

Brick Vaults and Beyond. The Transformation of a Historical Structural System

Vaults have been historically regarded as the ideal structure to span imposing spaces in representative and monumental buildings. Several studies have been devoted to the topic worldwide and cover the evolution of vaulting from antiquity to the progressive abandonment of vaults in the 18th century. Yet, also in the following centuries interesting evolutions in vaulting techniques took place as they were extensively used in historicism and attempts were made to adapt vaults to modern architecture. How did the changing architectural styles and functional needs, together with the introduction of new construction materials in the 19th and 20th centuries such as iron, steel and reinforced concrete, transform vaulting techniques?

This symposium *Brick Vaults and Beyond*, organised online in Brussels on April 29 & 30, 2021 brings together international architects, historians, engineers, and preservationists interested in construction and architectural history whose contributions add to the understanding of the development of the vaulting techniques during this fascinating period.

This event is funded by the EU H2020 Marie Skłodowska Curie Action and co-organised by Paula Fuentes and Ine Wouters from Vrije Universiteit Brussel and urban.brussels.



Church of Saint-François-Xavier in Anderlecht (Photo: P. Fuentes, 2019)

Vaulting in brick: From Guastavino to the future

John Ochsendorf, Massachusetts Institute of Technology

Tile vaulting has created surprising possibilities in architecture over the last 1,000 years in the Mediterranean region. More recently, the tile vault has extended beyond Africa and Europe to create new architecture in the Americas and Asia as well. By building arches in thin brick with a fast-setting mortar, it is possible to create durable vaulted structures with minimal support required during construction. This visual lecture will present historical highlights in the evolution of tile vaulting, with an emphasis on the engineering design of Guastavino vaults in late 19th and early 20th C United States. The Guastavino Company and others have invented new structural geometries by relying on the principles of traditional masonry vault design, assuming zero tensile capacity of the brick. Recent applications in contemporary low-carbon architecture demonstrate that the evolution of the tile vault will continue into the future, with exciting applications in regions with relatively low cost of labor.

John Ochsendorf is Class of 1942 Professor of Architecture and Civil and Environmental Engineering at the Massachusetts Institute of Technology (MIT). He is the author of *Guastavino Vaulting: The Art of Structural Tile* (Princeton Architectural Press, 2010), and the designer of numerous contemporary masonry vaults.



Droneport prototype (Venice Architecture Biennale, 2016)

The birth of tile vaulting in Belgium: The Royal Museum for Central Africa

Paula Fuentes, Vrije Universiteit Brussel

The Congo Museum (known today as the Royal Museum for Central Africa) was part of a large colonial complex planned by the Belgian King Léopold II in the municipality of Tervuren, a few kilometres from Brussels. The complex was commissioned to the French architect Charles-Louis Girault in 1901, but only the museum was completed. This building features vaults in many of its rooms, and the main space is covered by a two-shell dome with a span of 20 m. Different types of vaults were used, but the building is remarkable for the use of tile vaults, a technique that originated in the Mediterranean region and arrived in Belgium, with no known precedents, at the beginning of the 20th century.

Paula Fuentes is post-doctoral researcher at the Department of Architectural Engineering, Vrije Universiteit Brussel. Her research interests are focused on history of construction, masonry structures, and surveying and drawing of architectural heritage. On these subjects she has published several articles in specialized journals and international conferences. She is currently developing the project “Brick vaults and beyond: The transformation of a historical structural system (1830-1930)” funded by a Marie Skłodowska-Curie Fellowship.



Construction of the vaults of the lateral galleries in the Royal Museum for Central Africa
(Source: HP.1968.10.6-43, RMCA Tervuren collection, Charles Girault archives)

The restoration of the Royal Museum for Central Africa

Robin Engels, ORIGIN Architecture & Engineering

The temporary association, Stéphane Beel Architects - Origin Architecture & Engineering - Arup NL - Michel Desvigne Paysagistes - Niek Kortekaas Designers - RCR - Daidalos Peutz - Bureau Bouwtechniek, was commissioned to restore, renovate and expand the Royal Museum for Central Africa in 2007. To free the existing museum from the parasitic functions such as museum shop, restaurant and reception, which have occupied museum rooms over the years, these functions were relocated to a new reception pavilion. The museum itself, whose first floor originally consisted only of monumental museum rooms, could then be fully restored. Origin's tasks included the restoration of the facades, the roofs, the monumental interiors and furnishings of the museum building, and the director's and staff pavilion. The interiors with floor and wall coverings in various European marbles, painted wall canvases of gigantic surfaces, and rich stucco decoration of the ceilings are of special architectural-historical value.

Robin Engels is an architectural engineer with a Master in Conservation (Raymond Lemaire Centre Leuven) degree. Since 2007 he has worked at ORIGIN Architecture & Engineering where he has led the restoration of Saint-John-the-Baptist Church, Mercator-Ortelius and Antwerp Management School, Averbode Abbey and The Grand in Nieuwpoort.



Royal Museum for Central Africa
(ORIGIN architecture & engineering © Tim Fisher)

Brick vaults by J. C. von Lassaulx and A. Antonelli: An ancient building technique for the industrial age

David Wendland, Brandenburg University of Technology

Architect J. C. von Lassaulx (1781–1848) was one of the pioneers in the creation of new buildings based upon models of medieval construction. In 1829 he wrote an article explaining the construction of freehand vaults based on the observation of medieval vaults. His work had great impact on later handbooks and treatises. On the other hand, the architect Alessandro Antonelli (1798–1888) had a major influence through his structures. He combined ancient construction with the techniques of the industrial age. His structures were formed by a skeleton of slender pillars, thin brick walls and vaulted ceilings, using iron elements to take the horizontal forces. This presentation will address the contribution by these two architects in the industrial age, a period characterized by the great demand for new buildings, the mass production of building materials, and the introduction of new materials and technologies.

David Wendland studied architecture in Darmstadt, Venice and Stuttgart. His main research areas are vaults and shell structures, buildings with complex shape, stereotomy, and design processes in architecture. He received his doctorate at the University of Stuttgart. In 2012 he was awarded an ERC Starting Grant, conducting the research project “Design Principles in Late-Gothic Vault Construction – A New Approach Based on Surveys, Reverse Geometric Engineering and Reinterpretation of the Sources”. In addition, he established a collaboration with several major cathedral workshops with an ERC Proof of Concept Grant. Since 2018, he has been professor for construction history at the Brandenburgische Technische Universität Cottbus-Senftenberg.



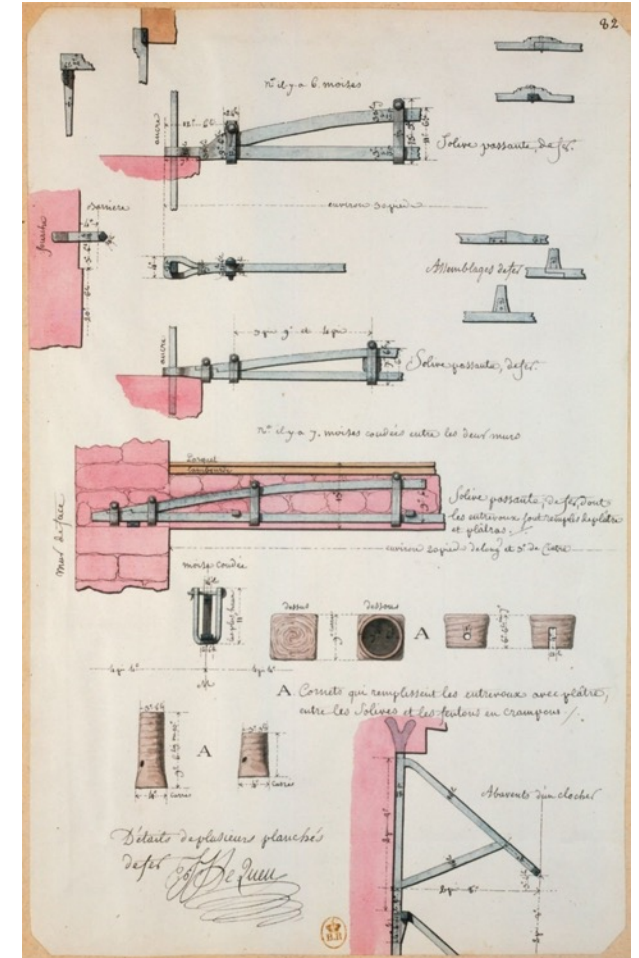
Turin, Mole Antonelliana, completed 1888 (Photo: D. Wendland)

Between reinterpretation and experimentation: The evolution of hollow-clay-pot vaulting in Paris

Lia Romano, University of Naples Federico II

This lecture provides an overview of the use of hollow-clay-pot vaults in Paris in the late 18th century and the first half of the 19th century. Starting with a description of the pots' artisanal production, the main construction methods of vaults and vaulted ceilings are then presented. Finally, some emblematic interventions using hollow clay pots – both in new buildings and in the restoration of existing ones – are described, grouped into three macro periods: a) the end of the 18th century, b) the 1810s to the 1830s, and c) the 1840s and beyond. The presentation concludes with a reflection on the transition between handmade pots (*poteries creuses*) and bricks (*briques creuses*), whose mass production was sanctioned by the Borie patent in the 1840s.

Lia Romano is an architect (2014) and PhD in history and restoration (2018). She is currently post-doctoral fellow in the Department of Architecture of the University of Naples Federico II. Between 2018 and 2019 she participated as a post-doctoral research fellow in the project “Naples Digital Archive: Moving Through Time and Space” (Cirice/Unina - Bibliotheca Hertziana of Rome) and was a Visiting Scholar at the Université Paris 1 Panthéon-Sorbonne in Paris. Her research focuses on historical construction techniques, in particular lightweight vaults, and on the circulation and transmission of building skills. On these subjects she has published several articles in international conferences, scientific journals and collective volumes.



J. J. Lequeu, Paris: Hôtel de Montholon (BnF, J.J. Lequeu, Détails de plusieurs planches de fer, 1786, EST VE-92)

Testing of tile vaults: The need to validate the system

Esther Redondo Martínez, Universidad Europea de Madrid

The first documented tests of tile vaults date from the end of the 18th century, and testing became more and more frequent throughout the 19th century and at the beginning of the 20th century. The beginning of testing coincided with the Enlightenment, a time when architects began to take a scientific approach to construction, which would lead to modern structural theory. For this reason, the first tests were also carried out in countries where Enlightenment thought began earlier, such as France and England. This presentation examines various tests carried out on tile vaults and analyses those for which numerical data could be found or could be deduced from images. Most of the tests confirm that it is always possible for the tile vaults, as for any other masonry, to find an equilibrium solution in which the vaults are subject only to compression forces.

Esther Redondo Martínez is an architect and PhD. She combines professional activity with teaching and research. In 2001, she started to teach at the School of Architecture of the Universidad Europea de Madrid. She has also worked as a guest lecturer at the ETSAM (Madrid), at the EaT (Toledo), and at the University of Ambato (Ecuador). In March 1999 she founded GV408 Arquitectos together with José Agulló, Antonio Alejandro and Rafael Álvaro, where she still works as a structural designer. Her field of research is the history of construction and structures. In this context, she has written several articles and participated in the organisation of related congresses.



Test of a tile vault (Guastavino Fireproof Construction Company architectural records)

Vaults and roofs in Belgian churches (1890–1910s)

Romain Wibaut, Vrije Universiteit Brussel & KU Leuven

In late 19th century, the need to combine steep Gothic pitches with the intention of reducing the volume of the roof voids led to the development of new ways of building vaults. On the one hand, this was fostered by the development of innovative construction materials and techniques, like efficient iron and steel structures or lightweight terra-cotta slabs. On the other hand, it became possible thanks to the progressive mentality of the Saint Luke Movement. Progressive architects pushed towards a more ingenious and rational Gothic Revival architecture, which combined archaeological studies and innovative construction techniques that were used truly, according to their respective structural properties. One of the innovative construction techniques is the use of metal transverse arches forming the pointed barrel vaults of their churches. Three examples of this system will be analysed: Saint Francis de Sales in Liège (1889–94), Saints Anthony and Apollonia in Pepinster (1893–99), and Saint Remigius in Molenbeek-Saint-Jean (1907–08).

Romain Wibaut is an architectural engineer who graduated from ULB-VUB in 2016. Since October of that year, he has been conducting doctoral research at the Department of Architectural Engineering of the Vrije Universiteit Brussel (Brussels) and at the Department of Architecture of the Faculty of Engineering of the KU Leuven (Leuven), under the supervision of Ine Wouters (VUB) and Thomas Coomans (KU Leuven). His research focuses on the evolving historical contexts, architectural considerations, building actors and construction techniques of the roof frames of 19th- and 20th-century Belgian churches and is funded by VUB Growth Funding, urban.brussels and FWO.



St Francis de Sales in Liège, 1888–1894
(Source: Royal Institute for Cultural Heritage, KIK-IRPA)

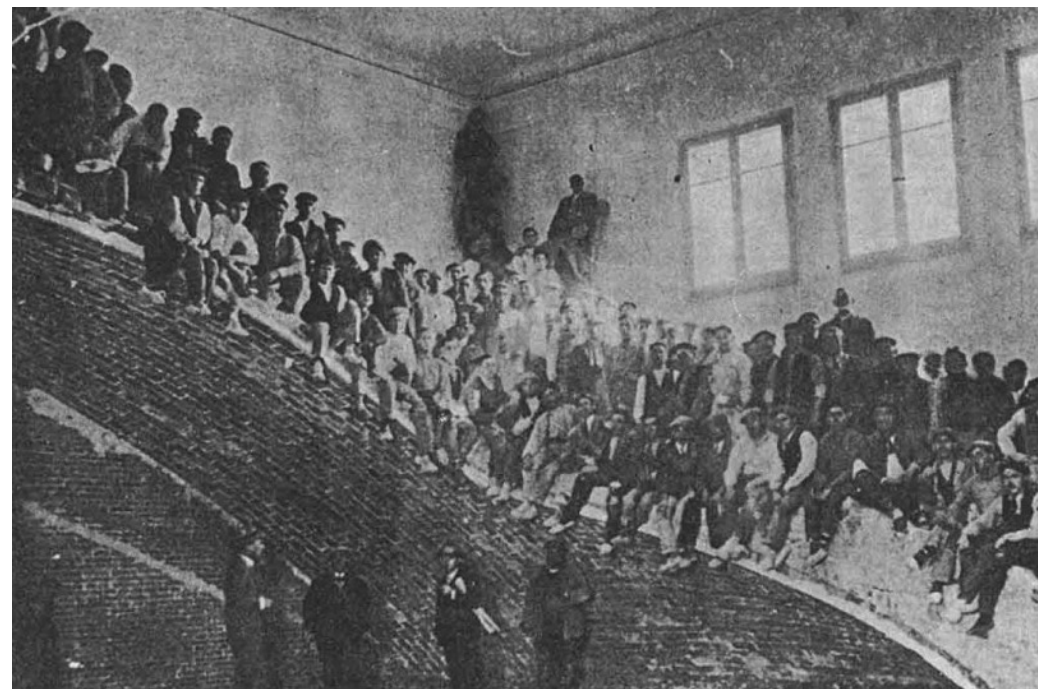
Tile vaults in post-war Germany

Santiago Huerta, Technical University of Madrid

Friday 30 April, 14h10

This lecture addresses the migration of an invention, the tile vault, from its origin, somewhere in the Mediterranean area around the 12th century, and its dissemination throughout Spain in the 16th and 17th centuries. In the 18th century its use also spread to France and Italy, and some examples are also known in South America. In the 1880s, the tile vault reached North America thanks to the inventiveness, passion and determination of Rafael Guastavino. In the 1940s, tile vaults experienced a renaissance in Europe due to the shortage of materials (iron and cement) during the war and post-war period. In particular, it was widely used in Spain, after the Civil War of 1936-1939, in the reconstruction of devastated regions and in the restoration of buildings. It was also used in France in the 1940s. This journey ends in Germany, more specifically in the city of Munich, where the tile vault migrated from Italy and Spain, being used both in restoration and in new construction by the company Gebrüder Rank between 1945 and 1970. The migration of tile vaulting spans eight centuries and at least two continents.

Santiago Huerta is professor at the School of Architecture, Technical University of Madrid. In the last twenty years he has worked as a consultant for the structural analysis of historical constructions. He is co-founder and president of the Spanish Society of Construction History and is currently the director of publications of the Instituto Juan de Herrera, a publisher specialized in this discipline. He is author of more than eighty publications, including books, papers in specialised journals and conference papers.



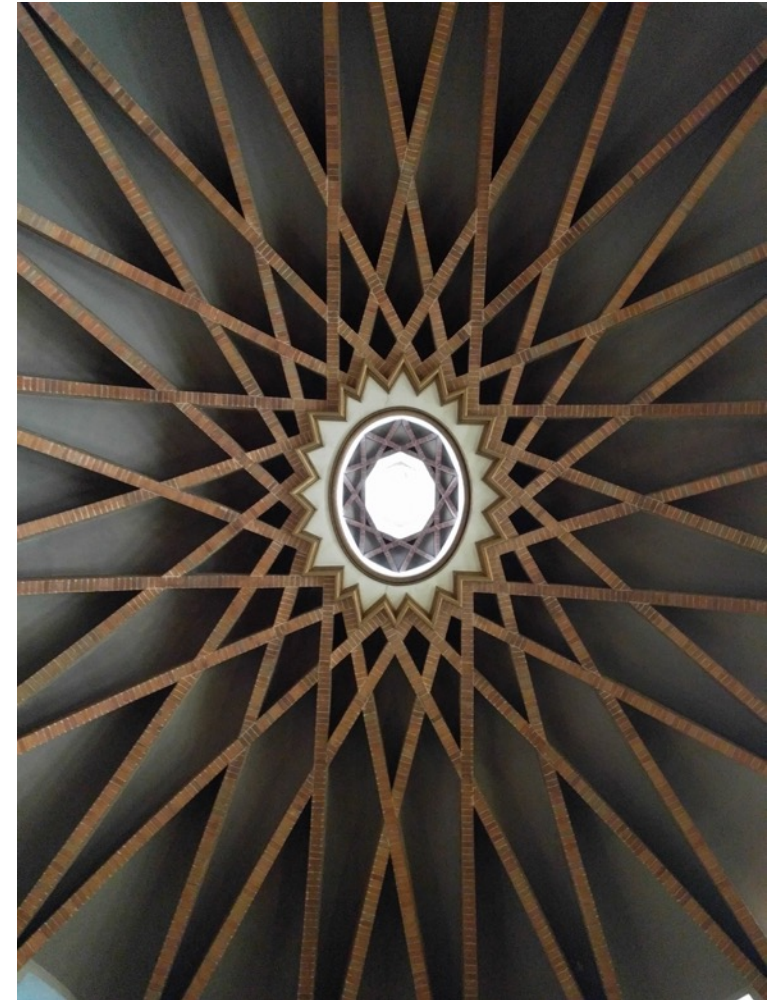
Great stair tile vault tested after completion (Bassegoda 1956)

Tile vaults in the architecture of Luis Moya (and partners)

Ignacio Javier Gil Crespo, Fundación Cárdenas

The architecture of Luis Moya (1904–1990) includes some of the most unique and personal work using tile vaults. Moya's work is afforded this status for formal and compositional reasons, and because it offers a development of the tradition at a time when vaulted construction was being abandoned. He built large vaults in unique buildings, and he also defended the vaulting technique in his publications and public exhibitions. Responding to limitations such as the shortage of materials in Spain in the post-war period, he developed a formal and constructive repertoire based on the tile vault. Despite the personalist image associated with Moya's architecture, the architect worked in collaboration and co-authorship with several colleagues who contributed knowledge, ideas and labour to the projects. This lecture will analyse these relations, as well as the historical context and the technical aspects of his vaults.

Ignacio Javier Gil is PhD architect, member of ICOMOS-ICOFORT Spain, director of the Research Centre "José Joaquín de Mora", member of the Board of Directors of the Spanish Society of Construction History and the Spanish Association of Friends of Castles, and distinguished member of the Chair "Gonzalo de Cárdenas" on Vernacular Architecture of Havana. He has been an invited professor at international universities and research institutions. His fields of expertise and interests are fortification, historical and traditional construction techniques, and vernacular architecture.



Vault in the church of San Agustín (Photo: I.J. Gil Crespo)

Tile vaults in the Spanish modern movement

Ana Rodríguez & Rafael Hernando, Universidad de Alcalá de Henares

The Spanish modern movement made frequent use of the tile vault. Tile vaults survived and coexisted naturally with new techniques in a number of important buildings, with some magnificent examples in the construction of staircases. On the other hand, after the Spanish Civil War there was a boom in tile vault construction, due not only to the scarcity of materials at the time, but also because the new political regime extolled the virtues of a traditional vision of architecture. This lecture will discuss the use of the tile vault before and after the Civil War, its use in modern buildings, and its coexistence with the unstoppable expansion of reinforced concrete, focusing on a more refined search for the possibilities of this technique for modern architectural approaches, addressing the key issues: tile vaults in buildings with several floor-levels and an appropriate solution to counteract the thrust.

Ana Rodríguez and Rafael Hernando studied architecture at School of Architecture, Technical University of Madrid, where they obtained their degree and their PhD in architecture. Since 2003 they have taught at the Escuela de Arquitectura de la Universidad de Alcalá (UAH). Their research interests focus on architecture and construction history of the 20th century. On these subjects they have published several articles in specialized journals and international conferences. In 2018, Ana Rodríguez received a research award from the 14th Spanish Architecture and Urbanism Biennial for her article "The Smithsons's garden. The Upper Lawn Folly Solar Pavilion". In the professional field, since 1991 they have worked as architects in their own architecture office, understanding professional practice, teaching work, and academic research as complementary facets of their architectural point of view.



The New Pavilion for the Residencia de Señoritas Estudiantes, 1933
(Photo: A. Rodríguez García and R. Hernando de la Cuerda, 2007)

Tile vaults in Belgium in the 1930s: The churches of Léonard Homez

Paula Fuentes, Vrije Universiteit Brussel & Rosa Ana Guerra Pestonit, Universidade de Santiago de Compostela

With no known precedents in the country, tile vaults were introduced in Belgium at the beginning of the 20th century. Widely used in churches, this technique allowed great flexibility in the design, together with economical and fast construction, which was especially important in the interwar period. In this context, Léonard Homez designed and built three churches, two in Brussels – Sainte-Alix in Woluwe-Saint-Pierre (1935–36) and Divin Sauveur in Schaerbeek (1935–37) – and Sint-Theresia in Dilbeek (1937–39), very close to Brussels. The vaults were built by Tignol and Joly, a contractor specializing in tile vaults. This lecture analyses the constructive characteristics of these vaults, their geometry, and their similarities as well as the evolution of their design and construction.

Rosa Ana Guerra is architect. In 1995 she completed a Masters in Restoration and Building Pathology. In 2012 she defended her PhD dissertation in the field of construction history. Her professional development is related to architectural heritage. As a researcher she has specialized in masonry structures, with a focus on state-of-the-art techniques for the metric survey of building heritage. She teaches engineering graphics at the University of Santiago de Compostela.



Church of Sint-Theresia in Dilbeek, 1937-1939 (Photo: P. Fuentes, 2019)

APRIL 29, 2021

18h00_Opening

Introduction by Ine Wouters & Paula Fuentes & urban.brussels

Keynote lecture

Vaulting in Brick: From Guastavino to the Future

John Ochsendorf_Massachusetts Institute of Technology

The birth of tile vaulting in Belgium: The Royal Museum for Central Africa

Paula Fuentes_Vrije Universiteit Brussel

The restoration of the Royal Museum for Central Africa

Robin Engels_ORIGIN Architecture & Engineering

20h00_Closing

APRIL 30, 2021

9h00_Opening & Part 1: Constructing vaults in the 18th and 19th centuries

Introduced by Paula Fuentes_Vrije Universiteit Brussel

Brick Vaults by J.C. Lassaulx and A. Antonelli:

An ancient building technique for the industrial age

David Wenland_Brandenburg University of Technology

Between reinterpretation and experimentation:

The evolution of hollow-clay-pot vaulting in Paris (18th and 19th century)

Lia Romano_University of Naples Federico II

[Coffee Break]

Testing of tile vaults: The need to validate the system

Esther Redondo_Universidad Europea de Madrid

Vaults and roofs in Belgian churches (1890–1910s)

Romain Wibaut_Vrije Universiteit Brussel & KU Leuven

12h00_Break

14h00_Part 2: Constructing vaults in the 20th century

Introduced by Ine Wouters_Vrije Universiteit Brussel

Tile vaults in post-war Germany

Santiago Huerta_Technical University of Madrid

Tile Vaults in the architecture by Luis Moya (and partners):

Historical context and technical elements

Ignacio Javier Gil Crespo_Fundación Cárdenas

[Coffee Break]

Tile Vaults in the Modern Spanish Movement, 1925–1965

Ana Rodríguez & Rafael Hernando_Universidad de Alcalá

Tile vaults in Belgium in 1930s: The churches of Léonard Homez

Paula Fuentes_Vrije Universiteit Brussel & Rosana Guerra_Universidade de Santiago de Compostela

17h00_Closing