred to as time-dependent. The unexpected failure of the Civic Tower of Pavia can be regarded not only as a terrible loss, because of four victims and the collapse of a remarkable monument,

意外不仅是一次可怕的损失，同时也是一项突破性研究的起点，增加人们对于影响大型历史建筑的复杂安全因素的理解。路易吉娅·宾达参与了为调查倒塌原因而成立的两个委员会之一。由于她的多学科融合视角、对复杂问题的浓厚热情和温和的研究方法，她能够将保护和结构安全问题与砖石砌体性能的丰富实验经验结合起来。作为一名具有良好结构力学背景的建筑师，她意识到砖石砌体结构虽然是最古老的建筑技术，但也是最不为人知的，对他的认知不能只依赖于同质性、连续性、各向同性和线弹性反应等看似合理的假设。她的坚持不懈使她得出了长期性能变化的岩石力学解释，并应用蠕变试验来研究历史砖石砌体；随后，她基于伪蠕变测试建立了更合适的测试程序，并探索了基于流变学和概率解释的不同建模方法。目前，在对包括塔楼和大教堂柱子在内的大型历史建筑的评估中，不可忽视她在实验测试、理论知识和现场应用方面所取得的成果（图 3）。

图 4：意大利拉文纳圣维塔莱大教堂厚砂浆接缝

Figure 4. View of thick mortar joints of St. Vitale basilica in Ravenna (Italy)

“砌体是一种智能材料”：砂浆接缝在砌体结构的力学性能及其耐久性中的作用

路易吉娅·宾达很早就对砖石砌体的受压特性产生了研究兴趣。自 1980 年代末以来路易吉娅·宾达和她的同事巴罗尼奥采用了系统的方法来研究盐结晶对砌体造成的损害。根据盐的状态图，可以找出扩散最快和有害程度最高的盐，硫酸钠被选为在最短的测试持续时间内最具侵蚀性的一种盐（图 4）。

but also as the starting point of a breakthrough research destined to throw new light into the understanding of the complex factors affecting the safety of massive ancient buildings. L. Binda found herself involved within one of two committees, which were formed for investigating the causes of the collapse. Thanks to her multidisciplinary attitude, a deep passion toward puzzling problems and a gentle approach she was able to combine conservation and safety issues with a robust experimental knowledge of masonry behavior. Being an architect with a sound background in structural mechanics, she was aware that masonry, despite being the most ancient architectural technique, was also the least understood and its knowledge could not rely on reassuring hypothesis like homogeneity, continuity, isotropy, and linear elastic response. Her willfulness led her to access the rock mechanics interpretation of long-term behavior and to apply creep tests to study ancient masonry; subsequently, she set up more suitable testing procedures based on pseudo-creep testing and explored different modelling methods based on both rheological and probabilistic interpretation. At present, the assessment of ancient massive constructions, including towers and cathedral pillars, cannot ignore the results she achieved in terms of laboratory experimentation, as well as theoretical knowledge and on-site applications (Figure 3).

“Masonry is a smart material”: the role of mortar joints in the mechanical behavior of masonry structures and their durability

Luigia Binda’s scientific interest was early dedicated to the mechanical compression behaviour of the masonry. Since the end of the 1980s, L.Binda and her colleague G. Baronio followed a systematic methodology to study the damage caused to masonry by salt crystallisation. On the basis of the state diagrams of the most diffused and harmful salts, the sodium sulphate was chosen as the most aggressive in the shortest duration of the test (Figure 4).

图 5：美山亭考古遗址在干预前（左）和后（右）

Figure 5. The Mỹ Sơn archaeological site before(left) and after(right) intervention.

“建筑保护有助于考古”：越南美山寺石材砌体的修复

2000 年，基金会和河内古迹保护研究所的考古学家邀请米兰理工大学结构工程系（DIS）参观了美山亭（越南）考古遗址。因为路易吉娅·宾达对历史砌体结构以及与干预材料兼容性相关的所有问题的深入了解，她参与了该项目。在这个项目之前，人们对此建筑的建筑技术和建造材料有很多疑问。人们普遍认为，这些建筑是用生砖砌成的，然后加热至熟。 此外，还可以确定建筑倾斜、裂缝的情况以及材料的物理、化学和生物劣化产生的结构问题（图 5）。

（王沁、王诗若编译）

“Architectural preservation can contribute to archaeology”: the restoration of the peculiar masonry of the Mỹ Sơn temple in Vietnam

In 2000, the archaeologists of the Foundation and the Institute for Conservation of Monuments in Hanoi invited the Dept. of Structural Engineering (DIS) of the Politecnico of Milano to visit the My˜Sơn (Vietnam) archaeological site. L. Binda was involved in the project thanks to her deep knowledge about historic masonry constructions and all the problems related to the compatibility of the materials for the intervention. Before this project, there were many doubts concerning the construction techniques and the materials used for the erection of buildings. It was widely believed that these architectures were made of raw bricks, afterwards cooked. Furthermore, it was possible to identify the structural problems emerging from the buildings leaning, their crack pattern and the physical, chemical and biological decay of their materials (Figure 5).

(translated and edited by WANG Qin, WANG Shiruo)

实践案例 Case Study

基于超声断层扫描技术的历史建筑木梁检测与评估
Assessment of Wooden Beams from Historical Buildings Using Ultrasonic Transmission Tomography

资料来源 Source：

Monika Zielińska & Magdalena Rucka (2022): Assessment of Wooden Beams from Historical Buildings Using Ultrasonic Transmission Tomography, International Journal of Architectural Heritage, DOI: 10.1080/15583058.2022.2086505

1 区位和方法

超声波勘察是在位于波兰北部奥尔内塔的历史悠久的圣凯瑟琳修女会修道院的木梁上进行的。这是一栋合院式建筑，内院呈长方形。该建筑建于 1586 年。根据 1956 年 11 月 17 日的决定，它以 A-189 编号列入波兰文化遗产在册名单。曾经，该建筑是来自奥尔内塔的圣凯瑟琳修女会的修道院。在 1880 年代，瓦尔米亚主教马辛·克罗默（Marcin Kromer）决定将废弃的修道院交给圣凯瑟琳会的众姐妹。多年来，这座城市的格局已然改变。17-20 世纪修道院的区位如图 1 的地图和照片所示。

超声断层扫描分别应用在三种梁上（图 2a），将他们依次编号为 #1、#2 和 #3。每个梁的尺寸为 19cm x 12cm（图 2b）。研究中使用了具有不同破坏程度的木梁。样品（#1）是一根完整的松木梁。该梁的边缘是直的，梁没有任何明显的损坏或裂缝。这种梁是被用来替换奥内塔修道院建筑屋顶桁架中受损的木构。另外两个样本（#2 和 #3）是屋架结构的旧梁。这些梁被严重损坏，一侧的材料存在缺陷。此外，裂缝沿着木纤维延伸。由于支撑性能差，它们被新的木梁取代。测试后，所有测试样本 #1-#3 在重建图像的高度处被切割。因此，可以在测量平面上准确识别纤维的延伸路线和损坏部位（图 2c）。

2 超声断层图像

基于飞行时间法（Time-of-flight）采集到的数据重建了测试木梁 #1-#3 的内部结构。

1 Localization and methods

The ultrasonic surveys were conducted on wooden beams taken from the historical Monastery of Congregation of the Sisters of St. Catherine located in Orneta, in the northern part of Poland. It is a four-winged building with an inner courtyard on a rectangular plan. The object was built in 1586. It is entered in the Registry of Cultural Property in Poland under the number A-189, in the accordance with the decision of November 17, 1956. In its original form, the building was a monastery of Beguines from Orneta. In the 1880s, the bishop of Warmia, Marcin Kromer, decided to hand over the deserted monastery to the sisters of the Congregation of St. Catherine. Over the years, the city has changed its urban layout. The location of the monastery in the 17th-20th century is shown in maps and photos in Figure 1.

The ultrasonic tomography was conducted on three beams (Figure 2a), denoted as #1, #2 and #3. The dimensions of each beam were 19 cm x 12 cm (Figure 2b). Beams with different degrees of destruction were used for the research. The specimen (#1) was an intact pinewood beam. The edges of this beam were straight and the beam did not have any significant damages or cracks. The beams of such type were used to replace the damaged pieces of wood in the roof truss in the monastery building in Orneta. The other two specimens (#2 and #3) were historical beams from the roof structure. These beams were significantly damaged. There were defects in the material on one edge. In addition, cracks run along the wood fibres. They were replaced due to their bad technical condition by new wooden beams. After the tests, all tested samples #1–#3 were cut at the height of the reconstruction image. As a result, it was possible to identify the course of the fibres and the damage exactly at the plane of measurement (Figure 2c).

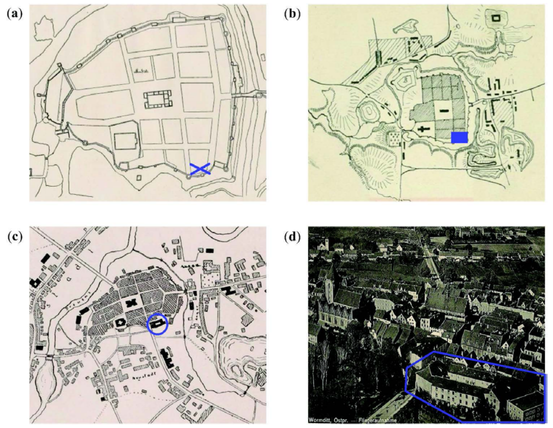

图 1：奥尔内塔的圣凯瑟琳修女会修道院区位图：（a）1627 年城市总平面，来自斯德哥尔摩的“Kriegsarchiv”收藏，（b）根据 Giesego 显示的 19 世纪初的城市布局，（c）1940 年的城市总平面，(d) 1930 年代的城市全景鸟瞰（Hliwiadczyn、Cholewska 和 Grunwald，2018）

Figure 1. Location of the monastery of congregation of the sisters of St. Catherine located in Orneta: (a) city plan from 1627 from the collection of “Kriegsarchiv” in Stockholm, (b) urban layout according to Giesego early 19th century, (c) city plan from 1940, (d) panorama of the city in the 1930s (Hliwiadczyn, Cholewska, and Grunwald 2018)

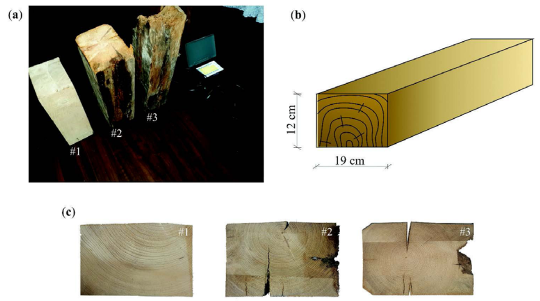

图 2：木梁的实验室模型：(a) 梁视图 (b) 梁尺寸 (c) 测试梁 #1-#3 的横截面

Figure 2. Laboratory models of wooden beams: (a) view of the beams, (b) dimensions of the beam, (c) cross-section of the tested beams #1–#3

木材是一种各向异性材料，其中超声波在径向-正切平面中的传播速度与年轮有关。波在径向上传播得更快，在切线方向上则减慢。在没有缺陷、木节的木材中，最高表观速度集中在横截面髓心的位置，因为髓心的位置与年轮有内在的联系。表 1 给出了每个木梁的波传播速度的定量分析，其中列出了最小、最大和平均速度，并辅以可变性度量数据，即标准偏差 (SD) 和浮动系数 (CV)。表 1 针对三个样本，分别

2 Ultrasonic tomography images

The internal structure of tested beams #1–#3 was reconstructed based on the collected TOFs (Time-of-flight). Wood is an anisotropic material in which the speed of ultrasonic waves in the radial-tangential plane depends on the direction of propagation, relative to the annual rings. The wave propagates faster in the radial direction and slows down going into the tangential direction. The highest apparent speed in wood without defects, knots is concentrated at the location of the cross-section pith since the pith location is inherently connected with annual rings. The quantitative analysis of wave propagation velocities for each of the beams is given in Table 1, where the minimum, maximum and mean velocity are listed, supplemented by the measures of variability, i.e., the standard deviation (SD) and coefficient of variation (CV). Table 1 summarizes the coefficient of variation (CV) for all 445 measurement paths, for each of the three samples separately. The coefficient was measured for two walls simultaneously. As an anisotropic material, examined wood samples showed a large change in properties depending on the direction of the fibers.

The first laboratory model (#1) was a new pine beam. The edges of this beam were straight and the beam did not have any significant damages or cracks. Figure 4 shows the resulting tomography velocity map for beam #1 together with the photograph of its cross-section. Significantly higher values of wave velocity were observed in the upper part of the image. This area indicates that the pith can be located near the upper edge of the cross-section or even outside of it. The measured values of the wave velocity for beam #1 ranged from 929.7 m/s to 1637.0 m/s, thus the difference between the lowest and the highest velocity was 707.3 m/s. The average value of the velocity for this beam was 1231.5 m/s. The variability of measurements along different paths was determined were: SD equal to 154.2 m/s and CV equal to 12.5%.

Beam #2 was taken from the historical roof frame-work. One of its sides included major wood fibrosis (see Figure 4a). The remaining three contained cracks. The ultrasonic tomography

木梁 Wooden beam	Vmin [m/s]	Vmax [m/s]	*ΔV= Vmax - Vmin*[m/s]	*Vavg* [m/s]	SD	CV
#1	929.7	1637.0	707.3	1231.5	154.2	12.5
#2	632.7	1442.3	809.6	1093.3	137.0	12.5
#3	478.6	1842.5	1393.9	1462.3	293.4	20.1

表 1. #1-#3 木梁中波的传播速度

Table 1. Wave propagation velocities for beams #1-#3

总结了 445 个测量路径的浮动系数 (CV)。同时测量两个细胞壁的系数，作为一种各向异性材料，测试过的木材样品显示出差异较大的性能变化，具体取决于纤维的方向。

第一个实验室模型（#1）是一个新的松木梁。该梁的边缘是直的，梁没有任何明显的损坏或裂缝。图 4 显示了梁 #1 的断层扫描速度图及其横截面照片。在图像的上部观察到明显更快的波速。该区域表明髓心可能位于横截面的上边缘附近，甚至很可能位于横截面之外。#1 号光束的波速测量值在 929.7m/s 到 1637.0m/s 之间，因此最低和最高速度之差为 707.3m/s。该光束的速度平均值为 1231.5m/s。沿不同路径测量的可变性系数确定为：SD 取 154.2m/s，CV 取 12.5%。

梁 #2 取自旧屋架结构。它的一面主要问题为木材纤维化（参见图 4a），其余三个面有裂缝。超声断层扫描图像清楚地指示了木梁损坏的位置（图 4b）。木材纤维化的边缘表现出波传递速度降低的现象，在裂缝所在的地方也观察到了类似的现象。此外，与参考木梁 (#1) 相似，在髓心的位置会发现速度增加。波传播速度在 632.7m/s 和 1442.3m/s 之间变化。因此，最小和最大速度之间的差异大于参考木梁 (#1)，等于 809.6m/s。波传播的平均速度为 1093.3m/s，标准偏差为 137m/s，这两个值都小于未破损的木梁。浮动系数等于 12.5%，与参考木梁 #1 的值相同。然而，应该注意的是，未破损梁的髓心在横截面之外，而在梁 #2 中，髓心在测试的横截面内。

木梁 #3 的破损程度最高。其中一面有

image clearly indicates the places where the beam is damaged (Figure 4b). The edge with the wood fibrosis showed the reduced wave transfer velocity. A similar effect was observed in the places where the cracks were located. Furthermore, an increased velocity may be spotted at the location of the pith, similar to the reference beam (#1). The wave propagation velocity varied between 632.7 m/s and 1442.3 m/s. The difference between the minimum and maximum velo-city was, therefore, greater than in the reference beam (#1) and equal to 809.6 m/s. The average velocity of wave propagation was 1093.3 m/s, the standard deviation was 137 m/s. Both of these values are smaller than in the undamaged beam. The coefficient of variation was equal to 12.5% and it was at the same value as for reference beam #1. However, it should be noted that the pith of the undamaged beam is outside the cross-section, while in beam #2, the pith is within the tested cross-section.

Beam #3 had the highest level of degradation. One of the sides included a significant cavity caused by insects (Figure 5a). This place is marked in blue on the ultra-sonic tomography map (Figure 5b). The remaining sides included cracks. The biggest crack is marked on the tomographic image. Similarly to beams #1 and #2 the greatest concentration of the wave propagation velocity determined the location of the pith. The propagation velocity of ultrasonic waves was between 478.6 m/s and 2262.3 m/s. The difference between the minimum and maximum velocity was the largest com-pared to the other two beams. It was twice as high as in the reference beam. The average velocity was 1462.3 m/s. The standard deviation (SD) was 293.4 m/s, while the coefficient of variation (CV) is 20.1%. Such a high value

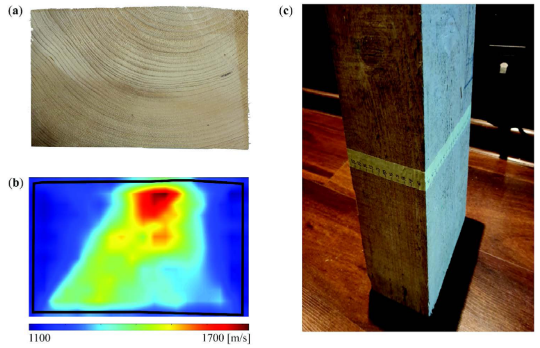

图 3：木梁 #1 测试结果：(a) 木梁顶视图 (b) 超声断层扫描图像 (c) 木梁的侧视图

Figure 3. Results obtained for beam #1: (a) top view of the beam, (b) ultrasonic tomography image, (c) side view of the beam

由昆虫引起的明显空洞（图 5a）。这个地方在超声波断层扫描图上以蓝色色块标记（图 5b）。其余面有裂缝，断层图像上标记了最大的裂缝。与木梁 #1 和 #2 类似，高速度波集中处体现了髓心的位置。超声波的传播速度在 478.6 m/s 和 2262.3m/s 之间。与其他两个木梁相比，最小和最大速度之间的差异最大。它是参考木梁的两倍。平均速度为 1462.3m/s。标准偏差 (SD) 为 293.4m/s，而浮动系数 (CV) 为 20.1%。如此高的值表明木梁破损情况十分严重。

3 髓心的位置

木材的各向异性显著影响超声波的传播速度。在波通过髓心时观察到最高速度，层析图上的这个位置表现为速度值增加的点。木材的这种特性在使用无损检测技术确定木构件的保存状态时造成了一些困难。与各向同性的材料相反，潜在破坏的位置确定更加困难。

本文提出了一种判定历史木梁保存状况的新方法。该方法包括确定髓心的位置，然后使用该信息来创建断层速度扫描图。一般来说，木髓心可以在进行检测的横截面积之内或之外。在提出的方法中，是以最快波速路径占采集的测量数据中的 5% 为理论基础。这些路径（在图 6 中用红色标记）被选中，以便确定每个木

indicates significant damage to the beam.

3 Location of the pith

The anisotropy of wood significantly affects the velocity of propagation of ultrasonic waves. The highest velocity is observed in the case of waves propagating through the pith. This place on tomographic maps is indicated as a point with an increased apparent velocity value. This property of wood causes some difficulties in determining the state of preservation of a wooden element using non- destructive testing methods. Contrary to isotropic elements, it is more difficult to indicate the places of potential destruction.

This paper proposes a novel approach to determining the quality of preservation of historic wooden beams. The method consists in determining the location of the pith and then using this knowledge to create tomographic velocity maps. In general, the wood pith may be within or outside the cross-sectional area for which the measurements are made. In the proposed approach, it was based on 5% of the fastest paths among the collected measurement data. These paths, marked in red in Figure 6, were selected in order to determine the location of the pith for each of the beams. If the fastest paths appear between a pair of opposite edges, it is an indication that the pith lies outside the examined area.

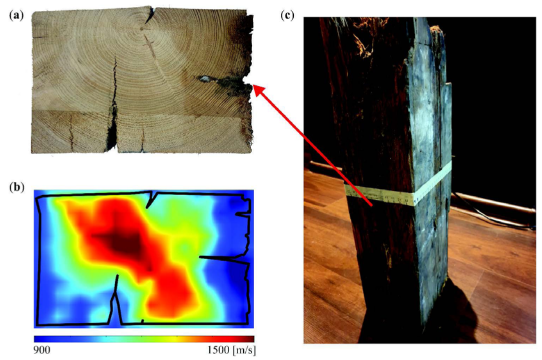

图 4：木梁 #2 测试结果：(a) 木梁顶视图 (b) 超声断层扫描图像 (c) 木梁侧视图

Figure 4. Results obtained for beam #2: (a) top view of the beam, (a) ultrasonic tomography image, (c) side view of the beam

This can be seen in the case of beam #1. For the remaining beams (#2–#3), pairs of opposite edges. This indicates

梁的髓心的位置。如果最快的路径出现在一对平行的边缘之间，则表明髓心位于检查区域之外。

这可以在木梁 #1 的实验中看到。对于剩下的木梁（#2-#3），最快的路径出现在两对平行的边缘之间，这表明了被测横截面内髓心的位置。此外，实验人员比较了从两个垂直壁传播的波的平均速度（表 2）。第一个边沿包括了发射器 t1-t18 和接收器 r1-r18 之间的测量值，而第二个边沿包括发射器 t19-t29 和接收器 r19-r29 之间的测量值。在髓心位于横截面之外的情况下，这种差异会大得多。这是因为垂直于纤维传播的波的速度比沿纤维传播的波慢得多。假设大于 1.15 的值表示髓心出现在测试横截面之外的可能性，那么该系数仅出现在梁 #1 中。

木梁 Wooden beam		*Vavg* [m/s]	*Vavg(1) /Vavg(2)*
#1	Wall 1	1286.9	1.19
	Wall 2	1083.7	
#2	Wall 1	1117.4	1.09
	Wall 2	1028.8	
#3	Wall 1	1455.3	1.02
	Wall 2	1480.2	

表 2. 两个垂直壁（垂直于木纹方向与平行于木纹方向）的波速比较

Table 2. Comparison of the velocity of waves propagating from two perpendicular walls

为确定髓心的位置，每根木梁划分为不同的网格。对于预期髓心在外侧的木梁，网格沿着传播最快射线的边缘扩展。因此，木梁 #1 的网格放大了 3 倍（图 7a）。在木梁 #2 和 #3 中，网格保持不变（图 7b-c）。对于每个方格，会选择距离发射器 t1-t29 和接收器 s1-s29 的最近路径。因此，为每个方格分配了 58 条射线。这些波的速度之和最高的方格表示髓的位置。选定的方格在图 7 中以红色显示。在木梁 #1 中，

the fastest rays occurred between two the location of the pith inside the tested cross-section. Moreover, the average velo-cities of waves propagating from two perpendicular walls were compared (Table 2). The first edge took into account the measurements made between the transmitters t1–t18 and the receivers r1–r18, while the second edge included the measurements made between the transmitters t19–t29 and the receivers r19–r29. In the case of the pith located outside the cross-section, this difference will be much greater. This is because waves propagating perpendicular to the fibres have a much slower velocity than waves propagating along the fibres. It is assumed that a value greater than 1.15 indicates the possibility of the wood pith occurring outside the tested cross-section. This coefficient appears only in beam #1.

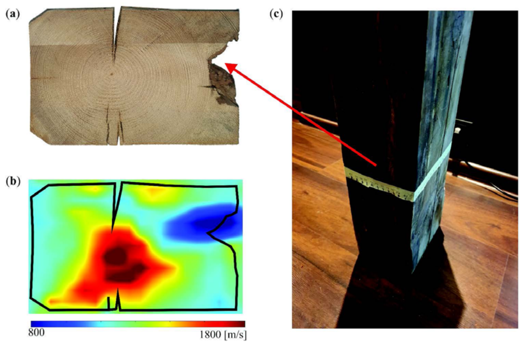

图 5：木梁 #3 测试结果：(a) 木梁顶视图 (b) 超声断层扫描图像 (c) 木梁侧视图

Figure 5. Results obtained for beam #3: (a) top view of the beam, (b) ultrasonic tomography image, (c) side view of the beam

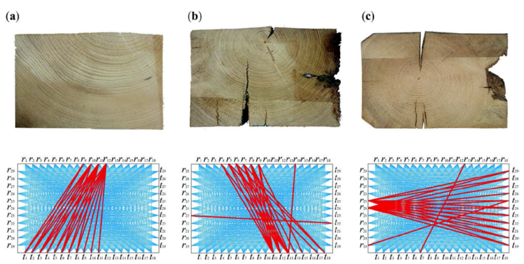

图 6：包含红色标记的 5% 的最快波的测量射线

Figure 6. Rays of performed measurements with the 5% fastest waves marked in red

它与髓心的实际位置重合，在木梁 #2 和 #3 中，由于木梁中的破损影响了波的路径，略有偏移。

在确定髓心位置后创建了木构件中波传播速度的理想图（图 8，第 2 行）。最高速度在指定的髓心处确定，等于初步超声断层扫描图中的最大值（图 3-5）。三个样品的结果均不同，样品 #1-#3 的速度分别为 1637m/s、1442.3 和 1842.5m/s。对于梁的外边缘的每个方向，速度呈圆形且均匀地下降。图 8 中的第 3 行总结了初始层析图，最终结果是第 4 行所示。它们是理想超声断层扫描和初始超声断层扫描之间的区别。由于减去了指示髓心位置的理想模型，在这些超声断层扫描图上只能看到由于不连续、空洞、划痕或纤维化而导致波传播速度降低的地方。具有可见木梁横截面的最终超声断层扫描图如图 9 所示。

（王沁、王诗若编译）

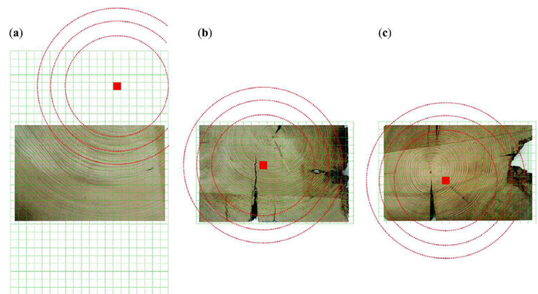

图 7：确定木梁 #1-#3 中髓心的位置

Figure 7. Determining the location of the pith form beams #1-#3

The wood pith was searched independently for each pixel into which the element was divided. In the case of the element for which the pith was expected to be out-side, the pixel grid was enlarged along the edge from where the fastest rays propagated. The pixel grid was therefore enlarged 3 times for element #1 (Figure 7a). In beams #2 and #3 the pixel grids remained unchanged (Figure 7b-c). For each of the pixels, the closest path from each transmitter t1–t29 and each receiver s1–s29 was selected. Thus, 58 rays were assigned to each pixel. The pixel for which the sum of the velocities of these rays was the highest indicated the positions of the pith. Selected pixels are shown in red in Figure 7. In beam #1, it coincides with the actual location of the pith. In beams #2 and #3, it is slightly shifted due to the failures in the beams affecting the course of the rays.

Idealized maps of wave propagation velocity in the wooden element were created after determining the pith location (Figure 8, second row). The highest speed was identified at the designated pith and was equal to the maximum value in the preliminary topographic map (Figures 3–5). It was different for each of the three samples and was 1637 m/s, 1442.3 and 1842.5 m/s respectively for samples # 1- # 3. The velocity decreased circularly and uniformly for each direction of the outer edges of the beams. The third row in Figure 8 summarizes the initial tomographic maps. The final result is the maps shown in the fourth row. They are the difference between idealized and initial maps. Due to the subtraction of the idealized model indicating the location of the pith, only places showing a decrease in wave propagation velocity due to discontinuities, voids, scratches or fibrosis are visible on these maps. The final ultrasound tomography maps with a visible beam cross-section are shown in Figure 9.

(translated and edited by WANG Qin, WANG Shiruo)

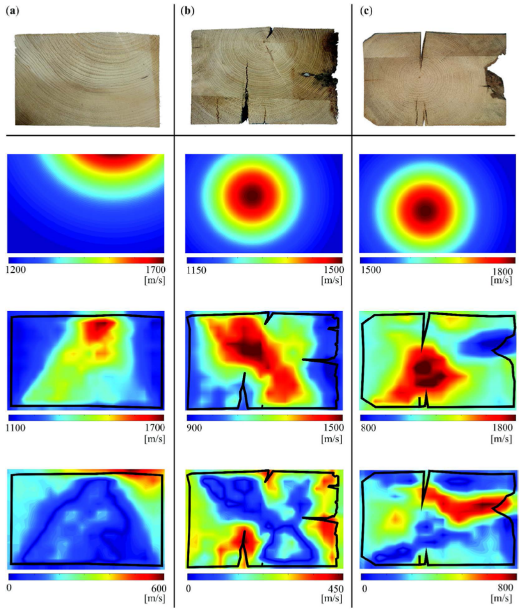

图 8：超声断层扫描图：横截面（第 1 行），理想模型，考虑髓心的位置（第 2 行），来自图 3-5（第 3 行）的初始断层扫描图，理想图与初始图之间的差异（第 4 行）

Figure 8. Ultrasound tomography maps: cross-sections (first row), idealized models, taking into account the location of the pith (second row), initial tomographic maps from Figures 3–5 (third row), the difference between the idealized maps and the initial maps (fourth row)

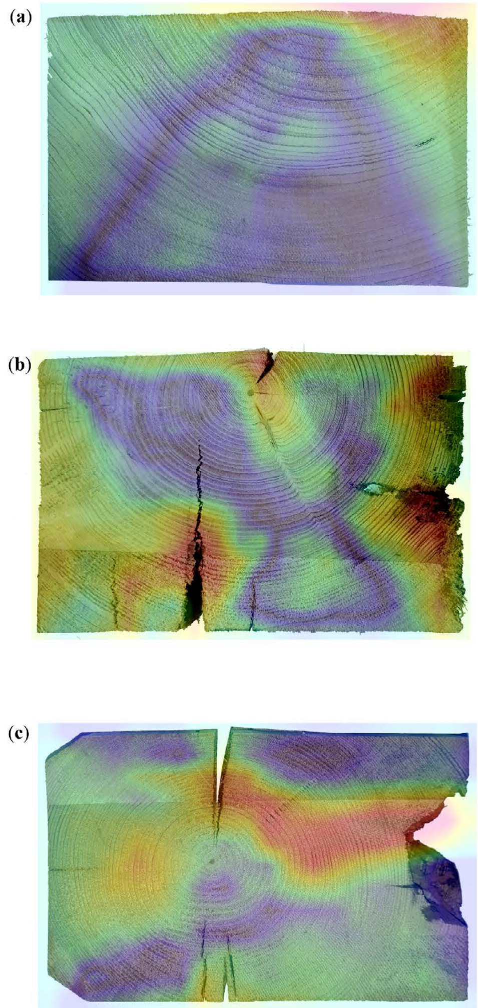

图 9. 叠加在实际测试木梁横截面上的最终超声波断层扫描图

Figure 9. Final ultrasonic tomography maps imposed on cross - sections of tested beams

活动动态 Latest Events

佛罗伦萨 Heri–Tech 国际会议 – 遗产科学与技术的未来

International Conference Florence Heri-Tech - The Future of Heritage Science and Technologies

资料来源 Source：https://www.florenceheritech.com/

图 1：会议海报
Figure 1. Conference poster

活动结束时间 :20/05/2022 - 17:00

活动地点 : 佛罗伦萨，国际会议将通过现场和线上两种方式进行

描述 :

18-20/05/2022 | 佛罗伦萨 - 意大利 | 第三版

佛罗伦萨 Heri-Tech 是由佛罗伦萨大学工业工程系 (DIEF) 和佛罗伦萨艺术与修复双年展于 2018 年发起的。目的是为了创造文化遗产和新技术之间的协同作用。会议汇集了来自世界各地的大量研究项目和学者，聚焦文化遗产产业的当前问题，特别是与文化遗产创新技术与技艺相关的问题。该会议是第 8 届佛罗伦萨艺术与修复双年展的一部分，是一个吸引了著名机构和公司的国际活动，并创造了一个独特的机会，将学术语言与行业结合在一起。因此，佛罗伦萨将成为国际修复、文化和环境遗产的中心，同时也是世界各地专家和爱好者开会和讨论的论坛。这次会议将是研究人员和公司之间进行交流的重要机会，为了促进卓越生产、技术发展、让年轻一代更好地利用文化，以及为研究生和博士生提供专业化的教育领域。

Heri-Tech- 遗产科学与技术的未来会

Event end date: 20/05/2022 - 17:00

Location of event: Florence, the International Conference will be held both in person and online

Description:

18-20/05/2022 | FLORENCE - ITALY | 3rd EDITION

Florence Heri-Tech was launched in 2018 by the Department of Industrial Engineering of University of Florence (DIEF) and Florence Biennial Art and Restoration Fair. The idea is to create a synergy between Cultural Heritage and New Technologies. The Conference involves a large number of research projects and scholars from around the world and puts the industry's current issues under the spotlight, specifically on issues related to innovative techniques and technologies for Cultural Heritage. The Conference is part of the 8th Edition of the Florence Biennial Art and Restoration Fair, an international event attracting prestigious institutions and companies and creating a unique opportunity to bring together the academic word with industry. The city of Florence will therefore be the international heart of Restoration and Cultural and Environmental assets as well as a forum for meeting and discussing for experts and enthusiasts from around the world. The Conference will be a significant opportunity for exchange between researchers and companies for the promotion of productive excellence, technological evolution, the greater use of culture for younger sections of the population and specialization in the educational field for graduates and PhD students.

The proceedings of Heri-Tech - The Future of Heritage Science And Technologies Conference will be published by Springer (abstracting and indexing in Scopus and others).

议的论文集将由 Springer 出版（能在 Scopus 等文献数据库中进行文摘和索引）。

领域和主题：

材料科学

主题包括但不限于：

· 用于保护 / 修复文化遗产的新材料、新方法的化学和物理的前沿进展

· 保护和修复技术的未来趋势：生物技术、纳米技术、靶向材料、物理技术

· 评估新保护处理和方法的有效性、相容性、可逆性

· 冰干喷砂法 (CO_2)

· 石材劣化

· 石材的物理和石化特性

· 保护性诊断和治疗的方法和器械

· 等离子体技术修复

· 纳米材料与修复的新技术

工程

主题包括但不限于：

· 考古遗址艺术保护与修复的技术应用

· 内置模型的保守修复

· 保守干预设计技术

· 文化遗产中虚拟探索与成果的交互方法与增强现实

· 以用户为中心的文化遗产体验

· 为了教育和应对社会挑战的 3D 建模和 3D 打印

· 考古中水下三维采集的方法与体系

· 文化遗产修复中用于服务任务的机器人及机器人平台

· 文化遗产的测绘学和结构建模

诊断和监测

Areas and topics:

MATERIALS SCIENCE

Topics include, but are not limited to:

•Chemical and Physical advancement in the development of new materials and methods for the conservation/restoration of CH

•Future trends in conservation and restoration technology: biotechnology, nanotechnology, tailored materials, physical technologies

•Assessment of effectiveness, compatibility, reversibility of new conservation treatments and methods

•Ice-dry sandblasting method (CO_2)

•Stone material decay

•Stone physical and petrochemical characterization

•Methods and instruments for the conservation diagnosis and treatments

•Restoration with plasma technologies

•Nanomaterials and novel technologies for restoration

ENGINEERING

Topics include, but are not limited to:

•Technology applications on art conservation and restoration on archaeological sites

•Conservative restoration of the built-in model

•Technologies for the design of conservative intervention

•Interactive methods and augmented reality for virtual exploration and fruition of cultural heritage

•User-centred experience of CH

•3D modelling and 3D printing for education and for societal challenges

•Underwater 3D acquisition methods and systems for archaeology

•Robot and robotic platforms for service tasks in CH Restoration

•Geomatics and Structural Modelling for CH

DIAGNOSTICS AND MONITORING

Topics include, but are not limited to:

•Advancement in damage assessment: diagnosis (I.R., U.V., Raman, X-ray

主题包括但不限于：

· 破损评估的进展：诊断（红外、紫外、拉曼、x 射线分光光度技术、断层扫描、x 射线、气相色谱和其他分析方法）与修复过程的监测、文化遗产的预防性保护和维护

· 发展和应用数学模型作为破损评估、监测和适应气候变化影响的工具

· 保护文化遗产免受地震、火灾、风暴、抢劫和极端事件的风险和破坏

· 评估遗产损失和诊断战争和武装冲突的影响

· 材料科学中发展的科学技术和方法为考古、艺术史和保护提供的宝贵信息

· 计划性保护：预防性和预测性保护

· 教育与绘画保护

信息通信技术和数字遗产

主题包括但不限于：

· 虚拟博物馆

· 提高遗产成果和展述的方法和系统

· 艺术、保护与修复教育的新方法

· 应用领域：文献图像处理与分析，古照片数字处理，古纸数字处理。自动理解古代文献上的文字和 / 或符号

· 测量、分析和理解艺术品的系统、方法和应用

· 数字文化遗产的普及和远程访问

· 物质文化遗产 4D 重建

· 多媒体，多语言，数据管理，存档

· 考古学分析与阐述性设计

· 为与物质和非物质文化遗产相关的成果的巩固、传播、示范和利用、培训和教育提供创新解决方案（包括开放获取文化遗产科学成果及其保护）

tomography, X-ray, gas-chromatography and other analytical methods) and monitoring for the restoration, preventive conservation and maintenance of CH

•Development and application of mathematic modelling as tools for damage assessment, monitoring and adaptation to climate change impacts

•Protecting cultural heritage assets from risks and damages resulting from earthquakes, fires, storms, looting and extreme events

•Assessing Heritage damages and diagnosing spell-over effects of wars and armed conflicts.

•Scientific techniques and methods developed in materials science to offer invaluable information to archaeology, art history and conservation

•Scheduled Conservation: preventive and predictive conservation

•Education and painting conservation

ICT AND DIGITAL HERITAGE

Topics include, but are not limited to:

•Virtual museums

•Methods and systems for enhancing heritage fruition and storytelling

•New methods for Education on art, conservation and restoration

•Applications: document image processing and analysis, ancient photograph digital processing, ancient paper digital processing. Automatic understanding of writing and/or symbols on ancient documents

•Systems, methods and applications for measurement, analysis and understanding of artistic artefacts

•Ubiquitous and remote access to digital cultural heritage

•4D Reconstruction of Tangible Cultural Heritage

•Multimedia, Multilingua, Data Management, Archiving

•Archaeological Analysis and Interpretive Design

•Innovative solutions for the consolidation, dissemination, demonstration and exploitation of results, training and education related to the tangible and intangible CH (including open access to scientific results

· 用于虚拟和数字修复的体系、方法和应用

· 3D 扫描、图像扫描、遥感和非接触无损方法

· 基于文化遗产的城乡更新

· 文化旅游及旅游应用

in cultural heritage as well as their preservation)

•Systems, Methods and applications for Virtual and Digital Restoration

•3D scanning, image scanning, remote sensing and no-contact and non-destructive methods

•Rural / urban regeneration based on cultural heritage

•Cultural Tourism & Travel Applications

保护科学——第四届建筑遗产保护技术国际学术研讨会

CONSERVATION SCIENCE - 4th International Symposium on Architectural Heritage Conservation Technology

资料来源 Source：http://icity.ikcest.org/news/view/10514&type=1

会议时间 :10-12/06/2022

会议地点 : 东南大学四牌楼校区（江苏省南京市四牌楼 2 号），网络会议同步直播

建筑遗产的保护理论和工作路径根植于所处的自然地理、历史文化和社会环境，世界各地都在探索适合于本土建筑遗产的保护理论和方法,探索更具适宜性的工作路径和保护技术。建筑遗产保护技术的研究与实践依赖于物理、化学、生物学、材料和计算机科学等多学科的理论和方法的综合应用,是多学科合作的科学。思想因多样而交流，因交流而互鉴，因互鉴而发展。为促进建筑遗产保护理论和科学技术的学术交流，东南大学拟于 2022 年 6 月 10-12 日在南京通过线上线下相结合的方式举办“保护科学——第四届建筑遗产保护技术国际学术研讨会”。

本次会议邀请了中国、意大利、比利时、葡萄牙、日本等国的建筑遗产预防性保护领域的专家做主旨发言，并欢迎国内外学者积极投稿，交流研究和实践成果，共同构建更加科学的建筑遗产预防性保护理论、技术和管理体系，携手保护人类共同的文化遗产。本次会议由东南大学、江苏省文物局主办，东南大学建筑学院、东南大学建筑国际化示范学院、建筑遗产预防性保护江苏省重点文物科研基地（东南大学）、城市与遗产保护教育部重点实验室（东南大学）和传统木构建筑营造技艺研究国家文物局重点科研基地（东南大学）承办，得到了国家文物局的指导，以及联合国教科文组织“亚洲遗产管理学会”、中国文物保护技术协会、中国古迹遗址保护协会等组织机构的支持。

主要议题：

（1）中国建筑遗产保护理论及其技术路径

· 新时代中国遗产保护理论

· 保护实践的技术方法与路径

（2）建筑遗产预防性保护科学与技术应用

· 劣化机理与耐久性研究

· 遗产监测与预警技术

· 保存环境科学研究

图 2：会议海报
Figure 2. Conference poster

Conference date: 10-12/06/2022

Location of event: Southeast University, Nanjing

The conservation theory and working path of architectural heritage are rooted in the natural geography, historical culture and social environment of the place. All over the world, theories and methods of architectural heritage conservation suitable for local soil are being explored, and more suitable working path and specific technologies are being explored. The research and practice of the specific technology of architectural heritage conservation depends on the comprehensive application of the theories and methods of physics, chemistry, biology, materials and computer science, etc. It is a multi-disciplinary cooperative science. Diversity of ideas leads to exchanges, mutual learning and development. In order to promote academic communication of architectural heritage conservation theory, science and technology, Southeast University (SEU) plans to hold 'Conservation Science - the 4th International Symposium on Architectural Heritage Conservation Technology', a combination of online and on-site activities, in Nanjing on June 10th-12th, 2022.

The symposium invite architectural heritage experts in the field of preventive protection from China, Italy, Belgium, Switzerland, Japan and other countries to do keynote speeches. We welcome the domestic and foreign scholars to communicate research and practice experiences actively, to build a more scientific architectural heritage preventive protection theory, technology and management system, and to protect our humanity's common cultural heritage together.

This symposium is hosted by Southeast University, Administration Bureau of Jiangsu Province, co-organized by School of Architecture SEU, Architecture Internationalization Demonstration School of Southeast University, Architectural Heritage Preventive Protection in Jiangsu Province Key Cultural Relic Research Base (SEU), Key Laboratory of Urban and Architectural Heritage Conservation (SEU) and Key Scientific Research Base of Technique of Traditional Wooden Architecture (SEU), State Administration for Cultural Heritage, China. It has received guidance from the State Administration for Cultural Heritage, as well as support from UNESCO's Asian Heritage Management Society, China Association for Conservation Technology of Cultural Heritage, ICOMOS China, and other organizations.

Main topics

(1) Chinese architectural heritage conservation theory and technical path

•The theory of Chinese Architectural Heritage Protection in the New Era

•Technical methods and paths of conservation practices

(2) Application of science and technology in preventive protection of architectural heritage

•Degradation mechanism and durability

•Heritage monitoring and early warning technology

•Conservation environmental science research

《文物保护协同创新系列讲座》第六讲暨《中国 – 希腊文化遗产对话：研究与保护》第三期

"Palace of Knossos: Conservation- restoration works and recent strategies within the HERACLES EU project"

资料来源 Source：https://mp.weixin.qq.com/s/1-0YUo9eQXPfiAHH3zO9-w

主讲人： 伊利萨维特·卡沃拉基（希腊克里特岛伊拉克利翁文物管理局）

讲座题目：《克里特岛克诺索斯王宫的保护修复工作与赫拉克勒斯欧盟项目的多元分

Elissavet Kavoulaki

Ephorate of Antiquities of Heraklion, Crete, Greece

Conference date: 28/09/2022 14:30 - 16:30

析策略》

讲座时间：2022 年 9 月 28 日下午 2:30-4:30

克诺索斯王宫的米诺斯宫殿代表着地中海流域第一个文明中心，即米诺斯文明。它是克里特岛所有米诺斯宫殿中规模最大、最古老的宫殿 (公元前 1900-1300 年)。1900 年，英国考古学家亚瑟·埃文斯爵士（Sir Arthur Evans）开始对克诺索斯宫进行系统挖掘，继续伊拉克利翁商人米诺斯·卡洛凯里诺斯（Minos Kalokairinos）于 1878 年开始的小规模调查。在不到五年的时间里，宫殿的大部分文物均被发掘。在第一阶段，埃文斯进行了小规模的重建干预，以保护脆弱的建筑材料。然而，这种结构被证实对风化很敏感，很快就被损坏了。它在战争（1922-1930）之间被一种广泛使用钢筋混凝土的新结构所取代。二战后进行了大规模的修复工程，并在九十年代进行了一个试点项目，主要涉及混凝土的修复。自 2000 年以来，希腊文化部在欧洲计划的背景下实施了一项完整的米诺斯宫保护和推广计划：砖石、石膏石和石灰石、古代涂料和灰泥、壁画、柱子和木材的复制品模仿，替换埃文斯的轻拱形屋顶和保护埃文斯的钢筋混凝土。伊拉克利翁古物长廊作为欧洲研究计划 HERACLES 的合作伙伴于 2016-2019 年参加，（“欧洲研究与创新框架计划”的“现场抵御气候问题的遗产韧性”）。这座纪念碑从 HERACLES 获得了多重好处，其主要目的是设计、验证和推广适当的解决方案，以通过涉及不同专家的多学科研究考虑整体方法，以有效地抵御气候变化影响的文化遗产。最终目标是优化利用文化遗产古迹——尤其是米诺斯宫殿——与它们的保护、修复和推广相结合。

（刘哲康、王诗若编译）

图 3：会议海报
Figure 3. Conference poster

The Minoan Palace of Knossos represents the centre of the first civilization of the Mediterranean basin; namely the Minoan civilization. It is the largest, the most glorious and longest-lived (1900-1300 BC) of all Minoan Palaces in Crete. The systematic excavation of the Palace of Knossos was launched in 1900 by the British archaeologist Sir Arthur Evans, continuing the small-scale investigation begun by the Heraklion merchant Minos Kalokairinos in 1878. In less than five years, most of the Palace had been revealed. During this first period, Evans carried out small-scale reconstruction interventions in order to protect the fragile building materials. This structure, however, proved sensitive to weathering and was soon damaged. It was replaced between the wars (1922-1930) by a new structure making extensive use of reinforced concrete. After World War II large scale restoration works were made and during the nineties a pilot project, mainly concerned the restoration of the concrete, had been carried out. Since 2000 a complete program of conservation and promotion of the Minoan Palace was implemented by the Greek Ministry of Culture, in the context of European programs: conservation of masonry, gypsum stones and limestones, ancient coatings and plaster, copies of frescoes, columns and wood imitations, replacement of Evans's lightly-arched roofs and conservation of Evans's reinforced concrete. The Ephorate of Antiquities of Heraklion participated from 2016-2019 as a partner of the European research program HERACLES, ('Heritage Resilience Against Climate Events on Site' of the 'European Framework Program for Research and Innovation'). The monument has multiple benefits from HERACLES, where the main purpose was to design, validate and promote appropriate solutions for effective resilience of Cultural Heritage against climate change effects, considering a holistic approach, through multidisciplinary study, involving different experts. The ultimate goal was the optimal utilization of cultural heritage monuments - especially the Minoan Palace of Knossos - combined with their conservation, restoration, and promotion.

(translated and edited by Liu Zhekang, WANG Shiruo)

[中国-葡萄牙文化遗产保护科学“一带一路”联合实验室建设与联合研究]
国家重点研发计划资助（2021YFE0200100）
2021年度江苏省政策引导类计划资助（BZ2021015）

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